Performance Monitoring of Rainscreen Wall Assemblies in Vancouver British Columbia

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EXECUTIVE SUMMARY

The purpose of this study was to monitor the in-service performance of rainscreen wall assemblies in five new or recently rehabilitated buildings. The monitoring was undertaken simultaneously for a period of at least one year to facilitate a relative comparison of performance of the walls at different buildings. A secondary goal was to increase the knowledge of rainscreen wall performance in-service to help identify opportunities for fine-tuning rainscreen assembly design to make them more cost effective and durable.

The results of the study indicate that the rainscreen wall assemblies at all three of the wood framed buildings, and the exterior insulated rainscreen walls on one of the high-rise buildings performed adequately. The other high-rise building incorporated a dual insulation exterior rainscreen assembly and exhibited higher than expected sheathing moisture content and interior humidity levels. These findings have already had a significant influence on the design of high-rise retrofit construction. The wall assemblies at this building require further investigation before conclusions can be reached with respect to long-term performance.

Another key study finding is that dryer vents can have a significant affect on the moisture content of the strapping and sheathing due to dryer air infiltrating behind the cladding.

The key recommendations include the continued monitoring of sheathing moisture contents for a five-year period. At the end of the five-year period a condition assessment of the buildings is recommended. The condition assessment should include some exploratory openings at key locations such as dryer vents to ensure that the moisture levels observed have not resulted in deterioration. Other recommendations include further research into how accurately in-service data correlates to hygrothermal simulations such as WUFI and further investigation of Building 3 to determine the impact of prolonged elevated moisture contents.

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1. INTRODUCTION

1.1 Background

Over the past decade the design and construction of multi-family residential buildings in the Lower Mainland of British Columbia has come under increasing scrutiny due to the high incidence of water ingress and the resulting deterioration of materials in the exterior wall assemblies of these buildings. Most new buildings and many of the rehabilitated moisture damaged buildings are being constructed using "rainscreen" wall assemblies, on the premise that these assemblies are more tolerant of moisture and will limit wetting to levels which can be accommodated by the building materials. Unfortunately, very little data is available that confirms how these assemblies actually perform in-service. As an industry, we require data on how "rainscreen" wall assemblies currently being designed and constructed, will perform on a long-term basis. Better knowledge of rainscreen wall performance in-service will also help identify opportunities for fine-tuning rainscreen assembly design to make them more cost effective and durable.

This report summarizes the monitoring program and some of the results. The quantity of the data is huge and clearly, further analysis could be undertaken beyond the scope of this study. Portions of the results have been analysed and are presented, that relate to factors of interest, such as the effect of overhang on wetting, the finding of unexpected moisture levels in the buildings, comparisons between the different cladding systems used in the study, and a comparison of actual wind and driving rain conditions compared with current design guidelines.

1.2 Objectives

The objective of the monitoring program is to provide data that can be used to assess the effectiveness of rainscreen wall assemblies. The program can also provide data regarding wetting in moisture sensitive materials, and if so, under what circumstances of weather and wall characteristics. The monitoring program was designed and implemented on five buildings being constructed or rehabilitated using a "rainscreen" wall assembly. The focus of the program to date has been on obtaining the raw data for analysis, and to identify significant anomalies, which fall outside the traditional assumptions for adequate performance. However, the opportunity for the expanded use and analysis of the data is enormous. Specific examples are:

- To correlate wetting events with exposure, weather conditions, and building interior conditions;

- To determine if wetted walls dry quickly enough to resist damage, and under what conditions drying takes place;

- To provide baseline data that can be used comparatively when assessing the performance of other rainscreen buildings, or alternatively when they are investigated in the future as part of warranty and maintenance requirements.

2. METHODOLOGY

2.1 General

The five monitored buildings include three multi-unit wood frame residential projects (2 new, 1 rehabilitation), a concrete frame mid-rise residential rehabilitation project, and a new residential high-rise construction project. All buildings are located in Vancouver, B.C. General building information and photographs are shown in Table 2.1.1.

The monitoring program was designed to measure temperature, moisture content, relative humidity, local weather conditions including rainfall, driving rainfall (rain contacting vertical walls), and pressure difference across the walls. A continuous, automatic electronic system records measurements from all sensors every 15 minutes. Five wall cavities on each building were monitored, each cavity contained 4 temperature, 4 moisture content, and 2 relative humidity sensors (Figure 2.1.1). On the non-combustible buildings, moisture content measurements on the steel studs was not applicable, therefore gold leaf wetness sensors were used to detect the presence of liquid water in these locations. The data acquisition and logging system is powered by a battery, which is charged by a solar panel; this allows the system to collect data during severe storms even if building power is interrupted. Four of the five cavity locations were chosen to be representative of areas most likely to be wetted during severe weather, while the remaining (5th) cavity was located in the center of the wall, away from details, to act as a control. Cavities were generally chosen on the east and south elevations at key details such as dryer vents, window sills, balcony transitions and saddle flashings where historically, high moisture levels have been observed (Figure 2.1.2).

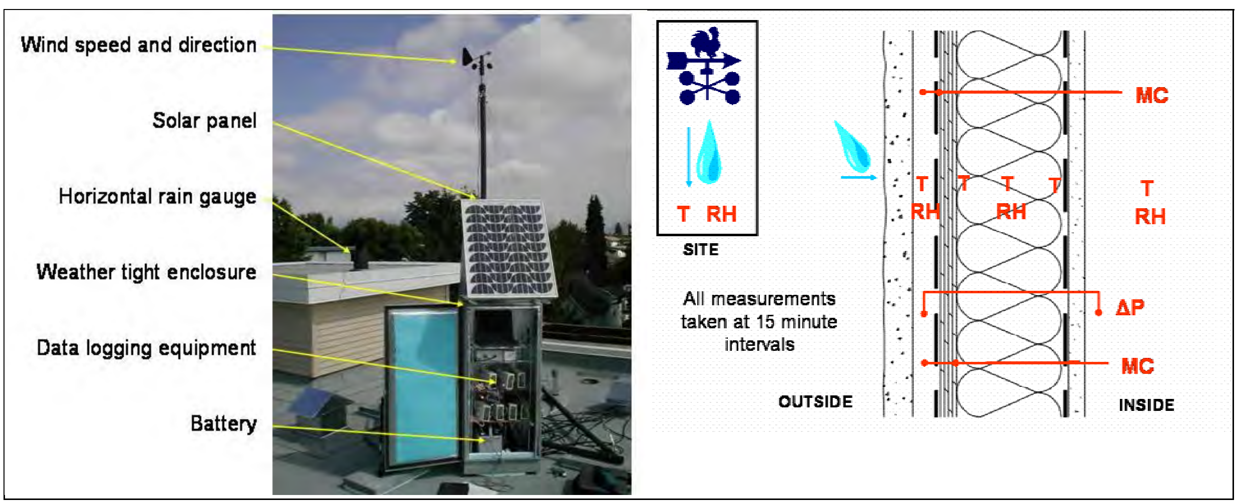
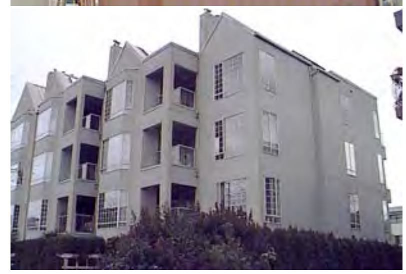


Figure 2.1.1 – Monitoring Equipment and Sensor Locations

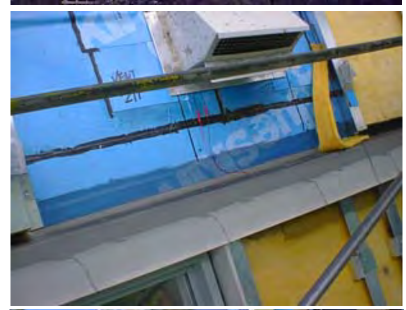
Table 2.1.1 – Building Information

Building 1
Height: 4 stories
Project Type: New Construction
Frame Type/Sheathing: Wood/Plywood
Insulation: Fiberglass Batt in stud cavity
Moisture Barrier: 2 layers of Building Paper
Cladding: Vinyl Siding on Wood Strapping


Building 2
Height: 4 stories
Project Type: Cladding Rehabilitation
Frame Type/Sheathing: Wood/Plywood
Insulation: Fiberglass Batt in stud cavity
Moisture Barrier: Tyvek commercial wrap
Cladding: Stucco on Wood Strapping

Building 3
Height: 6 stories
Project Type: Cladding Rehabilitation
Frame Type/Sheathing: Concrete/FFGB
Insulation: Rigid Fiberglass on exterior of moisture barrier + fiberglass batt in the stud cavity.
Moisture Barrier: Self Adhesive Bitumen
Cladding: Stucco on "Z" bars

Building 4
Height: 4 stories
Project Type: New Construction
Frame Type/Sheathing: Wood/Plywood
Insulation: Fiberglass Batt in Stud Cavity
Moisture Barrier: Building Paper
Cladding: Fiber Cement Board on Strapping


Building 5
Height: 30 stories
Project Type: New Construction
Frame Type/Sheathing: Concrete/FFGB
Insulation: Polystyrene on exterior of moisture barrier,
Moisture Barrier: Self Adhesive Bitumen
Cladding: Stucco on "Z" bars and Aluminum Window Wall

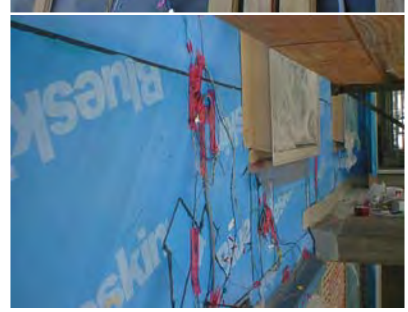



Figure 2.1.2 – Cavity Locations, Building 1
(1-Balcony saddle, 2-Window Corner, 3- Control, 4- Electrical Box, 5- Dryer Vent)

A description of the equipment and sensors is provided in Table 2.1.2. A detailed description of the setup and installation on each building is contained in Appendix A.

Table 2.1.2 – Monitoring Equipment

Wood Moisture Content	Two 3/8" brass screws installed 1" apart into the sheathing (Plywood) and sill plate (Wood Frame Buildings).
Gypsum Moisture Level	Two ¾" nails installed on a 45^o angle, 1" apart into gypsum sheathing. (Concrete Frame Buildings)
Temperature	Uni-Curve Thermisters part number 192-103LET-A01, by Fenwal Electronics
Relative Humidity	Honeywell HIH 3610-002
Wetness	Leaf Wetness Sensors (Concrete Frame Buildings)
Pressure Sensor	Setra Systems Model 265 – Differential Pressure Transducer
Rain Gauges	Vertical Rain: Davis Rain Collector II Driving Rain: Davis Tipping Bucket Sensor in Custom Built driving rain collector, 1' x 1' opening for driving rain only (Does not measure water accumulation running down wall surface)
Weather Station	OMEGA WMS-22B, Wind Speed and Direction Module R.M. Young Company Wind Sensor, 05103-10A Wind Monitor
Data Logging System	Buildings 1 and 2 - Lakewood 8 Channel Chart Pac CP-X loggers Buildings 3,4,and 5 – Campbell Scientific Inc. CR10X Logger w AM16/32 Multiplexer and modem

2.2 Duration of Monitoring Program

The original intent of the monitoring program was to simultaneously monitor all buildings for a period of 1 year. Buildings with similar completion dates were chosen for the study. However, due to significant delays in the construction and rehabilitation of the buildings, the commissioning of the monitoring systems was performed over a two-year period. The start and end dates for the full monitoring program is shown on Table 2.2.1. A reduced set of monitoring data (daily moisture content) is currently being logged on buildings 1, 2 and 3 to provide a total of 5 years of data for each building.

Table 2.2.1 Duration of Monitoring

Building	Date
1	01 January 2001 – 30 June 2004
2	31 May 2001 – 30 June 2004
3	17 January 2002 – 30 June 2004
4	26 March 2002 – 30 June 2004
5	01 January 2003 – 30 June 2004

2.3 Calculation of Moisture Content

The wood moisture content (MC) was determined by measuring the electrical resistance between the two sensors and estimating the percent of moisture content using the following equations developed by Forintek [4] to correct for temperature:

<u>Equation 1 at 21 degrees Celsius</u>

$MC_1 = 67.579 - 0.1224 \times (\log R)^3 + 2.6038 \times (\log R)^2 - 20.752 \times (\log R)$

R = resistance in K(Ohms)

<u>Equation 2 at 21.1 degrees Celsius</u>

$Y_2 = 0.850 \times (X_2) + 0.779$

Y_2 = Equivalent meter reading (R_s)

X_2 = MC_1 from equation 1

<u>Equation 3 – Temperature Correction Factor</u>

$MC_3 = \{(Rs + 0.567 - 0.0260\, t_o + 0.000051\, t_o^2) / [0.881 \times (1.0056)^{to}] - b\} / a$

Rs = Y_2 from equation 2

to = Temperature of the wood (degrees Celsius)

a, b = Species correction regression coefficients

<u>Equation 5 – Relating the estimated MC from equation 3 to the Forintek Lab test</u>

$X_5 = -0.9508\, Y_5 - 1.4216$

X_5 = MC (Final Moisture Content used in the experiment)

Y_5 = MC_3 from equation 3

Moisture level (ML) measurements in FFGB were calculated using the following formula, which was derived using a multi point calibration with a Delmhorst BD10 Moisture meter:

$ML = 56.056 \times \ln(MC) - 99.584$

MC = Y_2 from Forintek equation 2.

The formula for ML converts the electrical resistance measurement from the 0-100 reference scale on the Delmhorst BD10 series moisture meters. Moisture content measurements taken using the Campbell Scientific and Lakewood Logger systems were calibrated by taking readings on samples of plywood that had reached a steady state condition at a known relative humidity, using a Delmhorst BD-10 Moisture meter. The samples were not kiln dried to determine the exact moisture content. Known humidity test cells were created utilizing a supersaturated solution of the following salts.

1. Distilled Water, Cell 1 (100% RH)
2. Sodium Chloride, Cell 2 (75% RH)
3. Magnesium Chloride, Cell 3 (33% RH)

The calibration for plywood samples 1 to 4, using the Lakewood logger, and fiberglass faced gypsum board (FFGB) Test # 6, using the Campbell Scientific logger is shown in tabular form in Figure 2.3.1. The calibration of FFGB sample 1 and 2 using the Campbell Scientific logger, is shown graphically in Figure 2.3.1.

Relative Humidity (%)	Avg. of Plywood Tests 1-4	
	Calculated (MC%)	Delmhorst BD10 (MC%)
33%	10	10
75%	19	18
100%	+40	+40
Ambient	11	10

Relative Humidity (%)	Avg. DensGlass - Test #6	
	Calculated (ML%)	Delmhorst BD10 (ML%)
33%	37	28
75%	64	62
100%	85	89
Ambient		

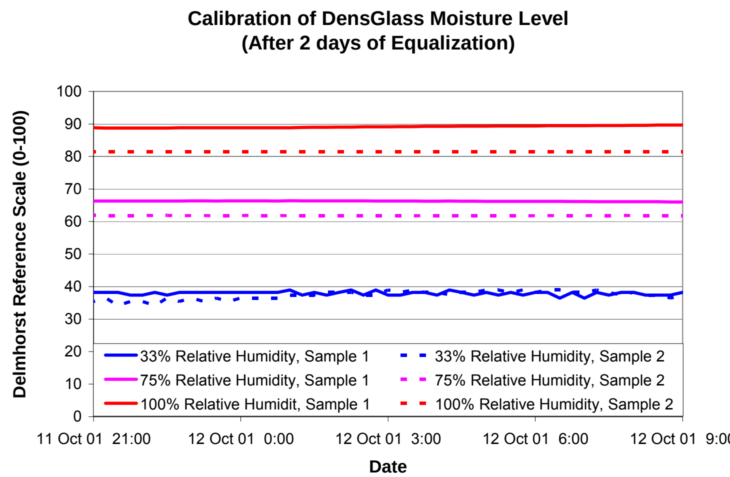


Figure 2.3.1 – Calibration of Moisture Measurements in Plywood and FFGB

The relationship between the calibration data and the monitored results is discussed further in section 3.2.

3. SUMMARY OF RESULTS

3.1 General

The raw monitoring data results for all buildings are contained in Appendix B on the DVD titled “Performance Monitoring – Raw Data”.

Over the course of the monitoring program there were a number of sensor malfunctions and failures, which resulted in erroneous results. Possible reasons for these erroneous readings include:

- Condensation on temperature and RH sensors
- Sensors extended past anticipated service life. The original scope of the program was to monitor for a period of 1 year. Due to the staggered start of the program the scope was extended to include at least one year of simultaneous monitoring of all 5 buildings in order to have comparative data for the same weather period. This meant that the sensors on some buildings had been installed for over three years during the final period, which was significantly longer than the anticipated life of the sensors.
- Data logger or multiplexer reading influenced by electromagnetic interference or power surge
- Possible damage during wall construction
- Sensor malfunction

In some data streams a sensor would malfunction for a period of time, providing readings that were outside of a realistic range, and then after a period of time they would come back on line with reasonable results. Other data streams, particularly temperature, the sensor would report an unrealistically high temperature for a single 15 minute period. Many of the RH and moisture content values are calculated using temperature as a key variable; therefore temperature sensor malfunctions can have a significant impact on the overall results. Since it was not possible to gain access to most of the sensors for replacement or repair it was decided to record all data and to eliminate erroneous data from failed or malfunctioning sensors prior to analysis. This was performed by manually reviewing all data streams and eliminating any data that was obviously erroneous. Calculated values based on erroneous data were also eliminated. The corrected monitoring data for all buildings is contained in Appendix B on the DVD titled “Performance Monitoring - Corrected Data”. The corrected data was used for all of the analysis in this report.

During the analysis of the data it was found that reviewing maximum, minimum and average values in tabular form to compare data was not always representative of each sample. For example several large moisture content readings could make one sample seem wetter than another sample that may have actually been wetter for most of the year. Conversely, trying to compare multiple data streams by reviewing the entire yearly data in chart form was found to be virtually impossible because of the large amount of the data and the high level of variance. It was found that the most effective method of comparing the data was to graph the maximum, minimum, average and one standard deviation. In these graphs the dark center band represents one standard deviation on each side of the average. The lighter colored bands on either side of the standard deviation represent the range from one standard deviation to the maximum and minimum. In a normally distributed sample 68% of the data is contained within 1 standard deviation of the mean. This allows an entire years worth of data to be represented by one bar, which can be graphed adjacent to the other data streams, allowing a visual comparison of the data. This approach was used for the majority of the graphs provided in the appendices.

Summary graphs are provided as yearly data and as yearly winter only data (December 21st to March 21st). This allows a comparison between winter effects and shows the effect of winter conditions on the annual values.

3.2 Moisture Content

Moisture content results are summarized in Appendix C. Results are shown graphically for each cavity as the maximum, minimum, average and ±1 standard deviation. Yearly data is provided along with winter-only data for comparative purposes. It is common in the industry to assess the relative risk of a moisture reading by categorizing the wood moisture content (MC) or gypsum Relative Moisture Level (RML) readings into three categories as shown in Table 3.2.1.

Table 3.2.1 - Typical Moisture Categories

Category	Wood	Gypsum	Typical Description
Low (Green)	MC<20	RML<40	Sample is at a moisture level that is expected under normal ambient relative humidity conditions and is generally immune to fungal growth and deterioration.
Elevated (Yellow)	20<MC<28	40<RML<80	Sample is at an elevated moisture level. This could be due to increased relative humidity or exposure to liquid water. Wood components are not at fiber saturation and therefore fungal growth will not generally be initiated. However, previously germinated fungi can continue to grow under some conditions. Fiberglass faced gypsum sheathing will not generally support mold growth at this level however it may lose strength if sample remains at this level for long time periods.
Wet (Red)	MC>28	RML>80	Sample is wet. Wood components are at or above fiber saturation and fungal growth and germination can occur. Fiberglass faced gypsum sheathing can loose structural strength. Corrosion of adjacent fasteners and steel studs is possible if maintained above this level for prolonged periods of time.

Moisture content and relative moisture readings were analyzed for all buildings according to these moisture categories and the results are summarized in Tables 3.2.2 and 3.2.3.

Table 3.2.2 – Typical YELLOW Category - Percent of Time Moisture Content (MC) of wood is Above 20% or Relative Moisture Level (RML) of Gypsum Sheathing is Above 40%

		Percent of Time That Moisture Content (wood) is Above 20% or Relative Moisture Level (Gypsum) Is above 40%															
Building	Cavity	Sheathing Control 2001	Sheathing Detail 2001	Strapping 2001	Sill Plate 2001	Sheathing Control 2002	Sheathing Detail 2002	Strapping 2002	Sill Plate 2002	Sheathing Control 2003	Sheathing Detail 2003	Strapping 2003	Sill Plate 2003	Sheathing Control 2004	Sheathing Detail 2004	Strapping 2004	Sill Plate 2004
1	1	0.01%	0.00%	0.00%	0.00%	0.07%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.81%	0.00%	0.00%
	4	4.66%	0.51%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	5	2.18%	7.56%	0.00%	0.00%	0.30%	7.88%	0.00%	0.00%	0.01%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.24%	0.00%	0.00%	0.05%	1.15%	0.00%	0.00%
	2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.03%	0.00%
	5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	1					81.82%	59.79%			72.00%	45.68%			54.72%	73.01%		
	2					68.63%	58.75%			16.91%	24.06%			43.27%	58.17%		
	3					78.99%	91.12%			57.03%	56.81%			6.84%	57.77%		
	4					77.87%	74.81%			87.22%	41.32%			93.36%	69.05%		
	5					81.84%	92.75%			0.00%	72.48%			0.01%	26.79%		
	6					81.84%	92.75%			58.49%	53.12%			37.60%	80.43%		
	7					83.78%	75.00%			41.03%	54.07%			36.52%	40.41%		
	8					47.46%	51.60%			42.07%	15.82%			30.29%	7.04%		
4	1					0.00%	5.24%	46.44%	0.00%	0.00%	0.00%	14.21%	0.00%	0.00%	0.00%	1.40%	0.00%
	2					0.00%	1.00%	1.31%	0.00%	0.00%	1.91%	1.07%	0.00%	0.00%	0.00%	0.00%	0.00%
	3					0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	4					0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	5					0.00%	0.00%	7.86%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	1									0.00%	0.00%			0.00%	0.00%		
	2									0.00%	0.00%			0.00%	0.00%		
	3									0.00%	0.00%			0.00%	0.00%		
	4									0.00%	0.00%			0.00%	0.00%		
	5									0.00%	0.00%			0.00%	0.00%		
	6									0.00%	0.00%			0.00%	0.00%		
	7									0.00%	0.00%			0.00%	0.00%		
	8									0.00%	0.00%			0.00%	0.00%		

Table 3.2.3 – Typical RED Category - Percent of Time Moisture Content (MC) of wood Above 28% or Relative Moisture Level (RML) of Gypsum Sheathing is Above 80%

		Percent of Time That Moisture Content (wood) is Above 28% or Relative Moisture Level (Gypsum) Is above 80%															
Building	Cavity	Sheathing Control 2001	Sheathing Detail 2001	Strapping 2001	Sill Plate 2001	Sheathing Control 2002	Sheathing Detail 2002	Strapping 2002	Sill Plate 2002	Sheathing Control 2003	Sheathing Detail 2003	Strapping 2003	Sill Plate 2003	Sheathing Control 2004	Sheathing Detail 2004	Strapping 2004	Sill Plate 2004
1	1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	5	0.04%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	1					3.11%	0.00%			0.32%	0.00%			3.99%	0.00%		
	2					2.78%	0.00%			0.00%	0.00%			0.00%	0.00%		
	3					16.93%	0.00%			6.31%	0.00%			0.00%	0.00%		
	4					0.00%	0.00%			22.32%	0.00%			32.44%	0.26%		
	5					0.00%	0.00%			0.00%	0.00%			0.00%	0.00%		
	6					13.56%	0.22%			6.61%	3.17%			3.56%	25.84%		
	7					11.21%	4.47%			0.00%	6.71%			8.28%	23.40%		
	8					16.25%	8.39%			0.00%	0.00%			0.00%	0.00%		
4	1					0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	2					0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	3					0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	4					0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	5					0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	1									0.00%	0.00%			0.00%	0.00%		
	2									0.00%	0.00%			0.00%	0.00%		
	3									0.00%	0.00%			0.00%	0.00%		
	4									0.00%	0.00%			0.00%	0.00%		
	5									0.00%	0.00%			0.00%	0.00%		
	6									0.00%	0.00%			0.00%	0.00%		
	7									0.00%	0.00%			0.00%	0.00%		
	8									0.00%	0.00%			0.00%	0.00%		

The results for the sheathing at the detail in Tables 3.2.2 and 3.2.3 are shown comparatively in Figure 3.2.1. During 2003 the sheathing in buildings 1, 2 and 5 typically remained within the low category except for relatively short periods of time at both dryer vents on buildings 1 and 2 where it entered the elevated category. Conversely, the sheathing on building 3 is in the elevated or wet category for large periods of time ranging from 15 % of the year to over 70% of the year.

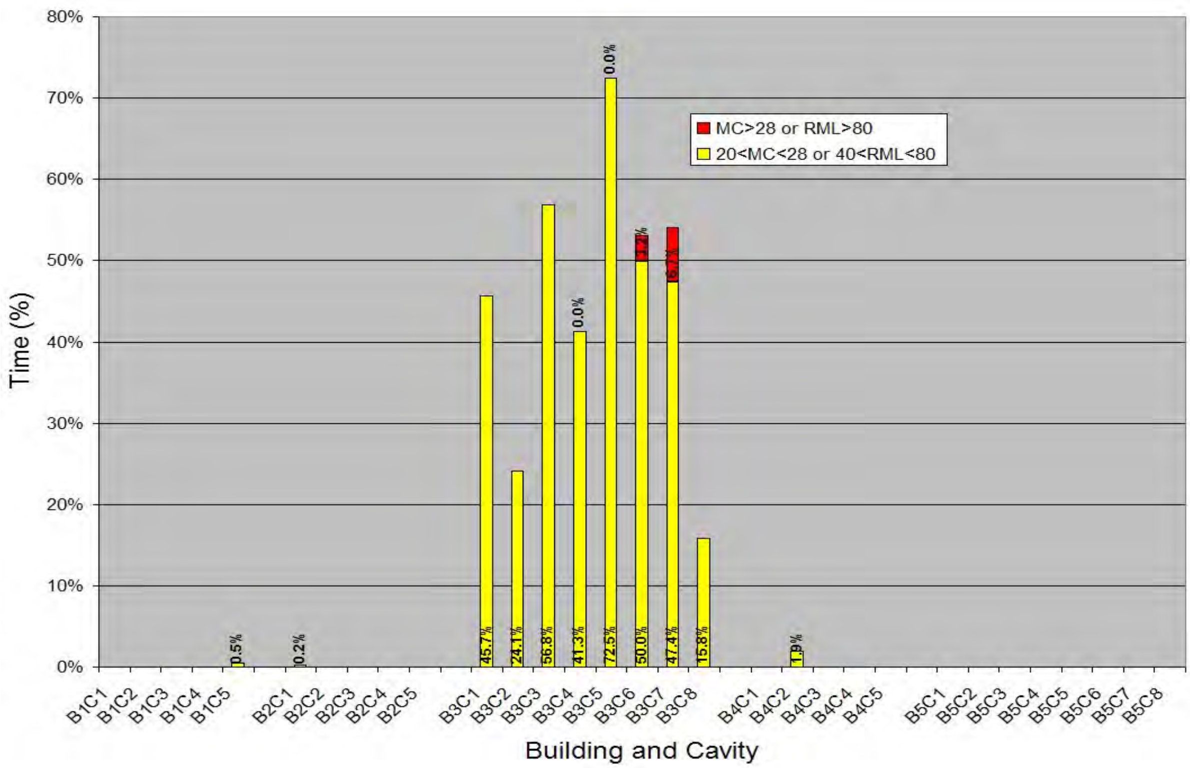


Figure 3.2.1 –Sheathing at Detail, 2003
Percent of Time Moisture Content (MC) of Plywood Sheathing is Above 20% & 28% or Relative Moisture Level (RML) of Gypsum Sheathing is Above 40 % & 80%

Building 1

The moisture content of the sheathing, strapping, and sill plate is generally within the expected range for wall cavities 1 through 4. Cavity 1 below the balcony/wall interface had some initial moisture content peaks in the 25 % MC range early in 2001, which were likely due to construction moisture. By 2003 all moisture content readings in cavities 1 through 4 remain below 20% MC.

Cavity 5, located at the dryer exhaust, exhibited very high moisture content levels in the sheathing during 2001 and early in 2002. This area was dismantled and modified to reduce water ingress at the detail. Moisture contents after this modification returned to levels which were similar to, but consistently higher than measurements in all other cavities. The higher moisture content levels were attributed to the increase in humidity in the drainage cavity caused by dryer air infiltrating through the cladding and raising the humidity on the exterior side of the sheathing.

Figure 3.2.2 indicates the wood moisture content in the control cavity on Building 1. This graph is an example of the typical seasonal wetting and drying cycle that was observed in virtually all cavities, on all buildings. The highest wood moisture content levels were found in Cavity 5 (Figure 3.2.3). The larger spikes throughout the year, which can be seen on cavity 5 compared to cavity 3 were caused by usage of the dryer exhaust vent and contact of the internal wall components with the warm humid exhaust air.

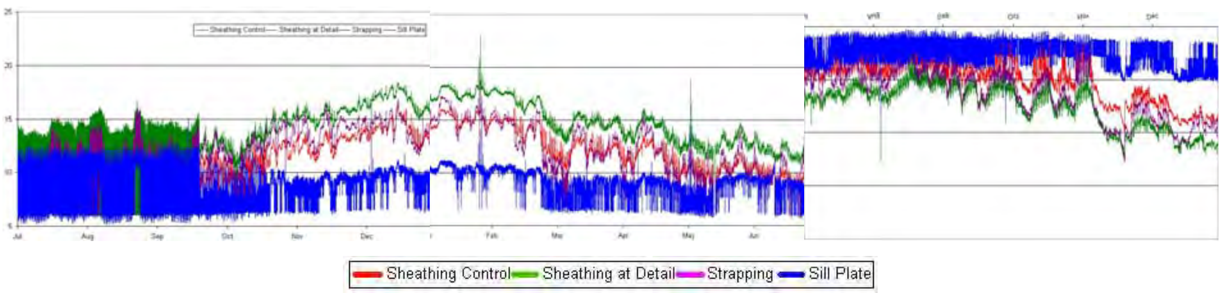


Figure 3.2.2 – Building 1, Cavity 3 (Control) Moisture Content (%), July 2001 to December 2002

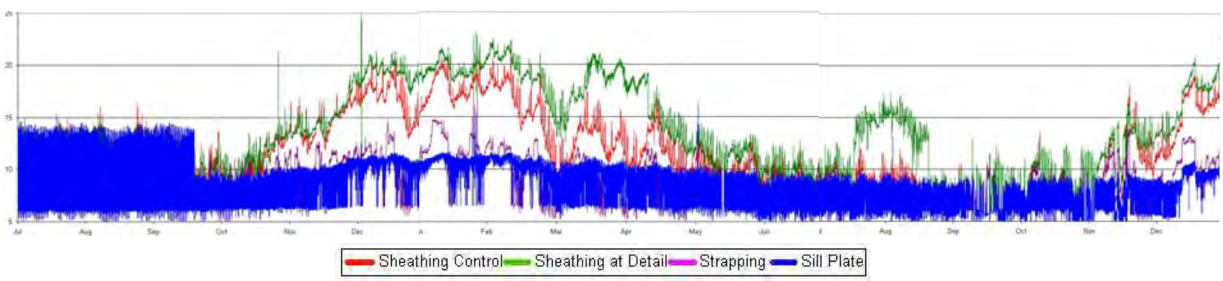


Figure 3.2.3 – Building 1, Cavity 5 (Exhaust Vent) Moisture Content (%), July 2001 to December 2002

Building 2

The moisture content of the sheathing, strapping, and sill plate is generally within the expected range for wall cavities 1 through 5. All moisture content readings in cavities 1 through 5 remain below 20% MC with a winter +1 standard deviation (the average reading plus one standard deviation) of less than 18% MC, with the exception of the sheathing below the dryer vent in Cavity 1 which had a maximum moisture content of 22%. The percentage of time that the sheathing was above 20% was less than 1.15%. The higher moisture content levels were attributed to the increase in humidity in the drainage cavity caused by dryer air infiltrating though the cladding and raising the humidity on the exterior side of the sheathing. The strapping below the window corner jamb in cavity 4 also peaks above 20% for 0.01 and 0.03 % of the time during 2003 and 2004 respectively.

Figures 3.2.4 and 3.2.5 indicate the wood moisture content for Cavity 4 below the window jamb and Cavity 1 below the dryer vent respectively for July 2003 to June 2004. Both graphs show the seasonal wetting and drying cycle that was observed on all buildings. The larger spikes throughout the year, which can be seen on Figure 3.5, are caused by usage of the dryer exhaust vent and the contact of the wall components with the warm humid exhaust air.

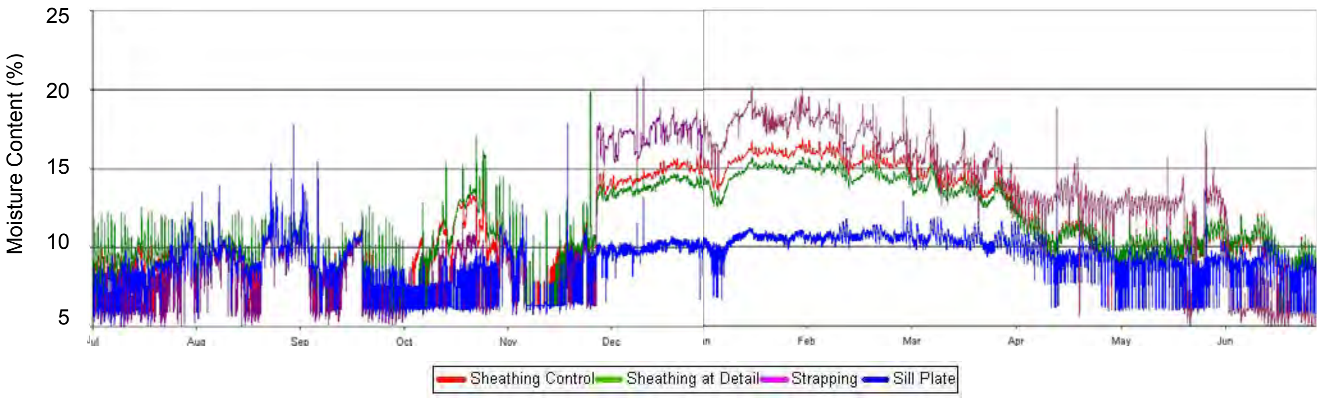


Figure 3.2.4 – Building 2, Cavity 4 (Below Window Corner) Wood Moisture Content (%), July 2003 to June 2004

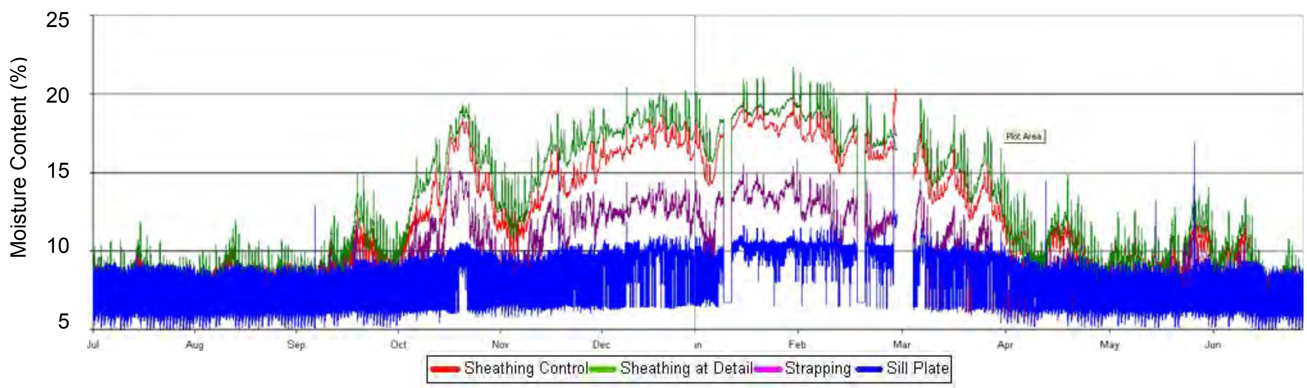


Figure 3.2.5 –Building 2, Cavity 1 (Below Dryer Vent) Wood Moisture Content (%), July 2003 to June 2004

Building 3

The relative moisture level of the gypsum sheathing on Building 3 was outside the expected range for wall cavities 1- 8. All cavities with the exception of 5 had relative moisture content readings in the wet range for prolonged periods of time. The moisture readings in gypsum sheathing have been calibrated to the 0-100 relative scale common to the Delmhorst BD10 and 2100 moisture meters and cannot be compared to wood moisture content readings on Buildings 1, 2, and 4. Calibration of the moisture sensors performed at the start of this study shows that moisture readings in the range of 80 to 90 in FFGB sheathing are indicative of exposure to conditions at 100% RH. The calculated winter

RH at the sheathing is close to 100% RH in cavities 6, 7 and 8 for most of the winter. In addition, during the period in February and March of 2002 when the high readings were observed, the gold leaf wetness sensors were reading levels that indicate condensation on the interior surface of the sheathing. The abnormally high humidity values can possibly be explained by examining the wall assembly in more detail. On Building 3 an exterior insulated rainscreen assembly was used that incorporated a vapour impermeable air/vapour/moisture barrier applied to the exterior sheathing. However, as this was a retrofit project, R8 batt insulation was left in the stud space and the polyethylene vapor retarder was removed. As the temperature cools down across the batt insulation, the amount of moisture that the air can hold decreases, increasing the relative humidity. At or below the dewpoint temperature, water will form on the surface of the sheathing and be stored by the sheathing material. Since the membrane on the exterior of the sheathing is impervious to water vapor, drying must occur towards the interior. Because the interior batt insulation is lowering the temperature of the sheathing and maintaining a high humidity during the winter months, drying will not occur until the warmer months when the heat flow through the walls is neutral or reversed. This phenomenon can be seen on Figure 3.2.6a. The calculated relative humidity at the exterior sheathing is at 100% for the majority of the period shown in Figure 3.2.6b, (March 1-8, 2002) and small reductions in moisture content of the sheathing are observed during periods of warm exterior temperatures when the calculated relative humidity drops below 100%. The high moisture levels observed in the exterior sheathing were relatively constant throughout the winter of 2002 and 2003. The moisture level started dropping in mid March and is relatively dry (35-50) between May and September at which time the levels start to increase again.

Figure 3.2.6a – Building 3 - Cavity 6, Relative Moisture Level (0-100 scale)
January 15, 2002 to June 15,2003

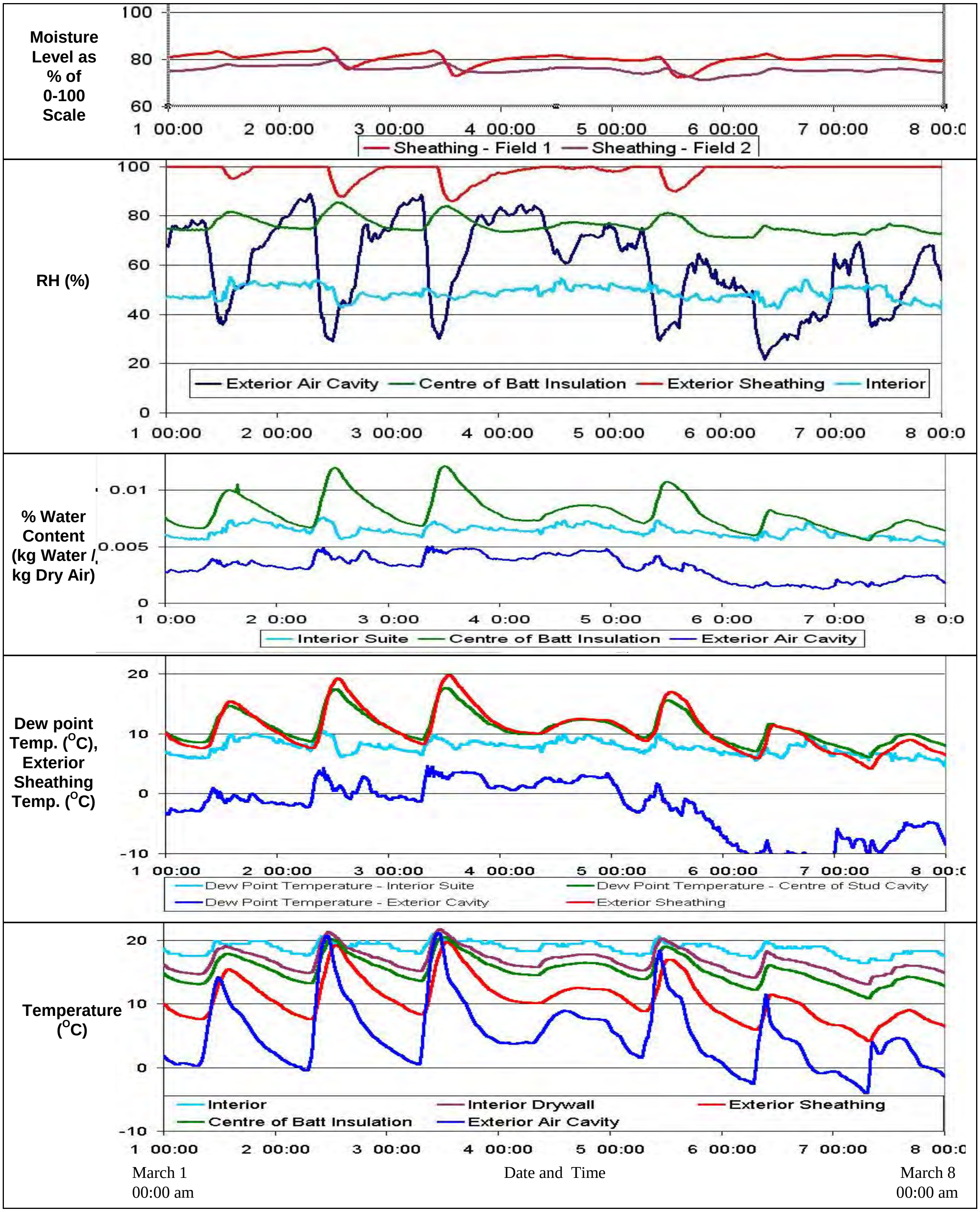


**Figure 3.2.6b – Relative Moisture Level (0-100 scale), Relative Humidity (%) and Temperature (°C)
Building 3 – Cavity 6 (control), March 1 – March 8, 2002**

Building 4

The moisture content data from Building 4 was corrupted with an unexplained echo that caused the moisture content reading to jump intermittently above the actual value. Diagnostics performed in February and March of 2005 confirms that the collected data is accurate when the echo is ignored. Figure 3.2.7 shows the calibration, which was performed with a Delmhorst BD10 moisture meter. An algorithm was applied to the data to remove the noise and the results are summarized in the Appendix C along with the other buildings.

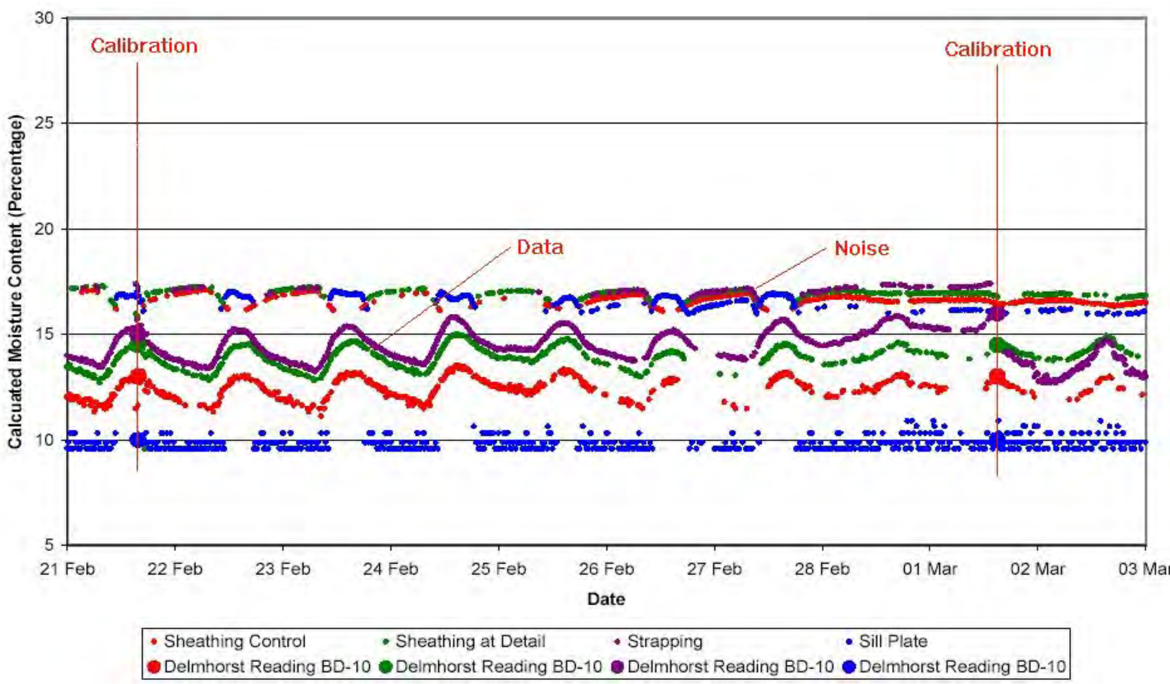


Figure 3.2.7 – Moisture Content Calibration, Calculated (Forintek) Wood Moisture Content and Delmhorst BD-10 Moisture Meter. February 21, 2005 to March 3, 2005

The moisture content of the wall components in Building 4 generally remains below 20 percent for the monitored period. The only notable exception to this is the strapping and to a much lesser extent the sheathing below the window jamb in cavity 1. It is likely that the lack of an end dam on the window sill flashing is contributing to an increase in water in the cavity in this location. However, further field work will be required to isolate the cause of this anomaly. Regardless of the increase in moisture in the strapping it does not seem to be having a lasting negative impact on the sheathing. In general the overall moisture content of the interior wood components and the relative humidity on both sides of the sheathing was found to be considerably lower than on either of Buildings 1 and 2. These lower moisture levels are likely due to the larger overhangs on Building 4 when compared with the other wood framed buildings (Building 1 and 2).

Building 5

The relative moisture levels in the sheathing on Building 5 stay below 40% RML for the monitored period. Building 5 is the only one of the five monitored buildings where the exterior sheathing never reaches the elevated category during the monitoring program. The moisture content of the exterior sheathing is only affected by the interior relative humidity, since it is protected on the exterior side by an air/vapour and moisture impermeable membrane, and all of the insulation is applied to the exterior of the membrane. The Leaf Wetness sensor data also supports this conclusion. The Leaf Wetness sensors consist of a gold matrix laminated onto to a plastic substrate. The electrical resistance of the sensor was measured and recorded. When the sensor is dry and there is nothing bridging the space between the gold coating, the resistance reading will be very high. Conversely, when moisture builds up to the point where it bridges the space between the gold coating, the resistance reading will be relatively low. The sensors are good for measuring wet or dry but are not useful for measuring the level of wetness since the reading for one drop of water is in the same range as numerous drops of water. As a result, the readings were normalized against the lowest resistance reading, and shown graphically on a logarithmic scale. Readings above 80% generally indicate that the sensor is wet and readings below 10 indicate that the sensor is dry. Figure 3.2.8 shows the Leaf Wetness sensors for cavity 1 and 2 along with the vertical and driving rain data for January 29, 2003 to Feb 23, 2003. The data indicates that the exterior surface of the cladding is immediately affected by rainfall and this is followed in most cases by more gradual wetting of the sensor located in the exterior drainage cavity behind the stucco cladding. Conversely, both sensors located on the interior of the membrane are unaffected by the precipitation. The moderate readings between February 11 and 14^{th} are a result of high fog levels as reported by Canada Weather Office.

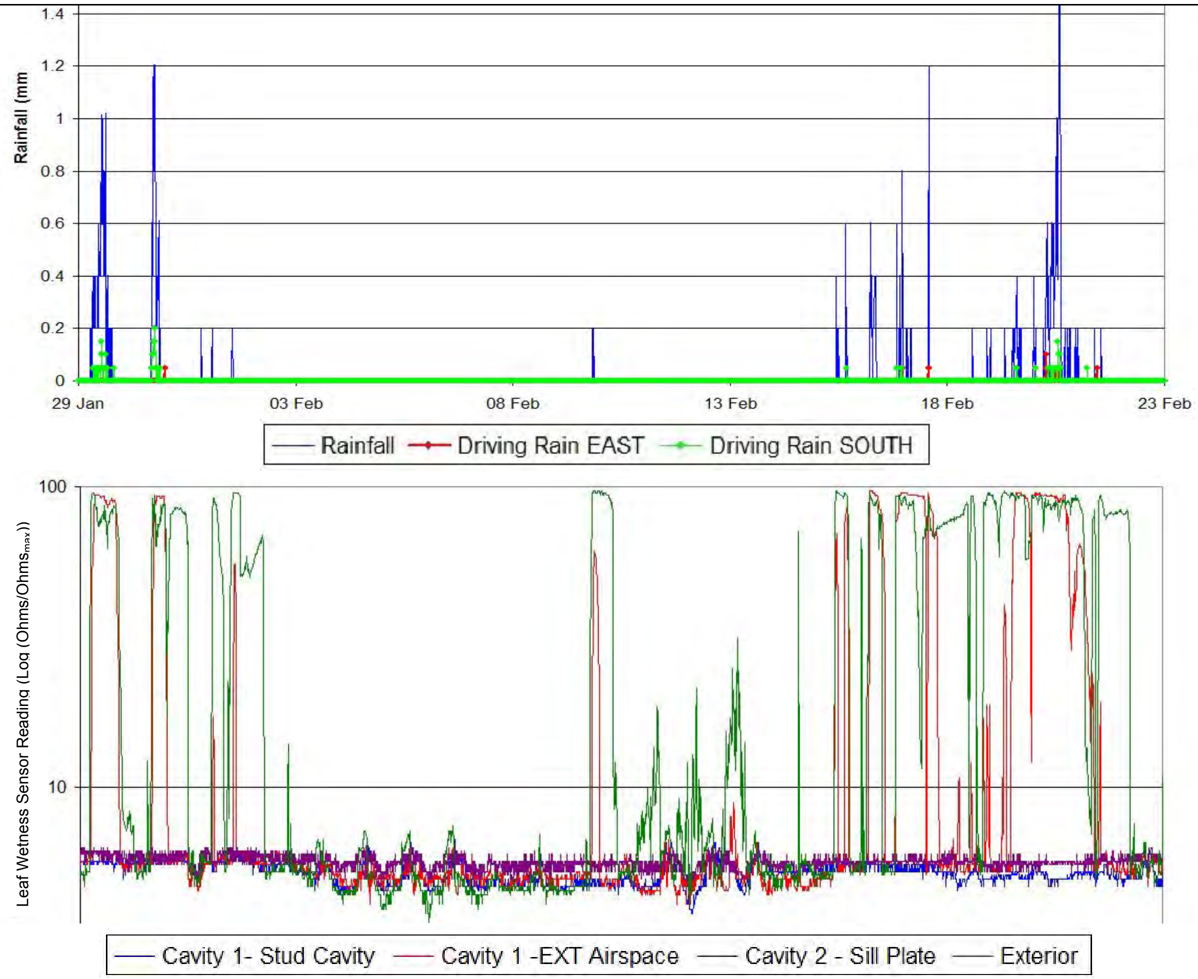


Figure 3.2.8 – Leaf Wetness Sensors and Vertical Rainfall Intensity Jan 29, 2003 to Feb 23, 2003

3.3 Surface Wetting and Driving Rain

The relationship between overhang protection and wetting on the walls was examined for all buildings by dividing the total driving rain by the total vertical rainfall for each building and elevation. The results of this analysis, shown on Table 3.3.1, indicate that the width of the overhang can significantly impact the amount of wetting from wind driven rain. For example, the east wall on Building 2, which has an overhang of 50mm, experienced close to three times more wetting from driving rain than the east wall on Building 1, which has a roof overhang of 500mm.

Table 3.3.1 - Effect of Overhang on Wetting (July 1, 2003 to June 30, 2004)

	Location of Driving Rain Gauge (Meters from roof line)	Overhang (mm)	Driving Rain (% of Vertical) East Elevation	South Elevation	North Elevation	Driving Rain (mm) East Elevation	South Elevation	North Elevation	Vertical Rain (mm) Roof
Building 1	4	500	3.28%	1.28%		35.85	13.95		1091.80
Building 2	4	50	8.91%	3.77%		93.90	39.70		1054.20
Building 3 - Floor 3	10	0	8.30%			95.00			1145.20
Building 3 - Floor 6	4	0	15.96%			182.80			1145.20
Building 4	8	1000/300		0.30%	0.55%		3.40	6.35	1148.20
Building 5 - Floor 30	10	0	1.20%	0.67%		10.55	5.85		875.60

The effect of overhang on wetting is shown graphically in Figure 3.3.1. Clearly the size of the overhang has an impact on the amount of water contacting the wall. In addition, there are factors other than overhang, that affect wetting. Building 5 had much lower driving rain readings on the 30th floor than most of the low rise wood frame buildings. These readings can be misleading, as the driving rain sensors will only pick up rain that is driven into the sensor but not water that is running down the wall. On a high-rise building much of the wetting that occurs on the lower floors is due to runoff water from the floors above. The comparatively low levels of driving rain on building 5 are likely a function of the unique orientation of the sensors in relation to local building shape and prevailing winds. Figures 3.3.2 indicates very low wind speeds on Building 5 -for the SE to SW wind directions where the driving rain gauges were located.

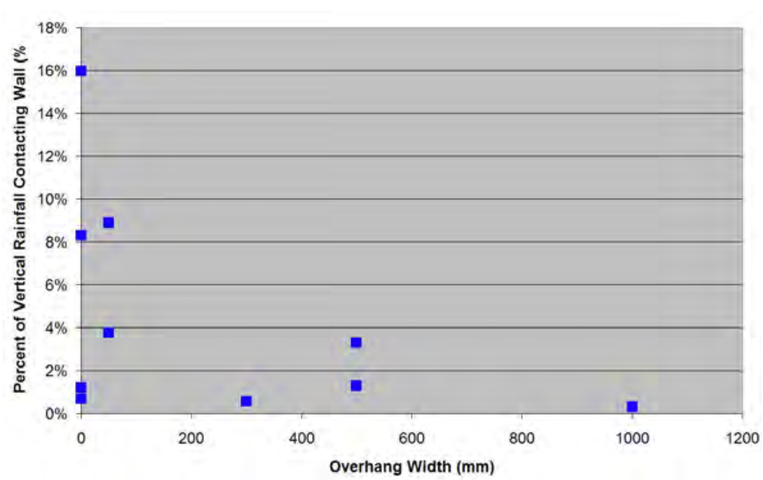


Figure 3.3.1 – Percent of Vertical Rainfall Contacting Wall vs. Overhang Width

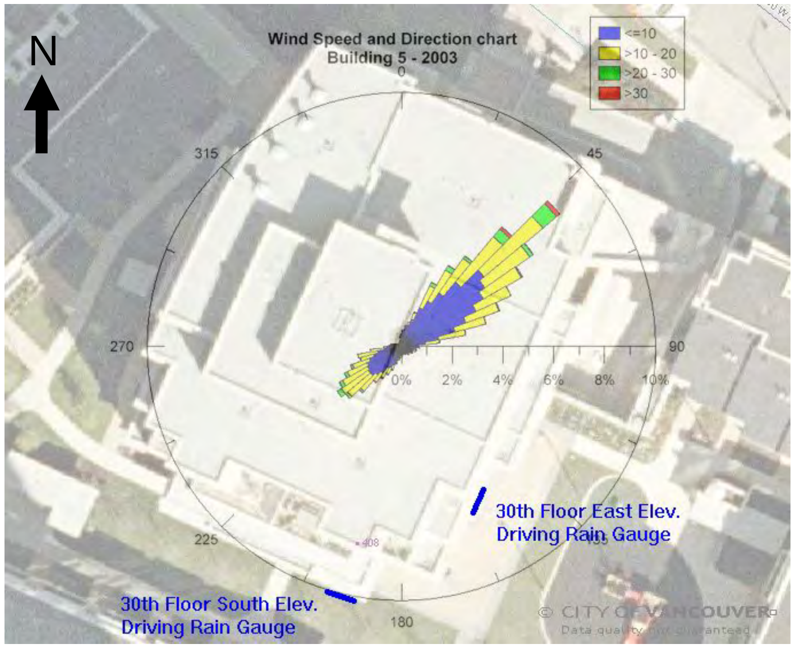


Figure 3.3.2 – Building 5 – 2003 Wind Rosette

A significant variance in the wetting of the walls was observed at the two locations monitored on Building #3 (Six Stories). The 3rd floor recorded only 52% of the driving rain that was recorded on the 6th floor. The reduced level of driving rain on the lower level can be explained by local exposure factors such as the location of adjacent buildings which protect lower portions of the east elevation, and the natural wind patterns on mid to high rise buildings which generally result in more wetting at the top of a building than in the centre.

The monitoring verified that in Vancouver, the primary direction of wind driven rain is from the east. In general, driving rain gauges on the east elevation measured significantly more wind driven rain than those on the south elevation.

The effect of significant driving rain events for cavity 2 on Building 1 can be seen on Figure 3.3.4. During the period shown there were 2 significant driving rain events. Each driving rain event was followed by an almost immediate corresponding increase in the moisture content in the strapping. This was followed a short time later by a corresponding peak in the moisture content of the sheathing, at the same time, as there was an increased potential for condensation on the back surface of the sheathing. After both rain events the elevated moisture content quickly returned to normal seasonal levels. The condensation potential in Figure 3.3.4 was derived by subtracting the calculated vapour pressure at the backside of the sheathing from the saturated vapour pressure at the same location.

When the calculated value is greater than zero there is a potential for condensation at this surface. Wind driven rain increased the moisture content of strapping quickly, but took longer to affect sheathing. In many cases when storm duration is small, sheathing moisture content was unaffected by the driving rain.

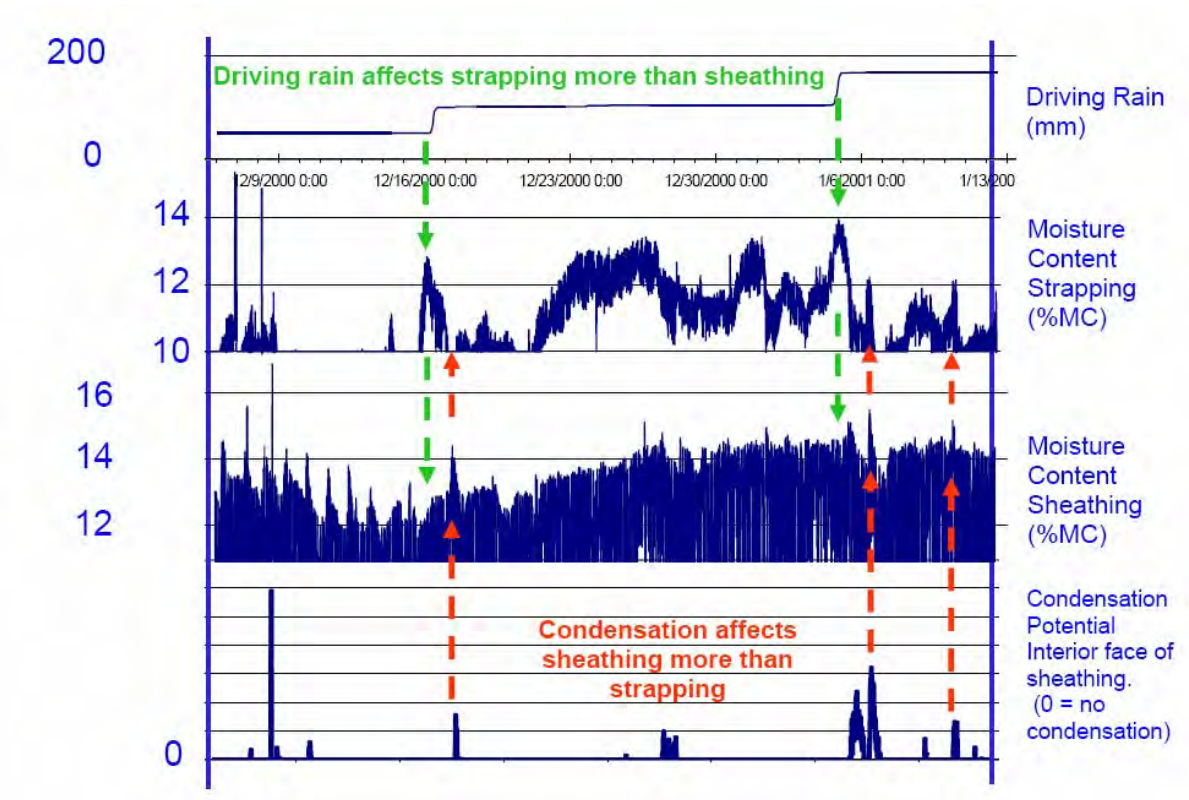


Figure 3.3.4 - Condensation Impact on Moisture Content (Winter)
Building 1, Cavity 2 December 6, 2000 to January 12, 2001

3.4 Vapour Diffusion

Data for a sample of winter and summer conditions was reviewed to examine the potential for inward vapour drive and the impact on the moisture content of the sheathing and strapping in Buildings 1 and 2. Figure 3.4.1 shows the vapour pressure at the exterior side of the polyethylene for a typical hot summer period without precipitation in 2001 between June 10 and July 12. In this period the vapour pressure curve did not touch the saturated vapour pressure curve indicating that no condensation should have occurred on the exterior of the polyethylene sheet from inward vapour drive. When the buildings are compared, it appears that the vinyl clad building is more resistant to inward vapour drive than the stucco clad building. This is likely a result of the higher air temperatures behind the cladding generally recorded on the stucco clad building and possibly the greater water storage capacity of the stucco.

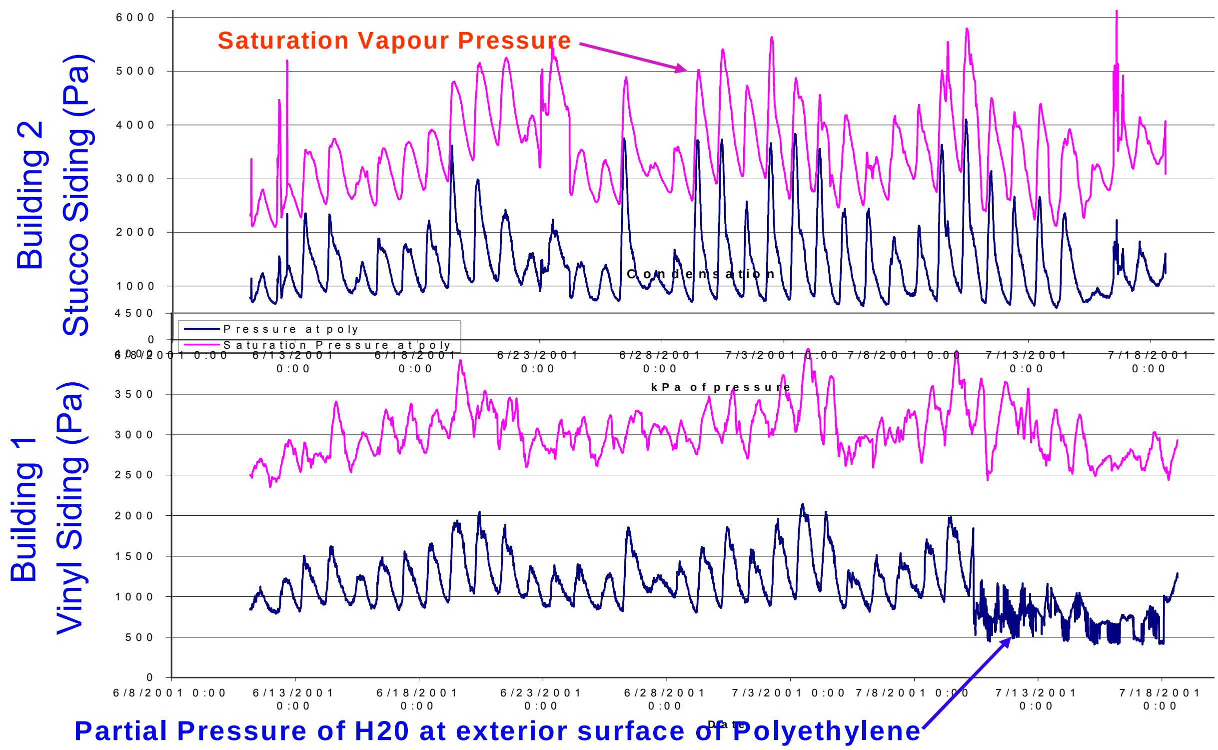


Figure 3.4.1 – Buildings 1 and 2 - Inward Vapour Drive Potential (June 10, 2001 to July 12, 2001)

Conversely, when driving rain is present, the inward vapour drive results in a more significant short term effect on the sheathing moisture content than driving rain alone. In Figure 3.4.2 the sheathing moisture content increased slowly during the period when the cladding was wetted from driving rain at a relatively low temperature. From April 10 to the 14th during the heavy rains the moisture content of the sheathing increased from 7% to 12%. However, a much larger and shorter spike in moisture content occurs on April 18th, which was a hot dry day that followed the several days of driving rain. As the wet cladding was heated, the wood moisture content in the sheathing peaked at approximately 15%. The increase in moisture content continued while the temperatures were elevated but quickly returned to normal as the temperature moderated.

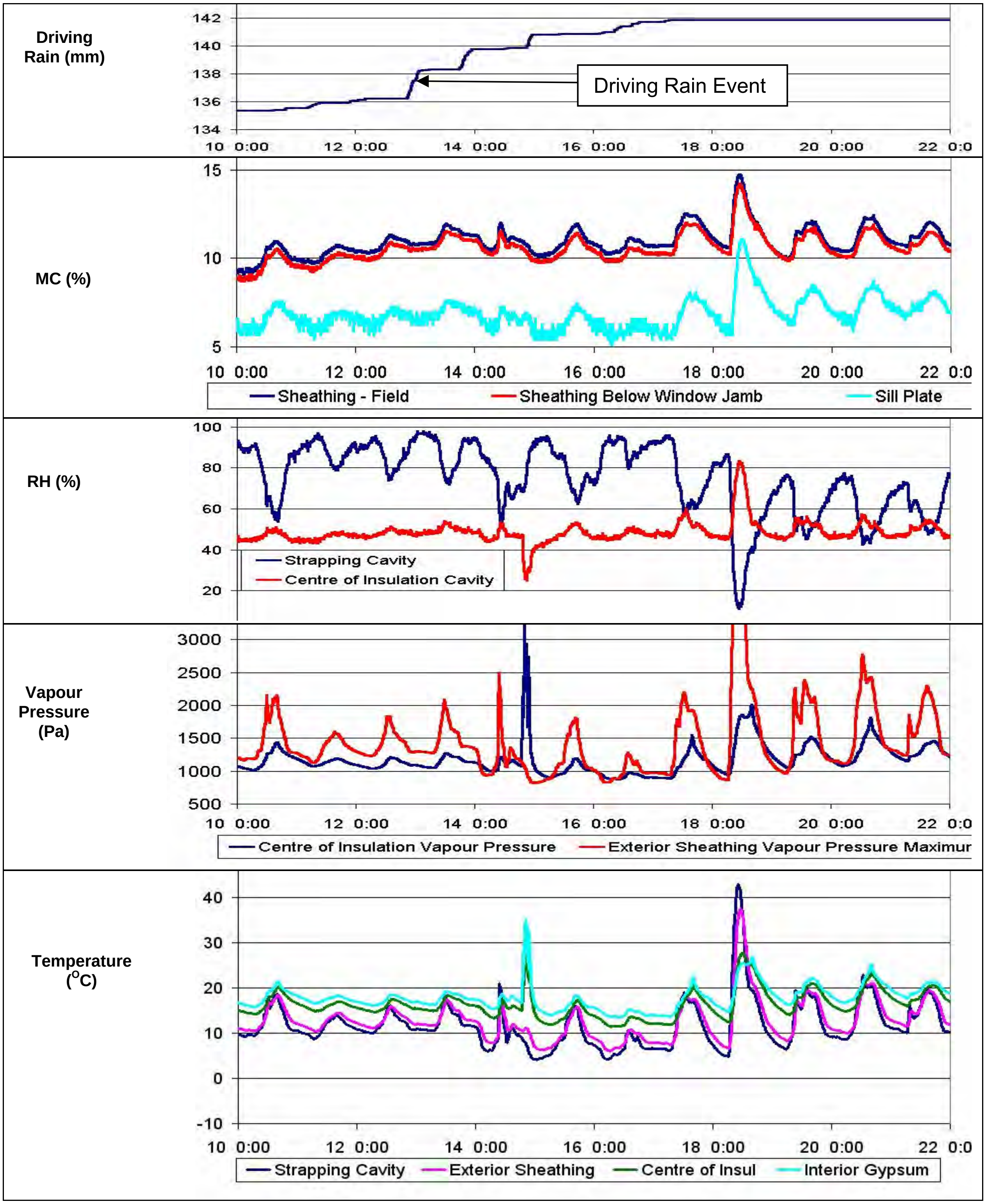


Figure 3.4.2 –Large Driving Rain Event followed by High Temperature Event
Building 2 – Cavity 4, April 10-21, 2002

3.5 Temperature

A summary of interior, exterior and strapping cavity temperatures for all years is contained in Appendix D. A summary of 2004 data is shown in Figure 3.5.1. The warmest and coldest temperatures recorded within the wall drainage cavity (Referred to as strapping location in Figure 3.5.1) were 59.5 ^{O}C on the 30th floor east elevation of Building 5, and –10.2^{O}C on the east elevation of Building 1 in 2004 respectively.

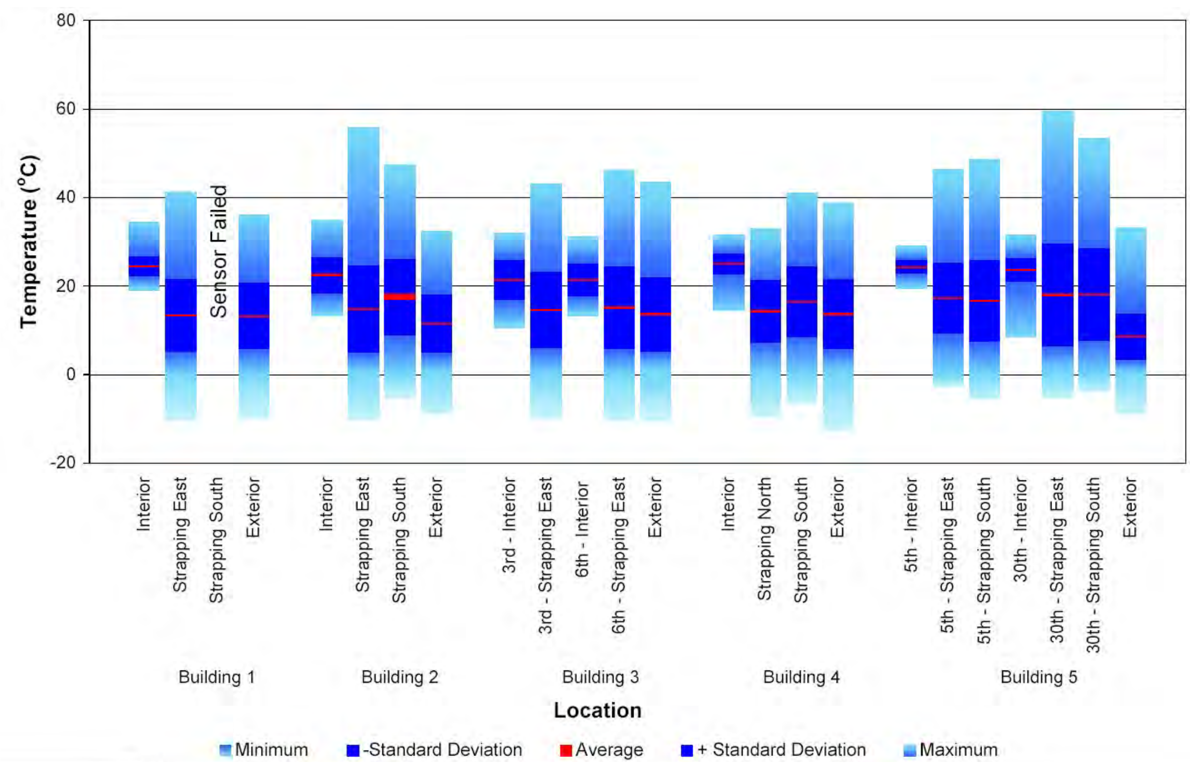


Figure 3.5.1 – 2004 Temperature Summary (Walls)

Interior temperatures ranged from 8.6 ^{O}C to 34.4 ^{O}C with an average of 23.3 ^{O}C for all buildings. Exterior ambient temperatures in 2004 ranged from –10.2 ^{O}C to 43.2 ^{O}C. The highest recorded temperature in a wall drainage cavity was 59.5 ^{O}C measured on the 30th floor of the east elevation of Building 5. The highest recorded temperature in a glazing cavity was 70 ^{O}C measured on the 30th floor of the east elevation of Building 5 on the interior side of the spandrel glass (Figure 3.5.2).

The temperature for the east elevation exterior airspace cavity, during one of the warmest weeks in 2004, is shown for various buildings in Figure 3.5.2. The coolest temperatures were located behind the brick masonry cladding. This is an expected result due to the high thermal mass of the cladding compared to the other systems. The vinyl and fiber cement panel siding temperatures are slightly higher than the masonry but remain lower than the stucco clad walls; this may be a result of the additional ventilation inherent in these systems. The three stucco sidings are consistently 5 to 15 degrees warmer than the other wall cladding systems; this is likely due to the larger panel size between vent areas. Temperature variations cannot be explained by colour of the stucco cladding as all buildings have similar colour tones and finishes. The highest temperatures were measured within the aluminum window wall on the interior of the spandrel glass, this is an expected result due to the high thermal conductivity of the aluminum components, the solar radiation absorbed by the spandrel glass, and the relatively small vent area from the spandrel airspace to the exterior.

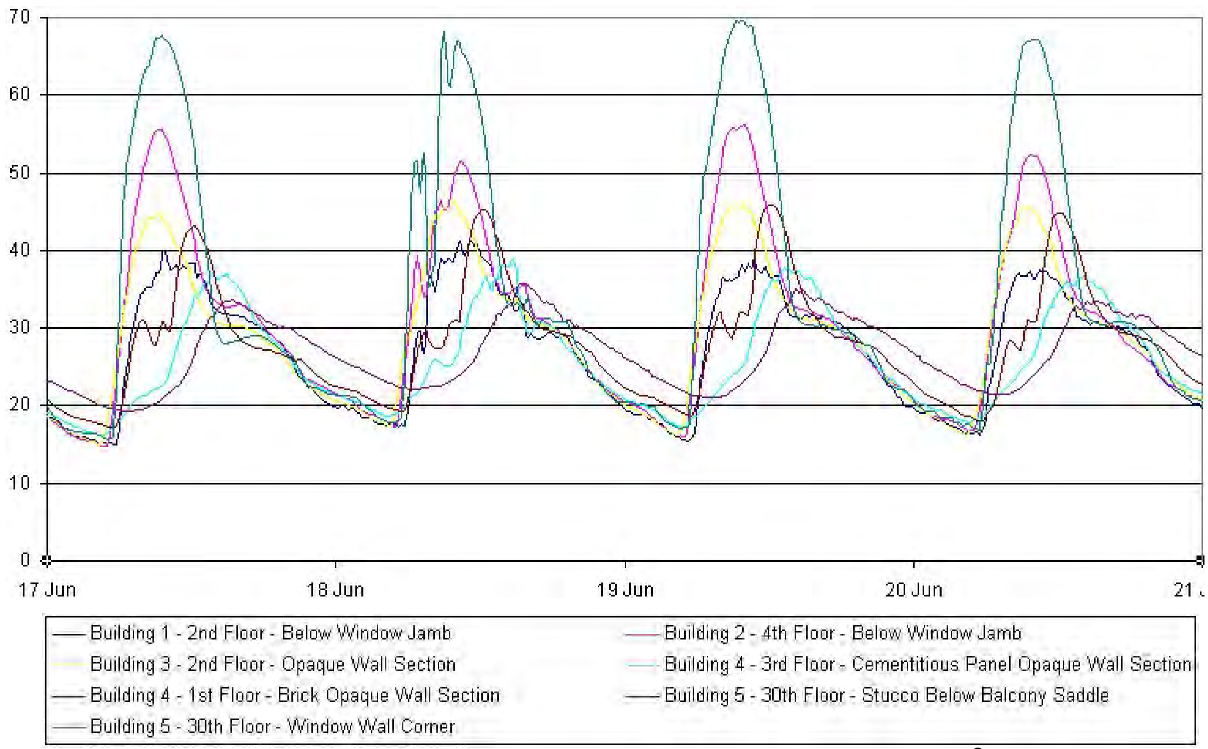


Figure 3.5.2 – East Elevation Wall Cavity Temperature Comparison (^{O}C)
June 17, 2004 to June 21, 2004

3.6 Wind and Building Pressurization

The summary of wind speed, building pressurization and yearly wind rosettes are contained in Appendix E. The maximum recorded wind speed, direction and associated pressurization is shown on Table 3.6.1. A summary of wind rosettes for 2003 are shown in Table 3.6.1.

The prevailing wind direction is from the east or southeast with the exception of Building 5, which is from the northeast. The maximum wind speeds and pressures were generally lower than expected for the mid-rise and high-rise buildings. We would have generally expected wind speeds and the corresponding pressures across the air barrier to be much higher on the mid-rise and high-rise buildings when compared to the wood frames low-rise buildings. The maximum pressures were within a reasonable range for the wind pressures that were recorded, however in all cases the measured pressures were lower than the theoretical calculated pressures based on the wind speed and the formula $P=\frac{1}{2}\rho V^2$ where $\rho=1.293$. This indicates that there is likely some sharing of wind loads between the cladding, the air barrier, interior drywall and the interior partition walls. In addition, since one reading was taken every 15 minutes, it is likely that many higher wind gusts were not recorded.

Table 3.6.1 – Maximum Wind Speed and Pressure Difference Between Exterior Drainage Cavity and Interior (Pressure)

	Pressure (Pa)	Elevation	Wind Speed (km/h)	Direction (Degrees from North)	Date
Building 1					
Maximum Infiltrating (-) Pressure	-83.3	East	65.2	177	12/16/01 16:00
Maximum Exfiltrating (+) Pressure	34.7	South	35.0	212	3/26/02 15:15
Maximum Wind Speed	9.4	East	67.6	301	12/14/01 11:45
Building 2					
Maximum Infiltrating (-) Pressure	-75.9	South	33.0	197	4/20/03 14:15
Maximum Exfiltrating (+) Pressure	59.6	South	30.1	136	1/2/03 9:15
Maximum Wind Speed	40.0	South	55.3	147	3/13/03 10:00
Building 3					
Maximum Infiltrating (-) Pressure	-11.9	East	27.3	154	3/13/03 7:45
Maximum Exfiltrating (+) Pressure	6.2	East	22.3	247	3/18/04 12:45
Maximum Wind Speed	4.3	East	31.5	291	10/28/03 17:15
Building 4					
Maximum Infiltrating (-) Pressure	-23.5	East	23.9	237	1/3/03 1:00
Maximum Exfiltrating (+) Pressure	5.6	South	20.3	291	3/9/04 13:15
Maximum Wind Speed	-22.4	East	29.9	215	5/6/02 7:15
Building 5					
Maximum Infiltrating (-) Pressure	-16.6	South (30th floor)	32.7	230	3/9/04 14:15
Maximum Exfiltrating (+) Pressure	32.2	South (30th floor)	34.6	48	2/5/04 21:30
Maximum Wind Speed	-3.2	South (30th floor)	38.8	45	12/4/03 19:30

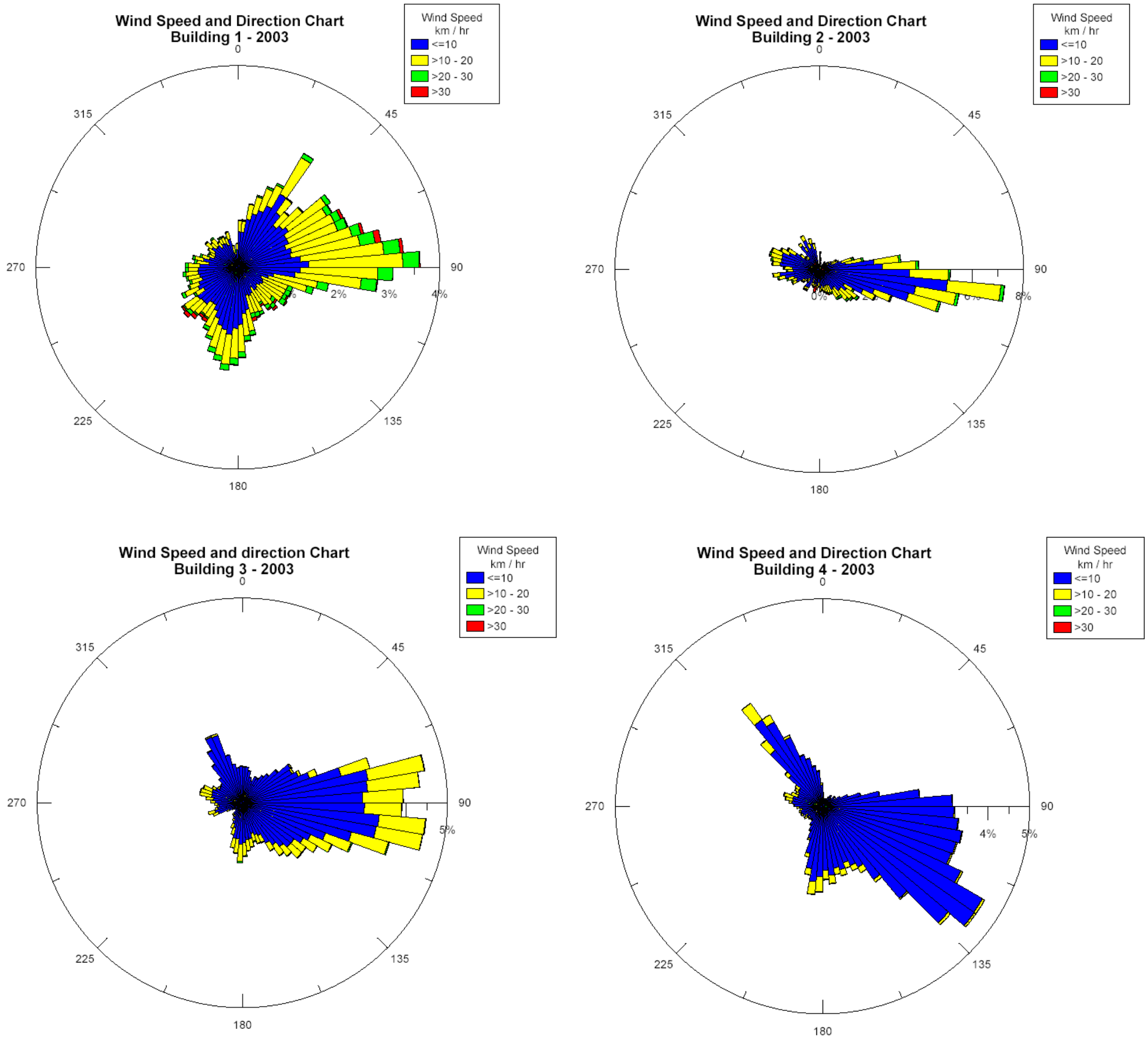


Figure 3.6.1 – 2003 Wind Rosettes (km/hr)
(see Figure 3.3.2 for Building 5)

3.7 Relative Humidity

Relative humidity summaries are contained in Appendix F for all buildings and years. Figure 3.7.1 shows the interior RH values for all five buildings during the winter of 2003/2004. The interior relative humidity in all five buildings exceeds 50% for some period of time during winter months. Readings on Buildings 4 and 5 are indicative of common assumptions with regards to interior relative humidity with an average winter RH of 32% and a standard deviation of 6%. Buildings 1 and 2 have elevated RH levels with the average being 43% and a standard deviation of 6%, meaning that it would not be unusual to experience interior RH values exceeding the commonly used design RH of 50% during the winter months. The interior RH measured for Building 3 is much higher than traditional expectations for winter RH. With an average RH of 61% and a standard deviation of 7% it would not be uncommon to find RH levels exceeding 68%. The consistency of the results between different units in the same buildings may also indicate that RH is impacted more by the interaction of the building envelope and HVAC system than the occupancy of the suite.

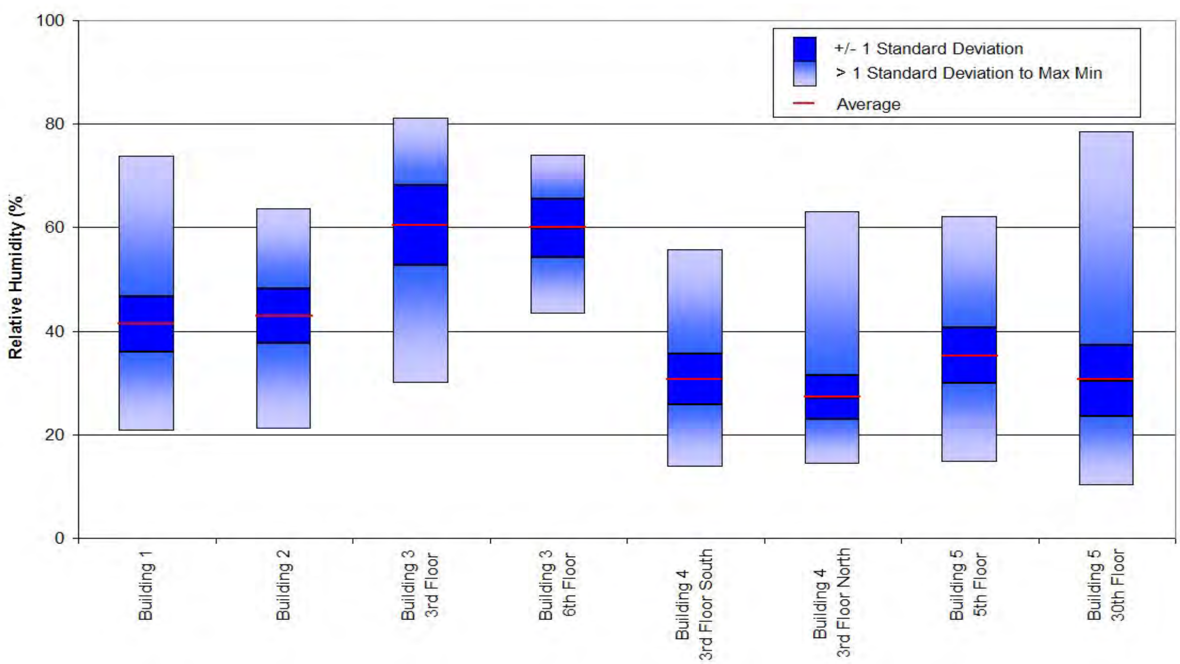


Figure 3.7.1 – Interior Relative Humidity Summary (Winter 2003/2004)

With the exception of building 5, all buildings had some locations where the relative humidity reached 95% on the interior and exterior of the sheathing during winter months. On buildings 1, 2, and 4 the relative humidity adjacent to the interior side of the sheathing reached 100% for brief periods before returning to lower values. The percentage of time that the surface of the exterior sheathing was above 95% for all years is contained in Table 3.7.1. Figure 3.7.2 shows the 2003 values in graphical format.

Table 3.7.1 – Percent of Time Sheathing is Above 95% RH

		Year			
Building	Cavity	2001	2002	2003	2004
1	1		1.9%	2.5%	2.3%
	2	0.5%	0.4%	1.0%	0.0%
	3	0.5%	0.4%	0.6%	0.0%
	4	0.8%	0.7%	1.3%	0.0%
	5	0.1%	0.5%	0.0%	0.0%
2	1	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	0.0%
	3	0.7%	0.0%	0.0%	0.0%
	4		0.4%	0.3%	0.4%
	5		0.0%	0.0%	0.0%
3	1		1.4%	0.0%	0.0%
	2		3.3%	1.0%	0.0%
	3		0.7%	0.8%	0.0%
	4		1.8%	0.6%	0.0%
	6		37.1%	38.6%	19.8%
	7		41.1%	45.9%	33.9%
	8		10.4%	2.7%	0.0%
4	1		0.0%	0.0%	0.0%
	3		0.0%	0.0%	0.0%
	4		0.0%	0.0%	0.0%
	5		0.0%	0.3%	0.0%
5	1			0.0%	0.0%
	2			0.0%	0.0%
	3			0.0%	0.0%
	4			0.0%	0.0%
	5			0.0%	0.0%
	6			0.0%	0.0%
	7			0.0%	0.0%
	8			0.0%	0.0%

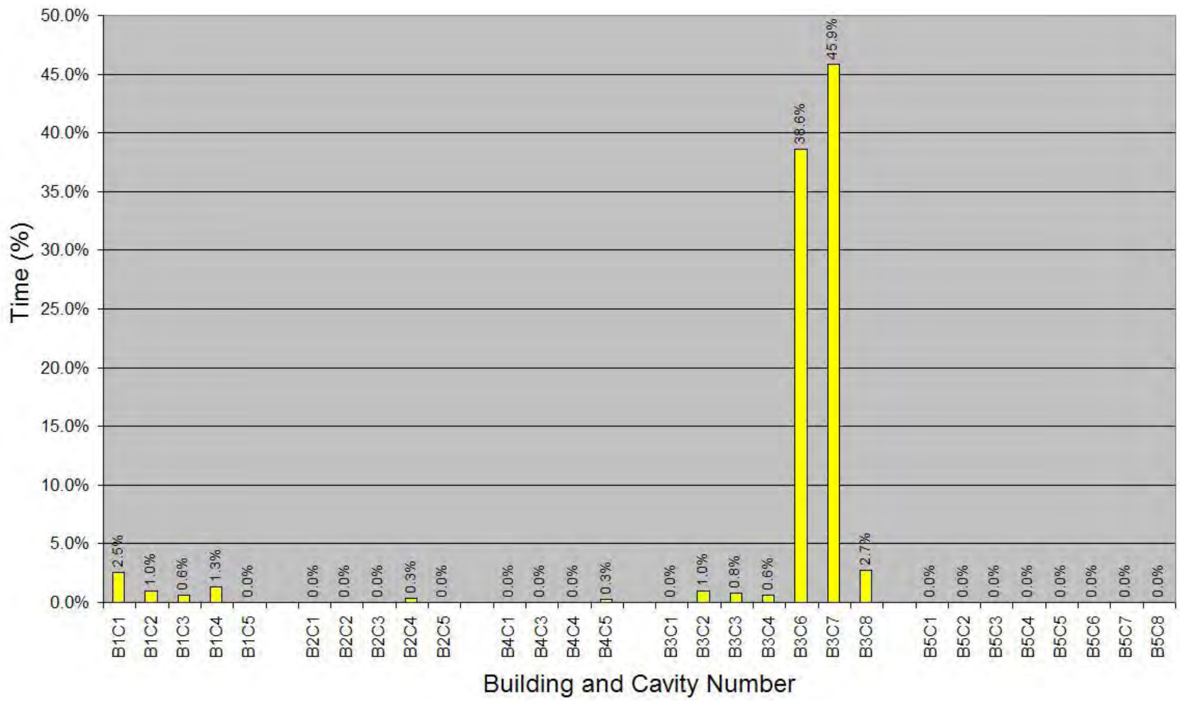


Figure 3.7.2 – Percent of Time Sheathing is Above 95% RH, 2003

The highest interior RH levels were observed in Building 3. Building 3 is a mid-rise building that was originally clad with a face seal stucco wall assembly and aluminum window assemblies. Building 3 had experienced water infiltration problems and high interior humidity levels since construction. Traditionally, these wall and window assemblies have allowed relatively high levels of air leakage both through and around the assemblies. As a result, mechanical designers were able to assume that a significant portion of the overall ventilation requirement would be taken up by air leakage through the wall and window assemblies. When the building was rehabilitated to reduce water infiltration and repair damage to underlying wall components, the conventional sheathing paper was replaced with a continuous self-adhesive modified bituminous air and moisture barrier membrane. In addition, the existing windows were replaced with higher performance windows and interface details were made more airtight. The resulting exterior building envelope was much more watertight and airtight than the original construction. Normally, a reduction in water infiltration would result in lower moisture levels and in turn lower humidity levels in the building after the work was completed. The continued high humidity levels observed post remediation are at least partially a result of the increased air tightness of the wall assembly invalidating the original mechanical assumptions regarding air leakage through the exterior walls. Occupant lifestyle and building HVAC systems are also likely playing a significant role in the abnormally high interior RH levels observed after the rehabilitation.

4. CONCLUSIONS

The moisture content in the sheathing and strapping on the wood framed buildings generally stayed below levels that can accelerate deterioration and promote fungi growth and decay. This finding indicates that rainscreen wall systems currently being utilized in the Lower Mainland can perform successfully.

The findings also support the use of caution when utilizing exterior insulated wall assemblies with a waterproof membrane on the exterior of the sheathing, in conjunction with conventional insulation in the stud cavity. More research on this wall type is required before conclusions can be made regarding its performance.

When remediating existing building enclosures, the mechanical ventilation strategy must consider the anticipated air and vapour tightness of the new wall assembly to ensure adequate supply and exhaust is provided in order to maintain reasonable RH levels post construction.

In addition to the primary goal of assessing performance, the monitoring program continues to provide information on how the building envelope reacts to weather and interior environmental conditions in a real world environment. Conclusions that can be made from the data collected to date include:

- Overhangs reduce wetting of walls in proportion to their size and ratio to wall height.
- Condensation at the interior poly vapour retarder from inward vapour drive during hot clear days in the summer was not observed.
- Condensation from inward vapour drive was measured at the exterior sheathing following some heavy rain events in the winter and spring.
- Outward vapour drive in the winter has an effect on the moisture content of the exterior sheathing.
- Wind driven rain increases moisture content of strapping quickly but takes longer to affect sheathing. In some cases when storm duration is small, sheathing moisture content is unaffected.
- Dryer exhaust air can significantly increase the moisture content of the sheathing if it is allowed to enter behind the cladding. Cladding systems with large ventilation capacities such as vinyl siding seem to be more susceptible to this venting mechanism.

- Rainscreen cladding systems alone will not prevent wood moisture contents from reaching levels capable of supporting fungal growth if interface details allow bulk water or dryer exhaust air to infiltrate behind the exterior cladding over a prolonged period.
- Caution must be used when assessing the performance of existing buildings using moisture readings of the exterior sheathing along with the risk categories commonly used in the industry. The monitoring has shown that sheathing and strapping on all buildings with the exception of building 5 were at elevated levels for short periods during the winter. When conducting moisture content surveys, the analyst must consider the moisture regime that the building has been under for some time preceding the reading. For example a reading of 23% moisture content during a particularly wet period in February should be interpreted differently than the same reading taken in July after a period of dry weather.

5. RECOMMENDATIONS

After the determination of the basic effectiveness of the rainscreen walls, the comparative analysis of wetting and drying on the different cladding assemblies offers the best opportunity for further research and knowledge. The following are opportunities for future research utilizing the data obtained, or the monitoring system prior to decommissioning at the conclusion of the study:

- Continue a reduced frequency, long term monitoring of moisture contents. At five year intervals, period perform condition assessments of the buildings including some exploratory openings at key locations such as dryer vents to ensure that the moisture levels observed have not resulted in deterioration.
- Compare results with data from a non-rainscreen building with active water infiltration problems during the same time period.
- Perform simultaneous wetting (water testing) on all buildings (stucco, vinyl and hardboard claddings) to examine and compare wetting and drying response times.
- Research the Hygrothermal behavior of fiberglass faced gypsum sheathing.
- Correlation of driving rain to wind speed and with vertical rain accumulation.
- Determine the rate at which construction materials dry out or become wet and what environmental conditions are required for each event.
- Determine the effects of relative humidity on building materials.
- Determine how accurate real life data correlates to hygrothermal simulations such as WUFI and what parameters during simulation are critical to the analysis.
- Further investigation of Building 3 to determine the effect of the prolonged increased moisture contents on the surface of the sheathing.
- Further investigation of Building 3 to determine the cause of the increased humidity levels. Modeling of the interior environmental conditions to examine the impact of ventilation on interior humidity.
- Investigate the window sill on building 4 to determine the source of the increased moisture content in the strapping.

RDH BUILDING ENGINEERING LIMITED

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[2] *1989 ASHRAE Handbook Fundamentals*, American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329.

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[4] *Envelope Drying Rates Experiment* - Final Report Appendix 7 - Data Acquisition System – Wood Moisture Measurement and System Testing, Forintek Canada Corp.

[5] *Wood Framed Envelopes in the Costal Climate of British Columbia*, Canada Mortgage and Housing Corporation, 1999

[6] Dalgliesh, W.A., *Journal of industrial Aerodynamics*, 1975, 1, pp. 55-66 NRCC 15130, Fig. 5, p.61

APPENDIX A

Installation and Setup - Buildings 1 to 5

Components and Methodology

Wood Moisture Pins

Brass Screws

The screws used for wood moisture content readings are 3/8" screws installed directly into the sheathing or sill plate. The brass screws were installed at buildings 1, 2 and 4. The readings range from 10 kΩ to 500+ MΩ. Wood moisture content has a decreasing effect on the woods resistance properties, therefore the lower the resistance the higher the wood moisture content.

Installation

The brass screws were soldered to a short length of wire with a quick connect attached to the other end of the wire. The screws were installed into the sheathing or sill plate, approximately 1" apart. Tool dip was placed on the exposed section of the screw to isolate the screw from exterior contaminants. The quick connect end of the wire was then attached to the wire which was attached to the logger system.

Measurement

A resistance measurement is taken between the two pins using a pulse 2.5 volt system. Depending on the logger system, the reading of the voltage is taken through different sense resistance, for the logger system on building 1 and 2 a sense resistor of 5100 Ω. Knowing the sense resistance, a resistance measurement can be taken based on the voltage measurement. At buildings 3-5 the measurement taken by the loggers is a resistance measurement. Wood moisture content can be calculated from this resistance measurement.

Voltage to Resistance Calculation

$$\Omega_{wood} = \Omega_{sense} \times [(V_{supply} / V_{reading}) - 1]$$

Resistance Measurement Calculation (John Straube) [1]

$\text{Log}(\Omega_{wood}) < 4$

$MC_{wood} = 622.34-896.79*\text{Log}(\Omega_{wood})+535.02*(\text{Log}(\Omega_{wood})\text{^}2)-$

$$156.95*(Log(\Omega_{wood})^3)+22.441*(Log(\Omega_{wood})^4)-1.2503*(Log(\Omega_{wood})^5)$$

$Log(\Omega_{wood}) \geq 4$

$MC_{wood} = 30.75403-3.68473 \times Log(\Omega_{wood})$

Resistance Measurement Calculation (Forintek) [4]

Equation 1 at 21 degrees Celsius

$MC_1 = 67.579 – 0.1224 \times (\log R)^3 + 2.6038 \times (\log R)^2 – 20.752 \times (\log R)$

R = resistance in

Equation 2 at 21.1 degrees Celsius

$Y_2 = 0.850 \times (X) + 0.779$

Y = Equivalent meter reading (R_s)

X = MC_1 from equation 1

Equation 3 – Temperature Correction Factor

$MC_3 = \{(Rs + 0.567 – 0.0260\, t_o + 0.000051\, t_o^2) / [0.881 \times (1.0056)^{to}] – b\} / a$

Rs = Y_2 from equation 2

to = Temperature of the wood (degrees Celsius)

a, b = Species correction regression coefficients

Equation 5 – Relating the estimated MC from equation 3 to the Forintek Lab test

$X = -0.9508\, Y – 1.4216$

X = MC (Final Moisture Content used in the experiment)

Y = MC_3 from equation 3

Moisture level (ML) measurements in FFGB were calculated using the following formula, which was derived using a multi point calibration with a Delmhorst BD10 Moisture meter:

$ML=56.056 \times \ln (MC)-99.584$

Brass Nails

¾" nails were installed one inch apart on a 45° angle into FFGB (Dens-Glass Gold). The nails were installed at buildings 3 and 5. Readings range from 10 kΩ to 500+ MΩ. Moisture content in the gypsum has a decreasing effect on the gypsum resistance properties, therefore the lower the resistance the higher the moisture content. The material is measured on the gypsum scale provided by the Delmhorst moisture meters on a scale from 1-100, where 100 would indicate complete saturation.

Installation

The brass nails were soldered to a short length of wire with a quick connect attached to the other end of the wire. The nail was installed into the gypsum sheathing on a 45° angle or sill plate, approximately 1" apart. Tool dip was placed on the exposed section of the nail to isolate the nail from exterior contaminants. The quick connect end of the wire is then attached to the wire which is attached to the logger system.

Measurement

A resistance measurement is taken between the two pins using a pulse 2.5 volt system. At buildings 3 and 5 the measurement which is taken by the loggers is a resistance measurement. Wood moisture content can be calculated from this resistance measurement.

Conversion from Wood Moisture Content to Gypsum Moisture Contents

ML=56.056xln (MC)-99.584

Temperature

UNI-CURVE INTERCHANGEABLE Thermisters

(part Number 192-103LET-A01, as manufactured by Fenwal Electronics)

The temperature probe is a two pronged resistor chip calibrated at 10 degrees Celsius. The reading at 25 degrees Celsius is 10.00 kΩ. The temperature range is between 0 and 70 degrees Celsius, with an accuracy of ±0.1 degree Celsius.

Installation

The temperature sensor is made up by soldering small wires to the ends of the temperature probes. Shrink tube was installed over the solder joint at both terminals of the resistor chip. At the other ends of the wire, quick connects were installed. The temperature thermister probe was then positioned in the wall cavity, and attached to a wire, which was connected to the logger system.

Measurement

A resistance measurement was taken. On buildings 1 and 2 the resistance measurement was taken across a sense resistor. The sense resistance for the temperature thermisters is 5.1 kΩ, for the other buildings the measurement is a resistance measurement. From this resistance measurement the temperature is derived from the equation provided by Fenwal.

Relative Humidity

Honeywell HIH 3610-002

The relative humidity is read using a three pronged chip, consisting of one power terminal, one ground terminal and one output terminal. The chip requires a 5 volt supply to function, connected between the power and ground terminals of the chip. The chip will provide a voltage measurement between 0-5 volts, where 5 volts would indicate complete saturation of the air and a zero reading is the air void of moisture. The chips are individually calibrated before being installed in order to provide the correct curve to the chip.

Installation

The relative humidity sensor is made up by soldering small wires to the ends of each prong, a red wire is connected to the power, a black wire is connected to the ground prong and a green wire is connected to the sense prong. Shrink tube was installed over the solder joint at all three terminals of the chip. At the other ends of the wires quick connects were installed. The relative humidity chip was covered with either a copper tube or a vinyl tube to ensure that the sensor was not damaged during the installation and working life of the sensor. The relative humidity sensor was then positioned in the wall cavity, and attached to three wires, which were connected to the logger system.

All RH sensors were calibrated using the following test cells:

1. Distilled water Test, Cell 1 (100% RH)
2. Sodium Chloride, Cell 2 (75% RH)
3. Magnesium Chloride, Cell 3 (33% RH)

The relative humidity sensor was installed into each cell and was left inside each cell for a minimum of one day. The measurements were taken by connecting a five volt power supply to the power and ground terminals, then using the Fluke 189 True RMS Multimeter, a Voltage measurement was taken across the ground and the sense probe. Using the values obtained and knowing the relative humidity for each of the test cells at saturation, a curve was generated for each sensor.

Measurement

A voltage measurement is taken. A five volt supply was provided for the sensor connected between the power and the ground. A voltage measurement was then taken between the sense terminal and the ground terminal. This reading then could be converted into a relative humidity reading using the curve obtained through the test cells.

Moisture

Leaf Wetness Sensors

The sensor measures the resistance of the circuit. The sensor requires a 5 volt power supply, connected to the white wire (power) and the red and black wire (ground). The resistive measurement is taken between the green wire (sense) and the ground. The chip provides reading between 0.10 – 500 MΩ. The lower the resistance the wetter the sensor is.

Installation

The leaf wetness sensor comes already assembled with a metal back plate sloped at 45^{o} and connected to 50 feet of telephone cable. In order to install the sensor the metal plate is removed. The telephone wire is cut to expose the wires. The white wire is connected to a quick connect, the red and black wires are connected to the same quick connect and also the green wire is connected to a quick connect. The sensors are then positioned in the cavity and insulation. The quick connect terminals are then connected to the logger via wires previously installed.

Measurement

A resistance measurement is taken. A five volt supply was provided for the sensor connected between the power and the ground. A resistance measurement is then taken between the sense terminal and the ground terminal. The resistive values were converted to a 1-100 scale where 0 is driest (highest resistance reading) and 100 is the wettest (lowest resistance reading). The 1-100 scale is not a linear approximation of how wet the sensors are. The leaf wetness sensors consist of a gold grid on a plastic plate. When moisture bridges the space between the gold strips the resistance is immediately reduced by an order of magnitude. Based on internal calibration at known humidity levels, the Leaf Wetness sensors were found to read greater than 90% when wet or at 100% humidity and will generally read below 24% when they are dry and are maintained at humidity levels less than 75%RH.

Pressure Sensor

Setra Systems Model 265 – Differential Pressure Transducer

The sensor measures the pressure differential between the two output nodes. The sensor requires a 5 volt power supply, connected between the excitation terminal (Power) and the Common terminal (ground). The output of the sensor is between 0 and 5 volts, where a reading of 2.5 volts would be an equal pressure. The values provided in voltage can be converted to a pressure, using the calibration provided by Setra.

Installation

The unit is provided already assembled. The sensor is installed using copper and vinyl tubing. The copper tubing is installed through all wall sheathing and the vinyl tube connects the copper tube to the node, so that one node is connected to the outside and the other is connected to the interior. The nodes are then connected to the data loggers via cables.

Measurement

A voltage measurement is taken. A five volt supply was provided for the sensor connected between the excitation node and the common node. A voltage measurement was then taken between the output node and the common node. This reading then could be converted into a pressure reading using the calibration provided by Setra.

Tipping Rain Gauges

Rain Collector, 0.01" (or 0.2 mm) Increments, Standard (7852(M))

Custom-Built driving rain gauge, 1' x 1' opening with a 0.05mm Increments

The tipping rain gauges operate utilizing a pulse sensor, for each tip a counter is set off. The increments for the driving rain are different from the vertical rain gauge; these values are 0.2 mm for the vertical rain gauge and 0.05 mm for the driving rain gauges. The value provided from the sensors is a count of the number of tips, from this number a multiplier is applied and a value in mm is provided.

Installation

The sensor equipment is provided fully assembled, complete with 50 feet of telephone cable. The telephone cable on the sensor is disconnected and each pair of wires is connected to a quick connect. The sensor is installed so that it is level and is free to tip. The vertical rain gauge is installed on a level surface on the roof, so that it is secure and will not blow away. Once the sensor is installed, the wires are connected to wires which are connected to the logger system.

Measurement

A voltage is provided to one of the wires and the other is connected to the ground through the logger. For each tip of the bucket an electrical pulse is sent to the logger triggering a counter. The pulse is then converted to a millimeters of rainfall or horizontal rain by a simple multiplier.

Weather Station

OMEGA WMS-22B, Wind Speed and Direction Module

The wind speed and direction module is supplied with power. The wind speed and direction station provides a 4-20mA output, which can be converted into both azimuth and speed. The wind speed range is between 0 – 136 mph and the wind azimuth provides values between 0 and 360 degrees.

Installation

The wind module is installed on a post located 10 feet above the flat section of the roof. The wind module is installed so that it is level, and is set so that it is facing compass north. It is then connected to the logger system through cabling provided by Omega.

Measurement

The software used for the readouts of the weather vane are calibrated to accept and read a milliamp reading, and convert it into the specific reading in degrees and in mph.

R.M. Young Company Wind Sensor, 05103-10A Wind Monitor

The wind speed and direction module is supplied with power. The RM Young wind sensor is calibrated for the specified logger system. It is measured in a variety of methods, one such method is to output milliamp and the other is to provide a voltage reading.

Installation

The wind module is installed on a post located 10 feet above the flat section of the roof. The wind module is installed so that it is level, and is set so that it is facing compass north. It is then connected to the logger system through cabling provided by Campbell Scientific.

Measurement

The software used for the readouts of the weather module is calibrated to accept and read, a miliampere reading and voltage, and convert it into the specific reading in degrees and in kph.

Data Acquisition and Logging System

Buildings 1 and 2

- Lakewood 8 Channel Chart Pac CP-X Loggers
- LS4, DOS based software

Buildings 3, 4, and 5

- Campbell Scientific Inc. CR10X Logger
- AM 16/32 Multiplexer
- Custom low resistance device
- Modem
- PC-208, windows based software

LOCATION OF CAVITIES		
Building	Cavity	Location
1	1	2nd Floor, East Elevation - Balcony Wall Connection
1	2	2nd Floor, East Elevation - Base of Window Jamb
1	3	2nd Floor, East Elevation - Opaque Wall Section
1	4	2nd Floor, East Elevation - Opaque Wall Section, at Interior Electrical Outlet
1	5	2nd Floor, South Elevation - Below Dryer Vent
2	1	4th Floor, East Elevation - Below Dryer Vent
2	2	4th Floor, East Elevation - Opaque Wall Section, at Interior Electrical Outlet
2	3	4th Floor, East Elevation - Opaque Wall Section
2	4	4th Floor, East Elevation - Below Window Jamb
2	5	4th Floor, South Elevation - Below Guard Rail
3	1	2nd Floor, East Elevation - Below Dryer Vent (of 3rd Floor)
3	2	3rd Floor, East Elevation - Below Balcony Connection
3	3	3rd Floor, East Elevation - Below Window Jamb
3	4	3rd Floor, East Elevation - Opaque Wall Section
3	5	5th Floor, East Elevation - Below Dryer Vent (of 6th Floor)
3	6	6th Floor, East Elevation - Opaque Wall Section (of 6th Floor)
3	7	5th Floor, East Elevation - Below Balcony Connection
3	8	6th Floor, East Elevation - Below Window Jamb
4	1	3rd Floor, North Elevation - Below Window Jamb
4	2	3rd Floor, North Elevation - Opaque Wall Cavity, at Interior Electrical Outlet
4	3	3rd Floor, South Elevation - Opaque Wall Cavity, at Interior Electrical Outlet
4	4	3rd Floor, South Elevation - Below Window Jamb
4	5	2nd Floor, South Elevation - Opaque Wall Section, Behind Brick Cladding
5	1	5th Floor, South Elevation - Opaque Wall Section
5	2	5th Floor, East Elevation - Below Vent
5	3	5th Floor, East Elevation - Below Window Jamb
5	4	5th Floor, East Elevation - Below Balcony Connection
5	5	30th Floor, East Elevation - Opaque Cavity
5	6	30th Floor, East Elevation - Spandrel Panel
5	7	30th Floor, East Elevation - Spandrel Panel
5	8	30th Floor, South Elevation - Spandrel Panel

FIGURES

Building Location, Overview and Sensor Layout

Figure A1.01 - Building Locations

Figure A1.02 - Building 1 - South Overview

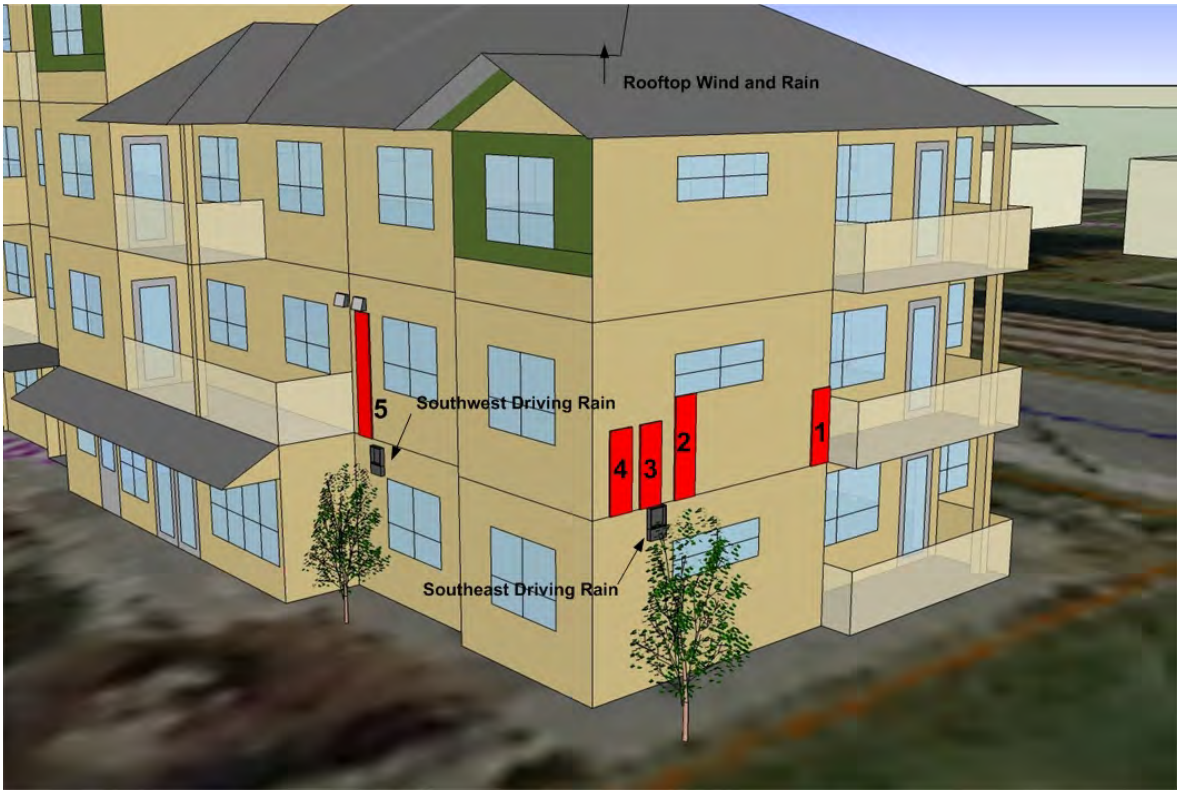


Figure A1.03 - Building 1 - Sensor Layout

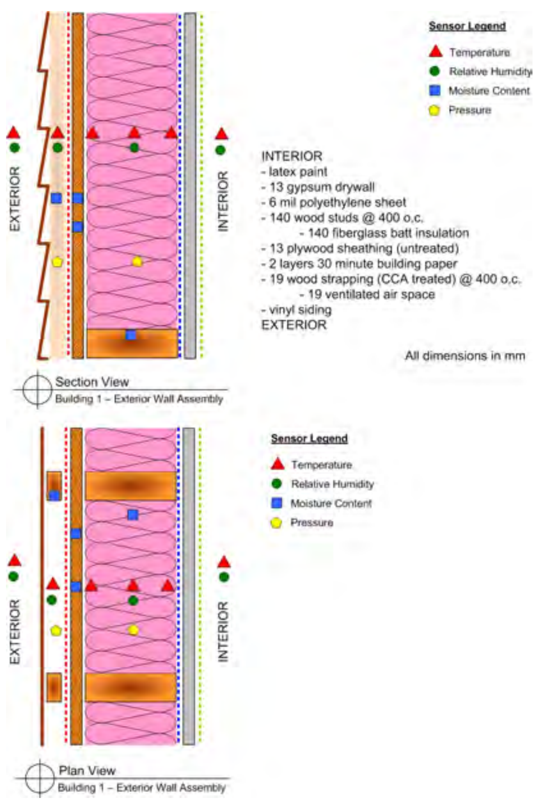


Figure A1.04 - Building 1 - Wall Sections

Figure A1.05 - Building 2 - South Overview

Figure A1.06 - Building 2 - Sensor Layout

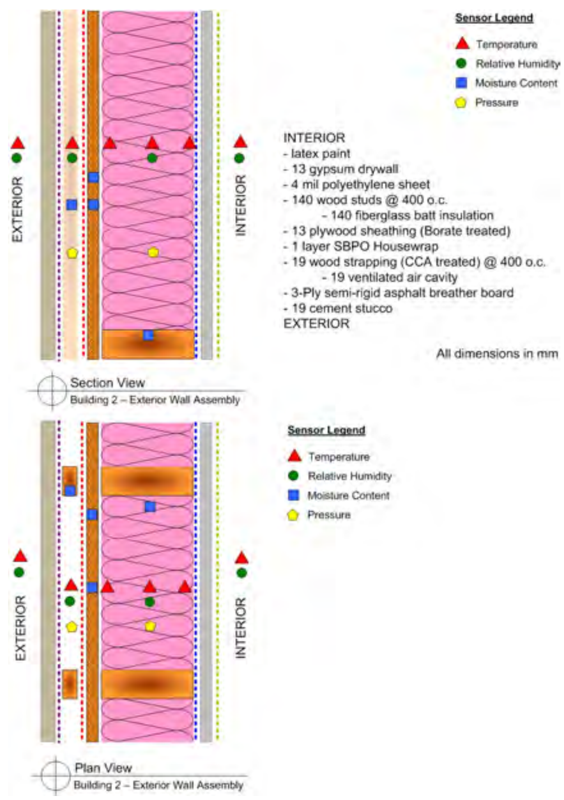


Figure A1.07 - Building 2 - Wall Sections

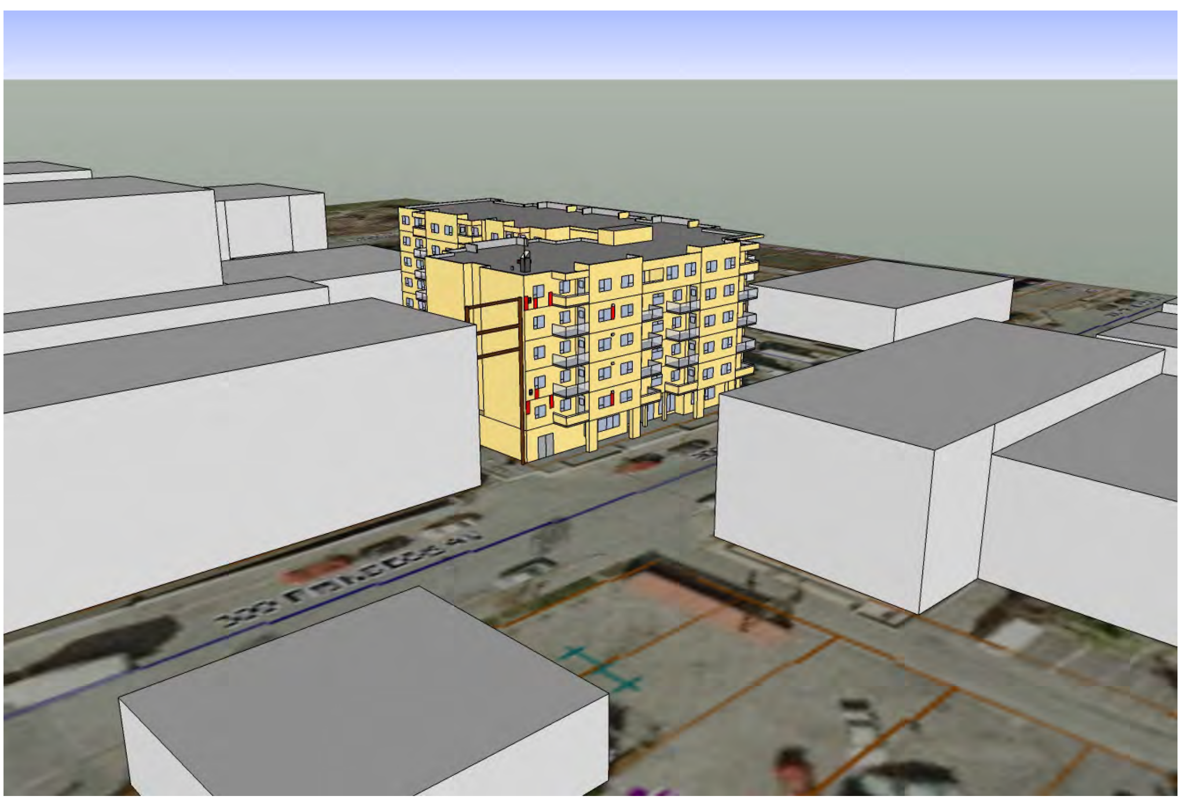


Figure A1.08 - Building 3 - Southeast Overview

Figure A1.09 - Building 3 - Sensor Layout

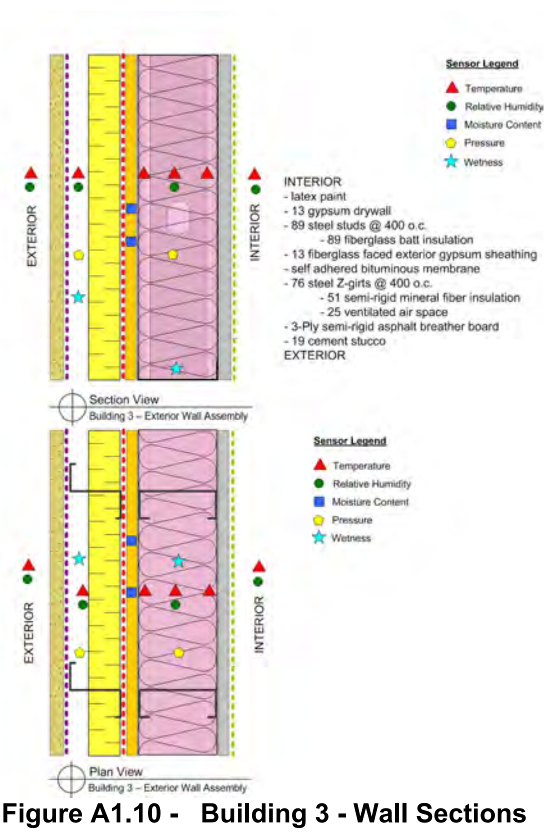


Figure A1.10 - Building 3 - Wall Sections

Figure A1.11 - Building 4 - Southwest Overview Far

Figure A1.12 - Building 4 - Sensor Layout North

Figure A1.13 - Building 4 - Sensor Layout South

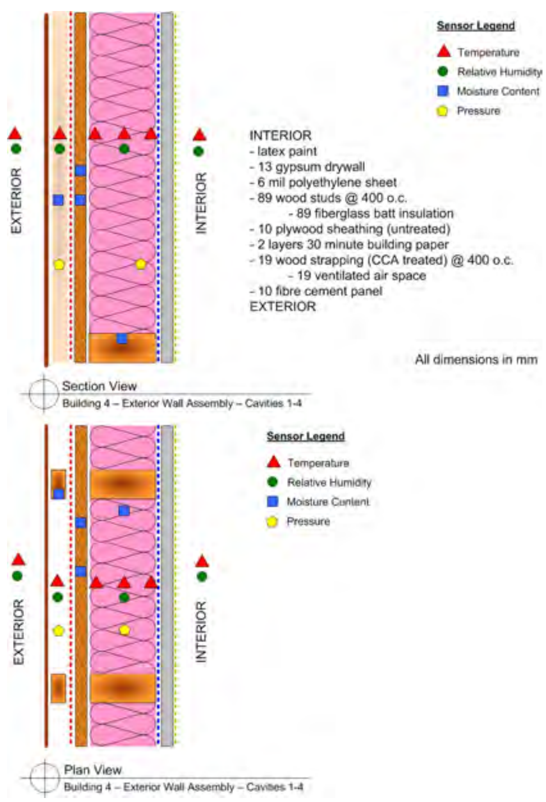


Figure A1.14 - Building 4 - Wall Sections 1-4

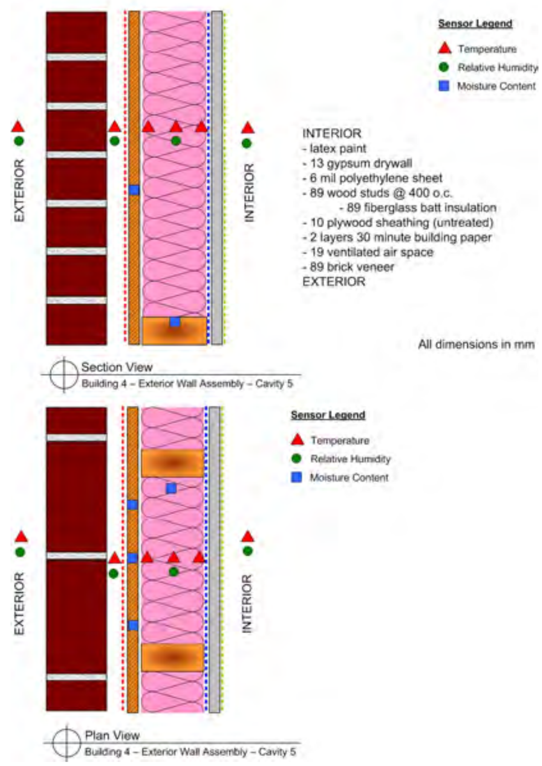


Figure A1.15 - Building 4 - Wall Sections 5

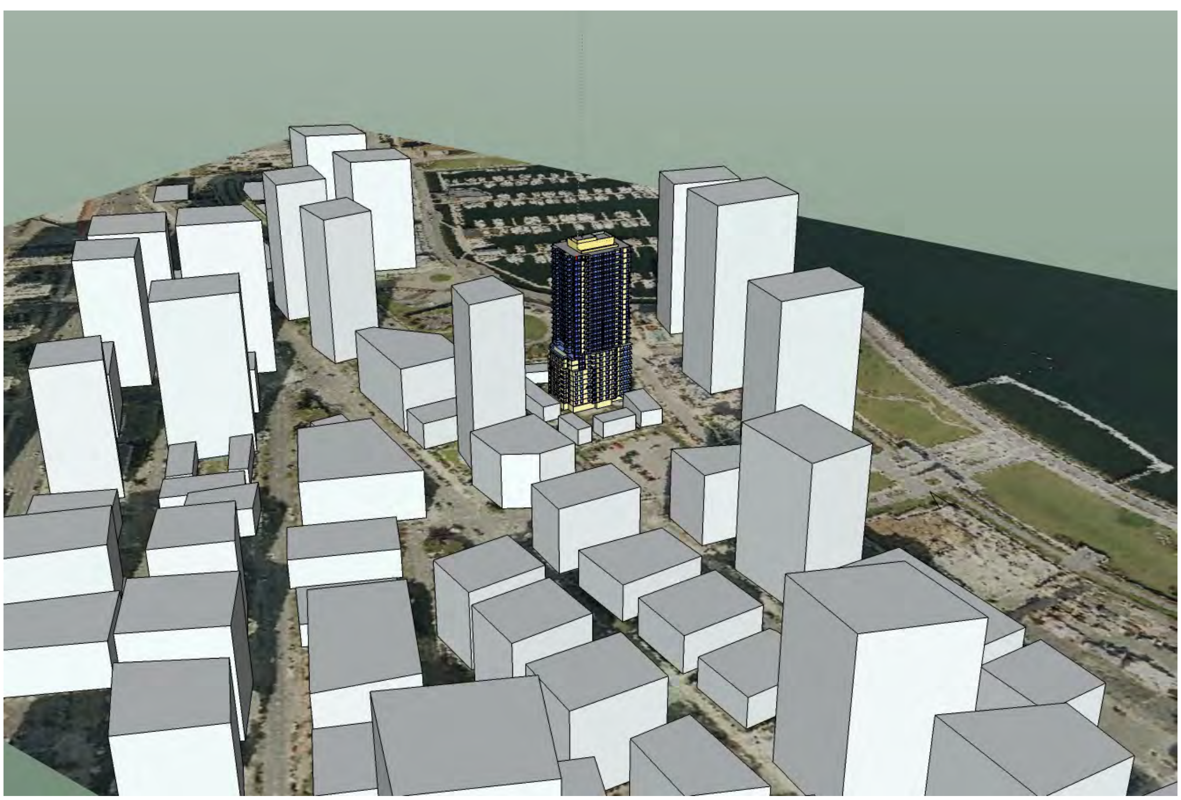


Figure A1.16 - Building 5 - Southeast Overview

Figure A1.17 - Building 5 - Southeast Closeup

Figure A1.18 - Building 5 - 5th Floor Sensors

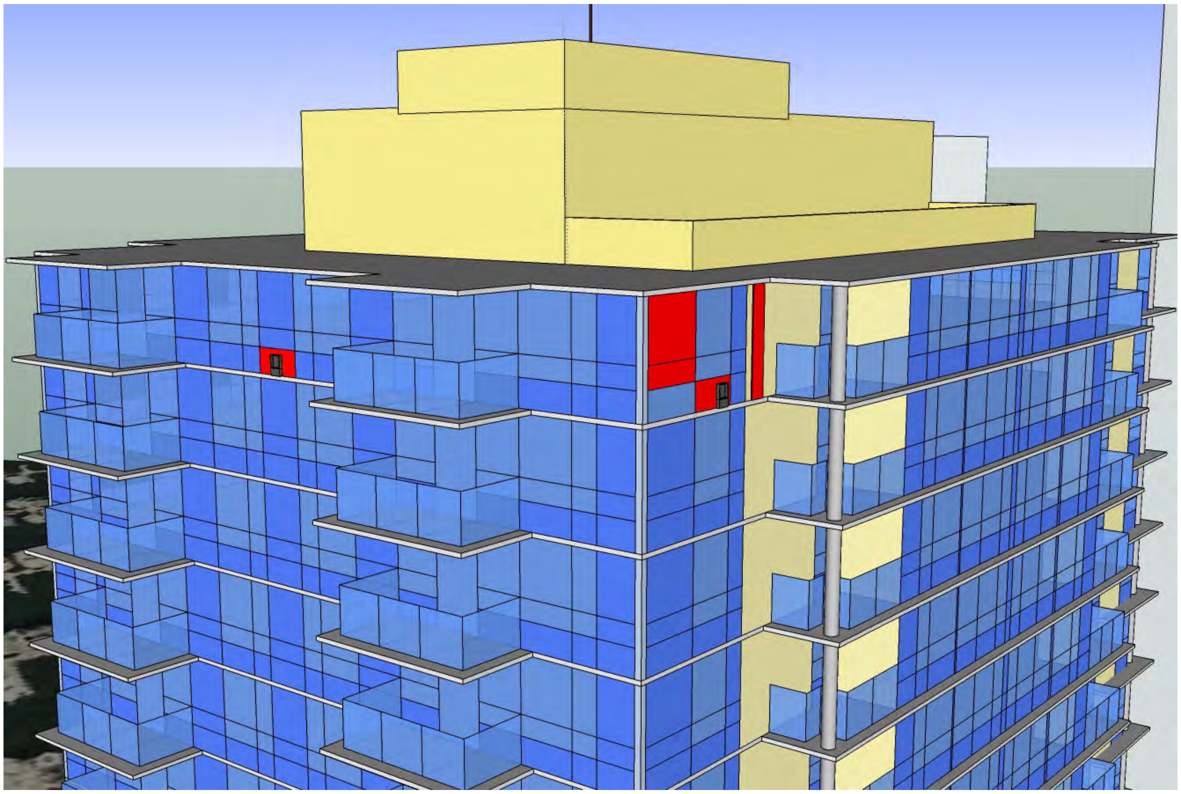


Figure A1.19 - Building 5 - 30th Floor Sensors

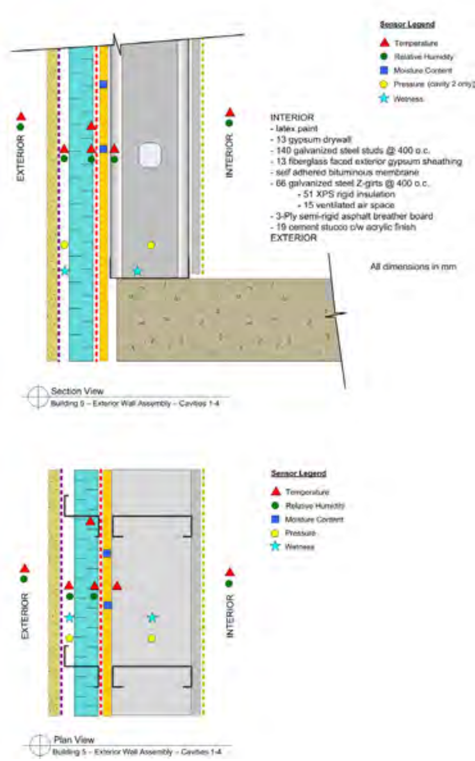


Figure A1.20 - Building 5 - Wall Sections 1-4

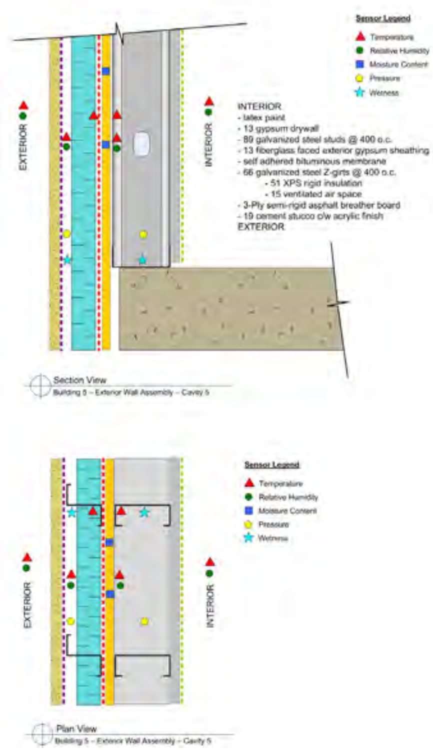


Figure A1.21 - Building 5 - Wall Section 5

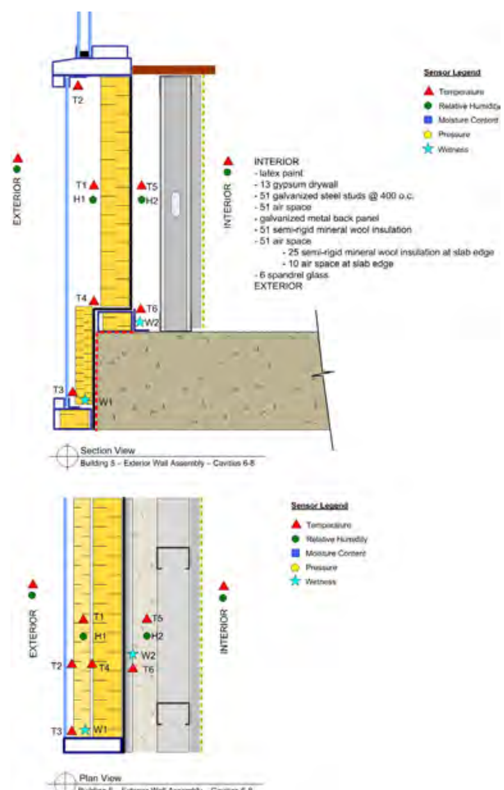


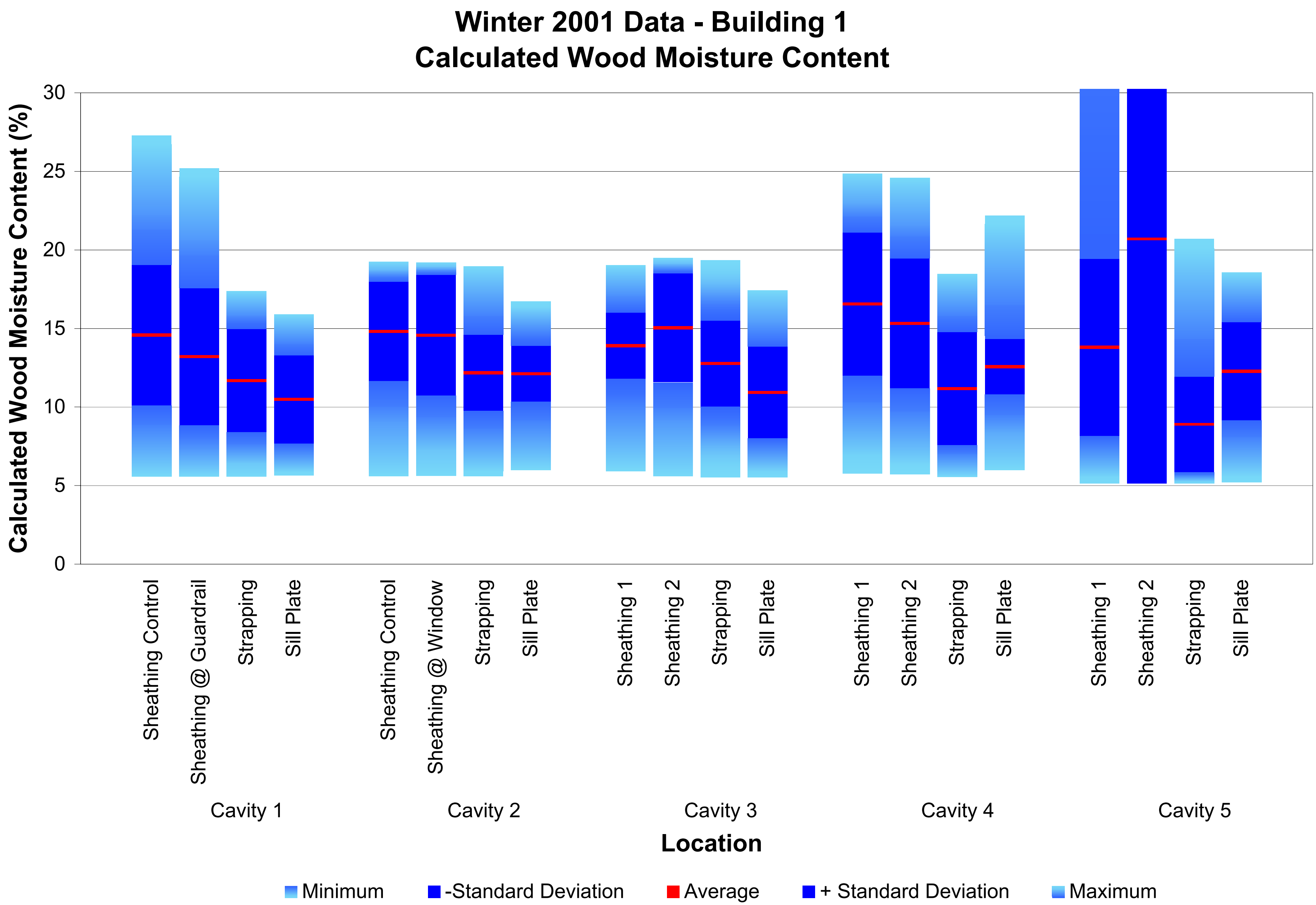
Figure A1.22 - Building 5 - Wall Sections 6-8

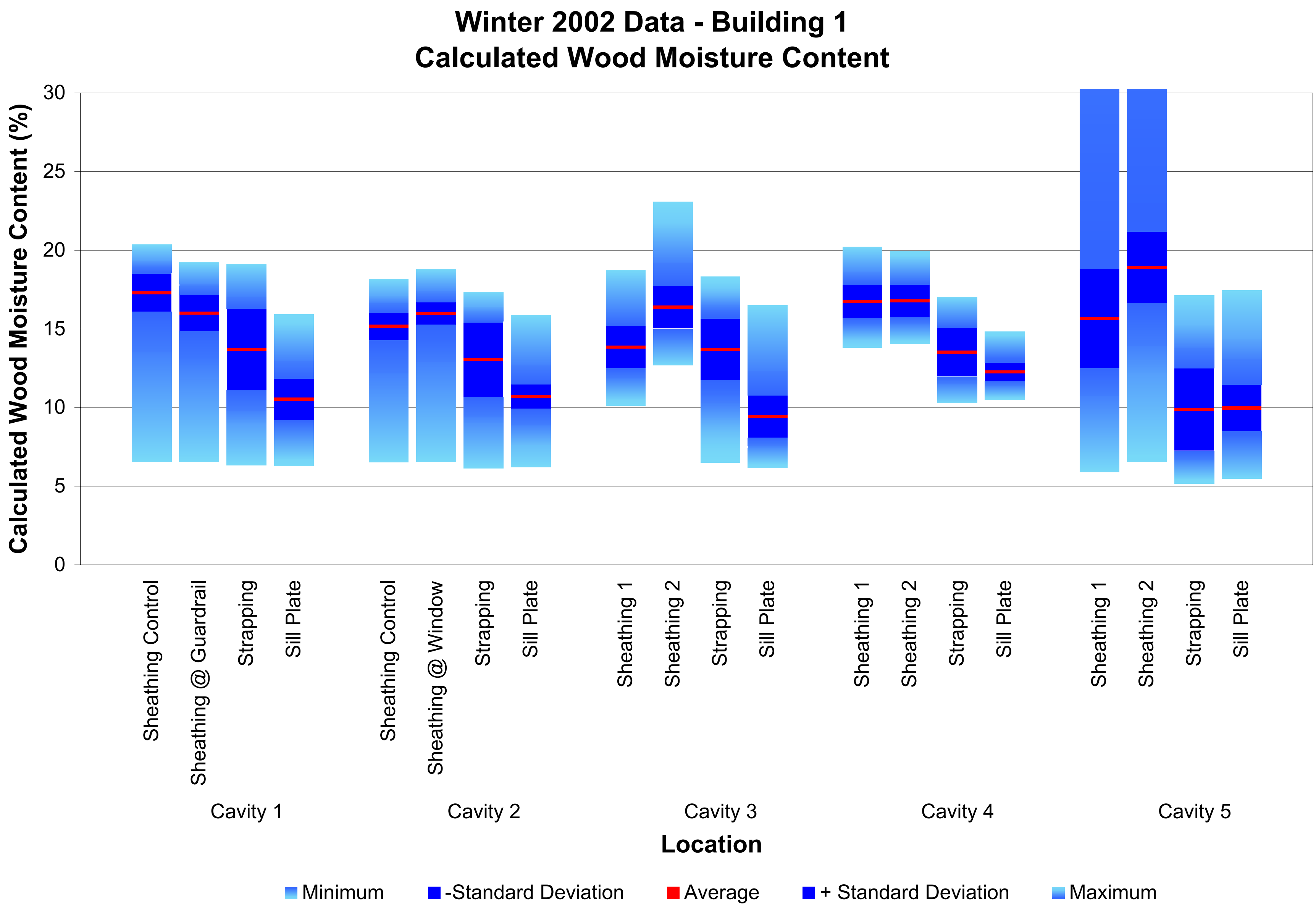
APPENDIX B

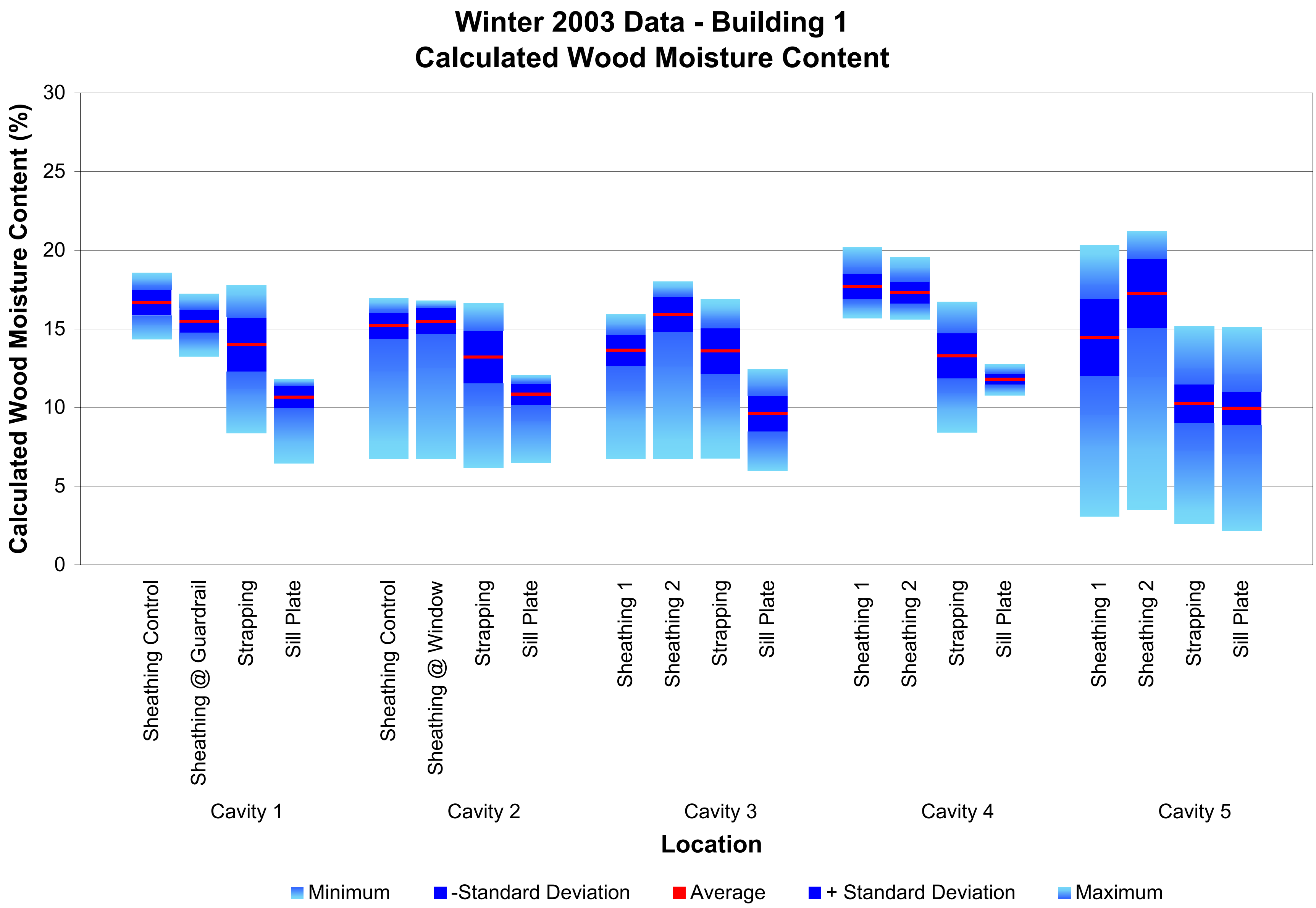
Raw and Corrected Data (DVD)

APPENDIX C

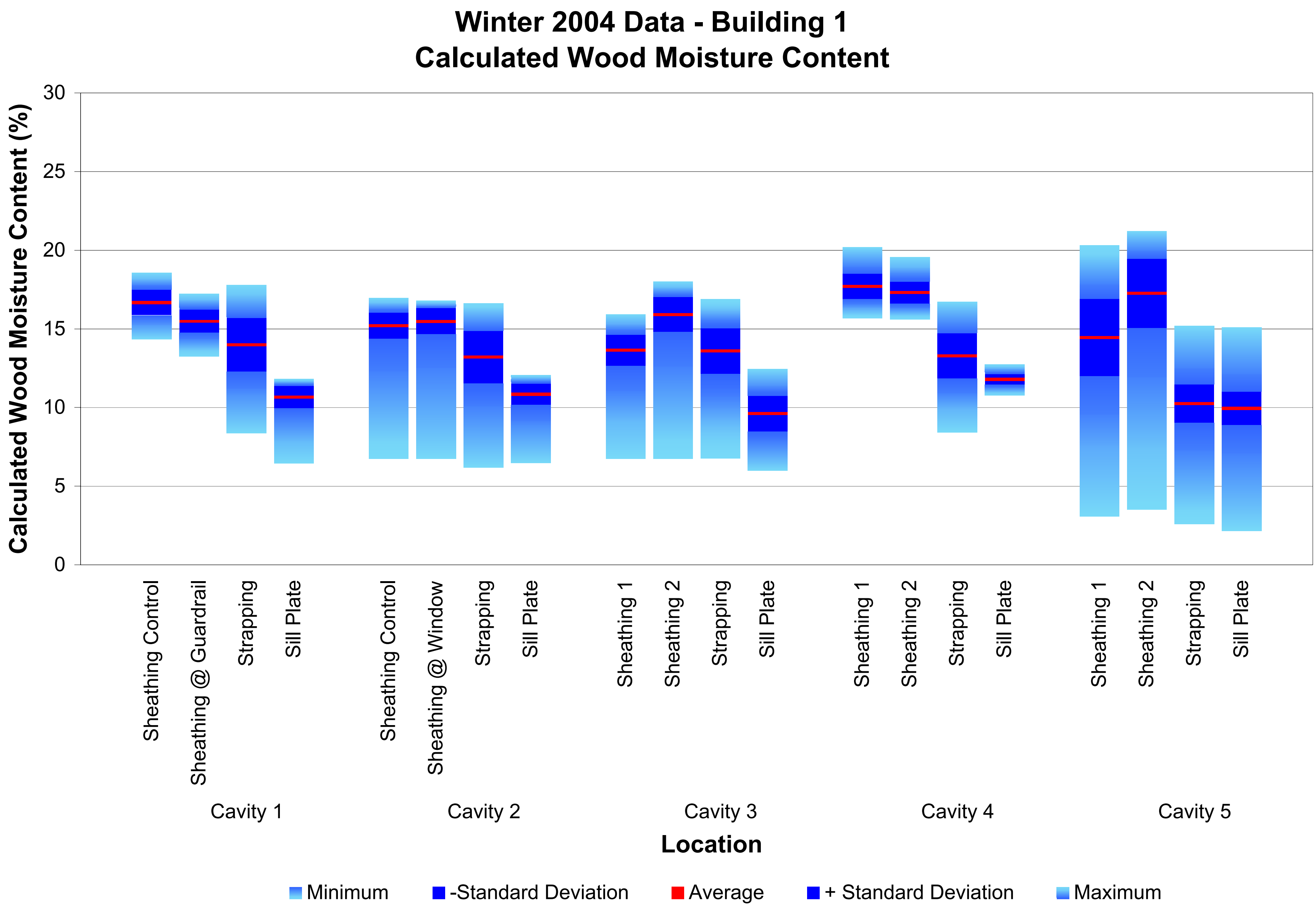
Moisture Content Summary

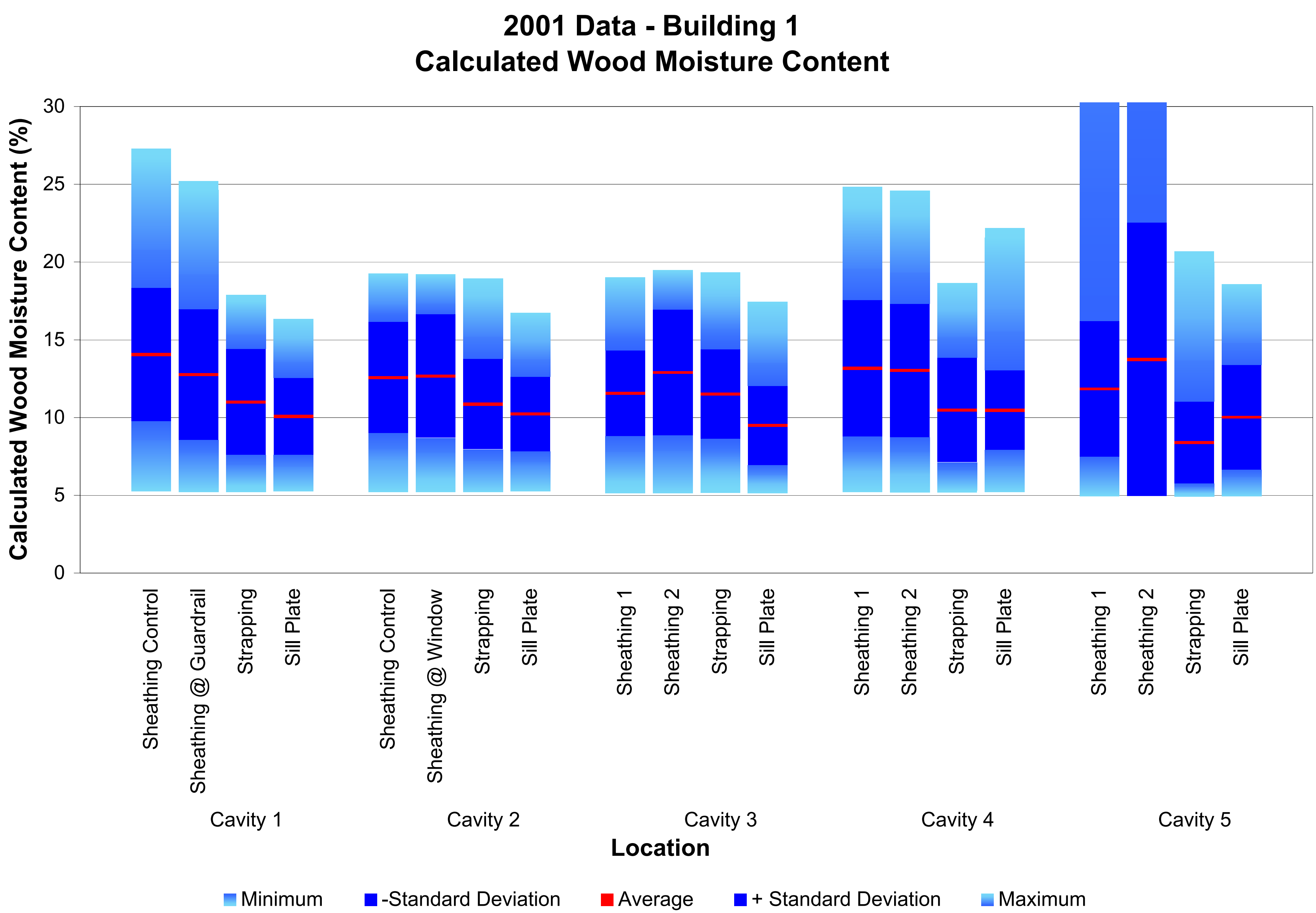

Winter 2001 Data - Building 1
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
0
5
10
15
20
25
30
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


Winter 2002 Data - Building 1
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

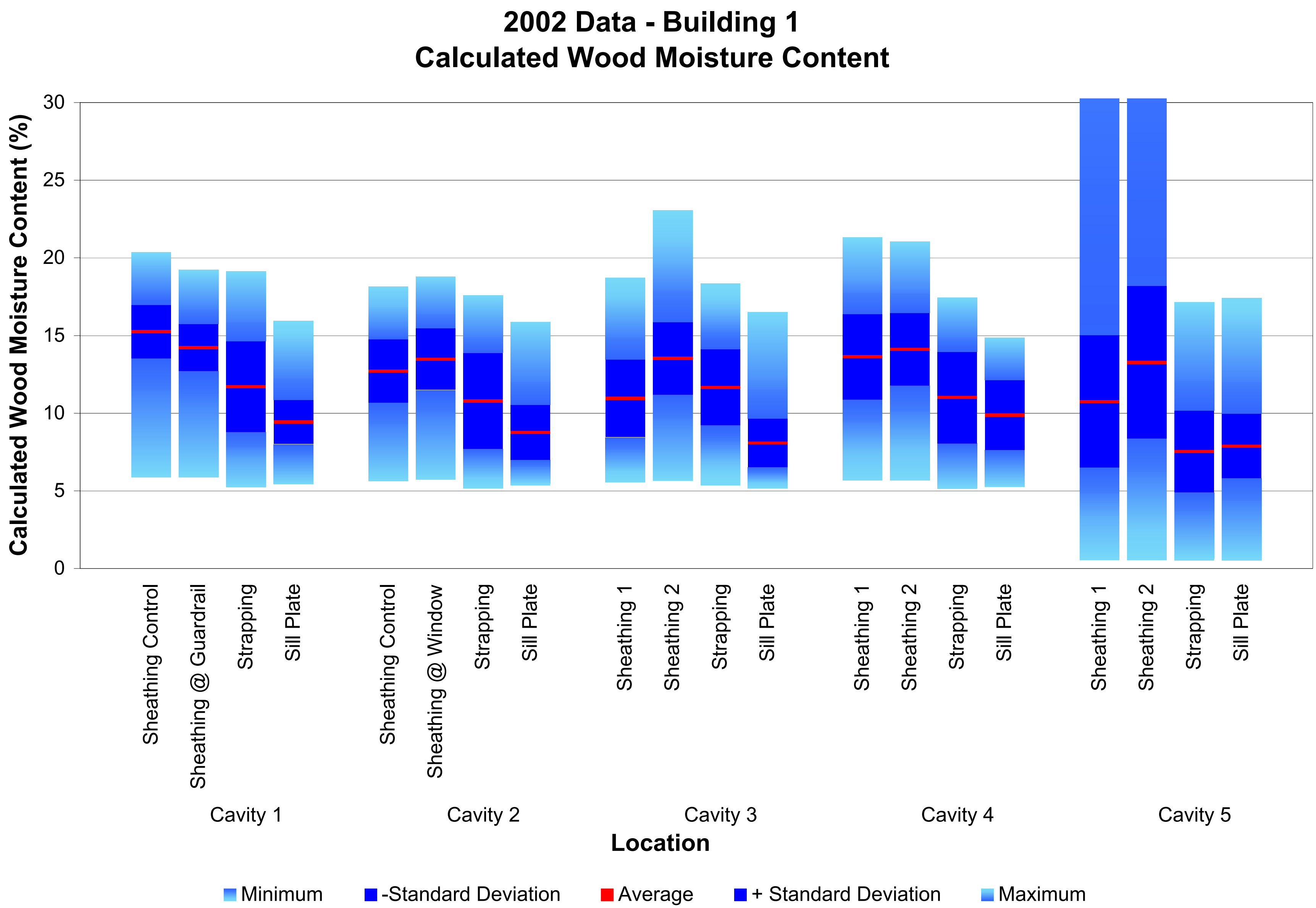


Winter 2003 Data - Building 1
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

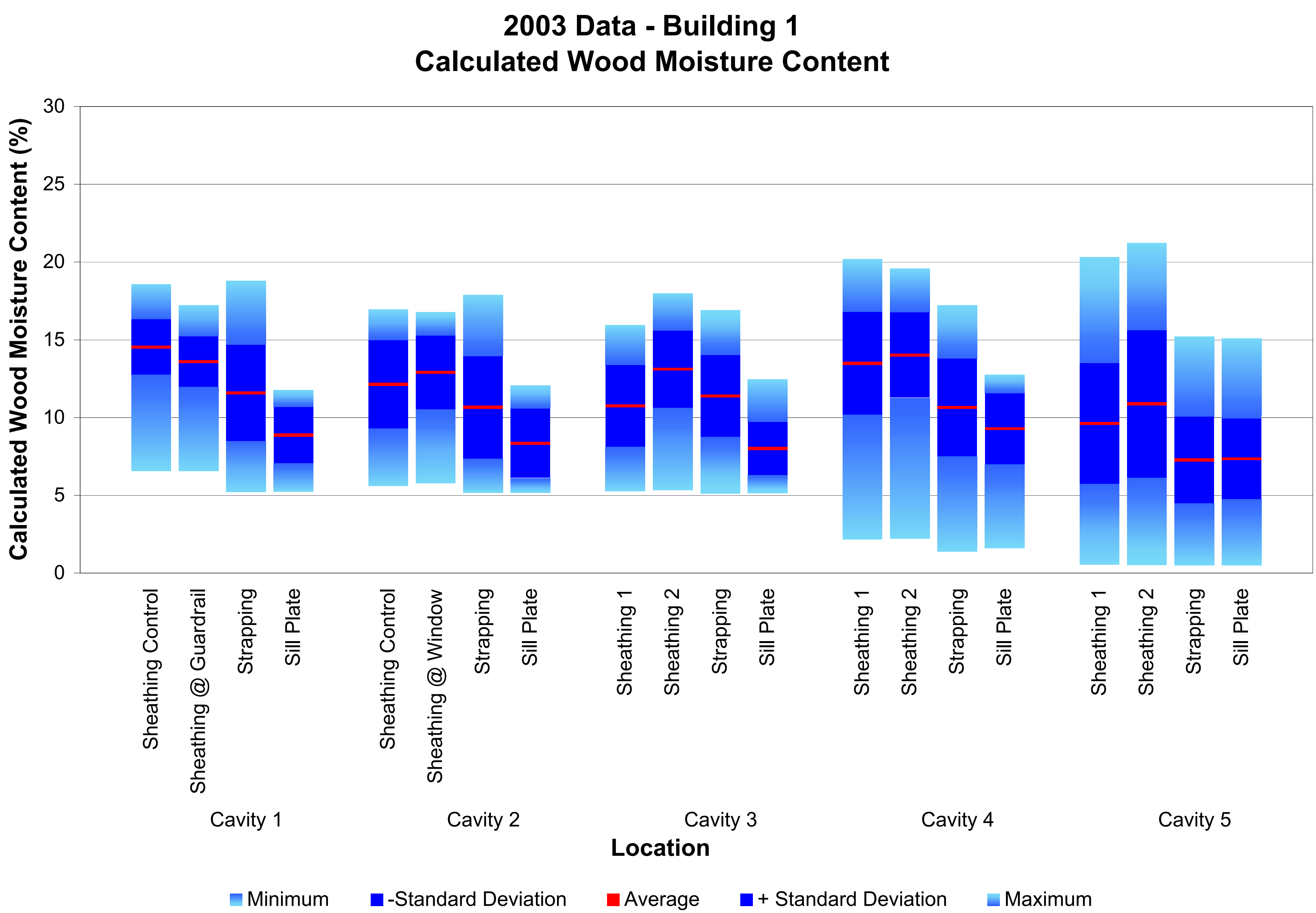

Winter 2004 Data - Building 1
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



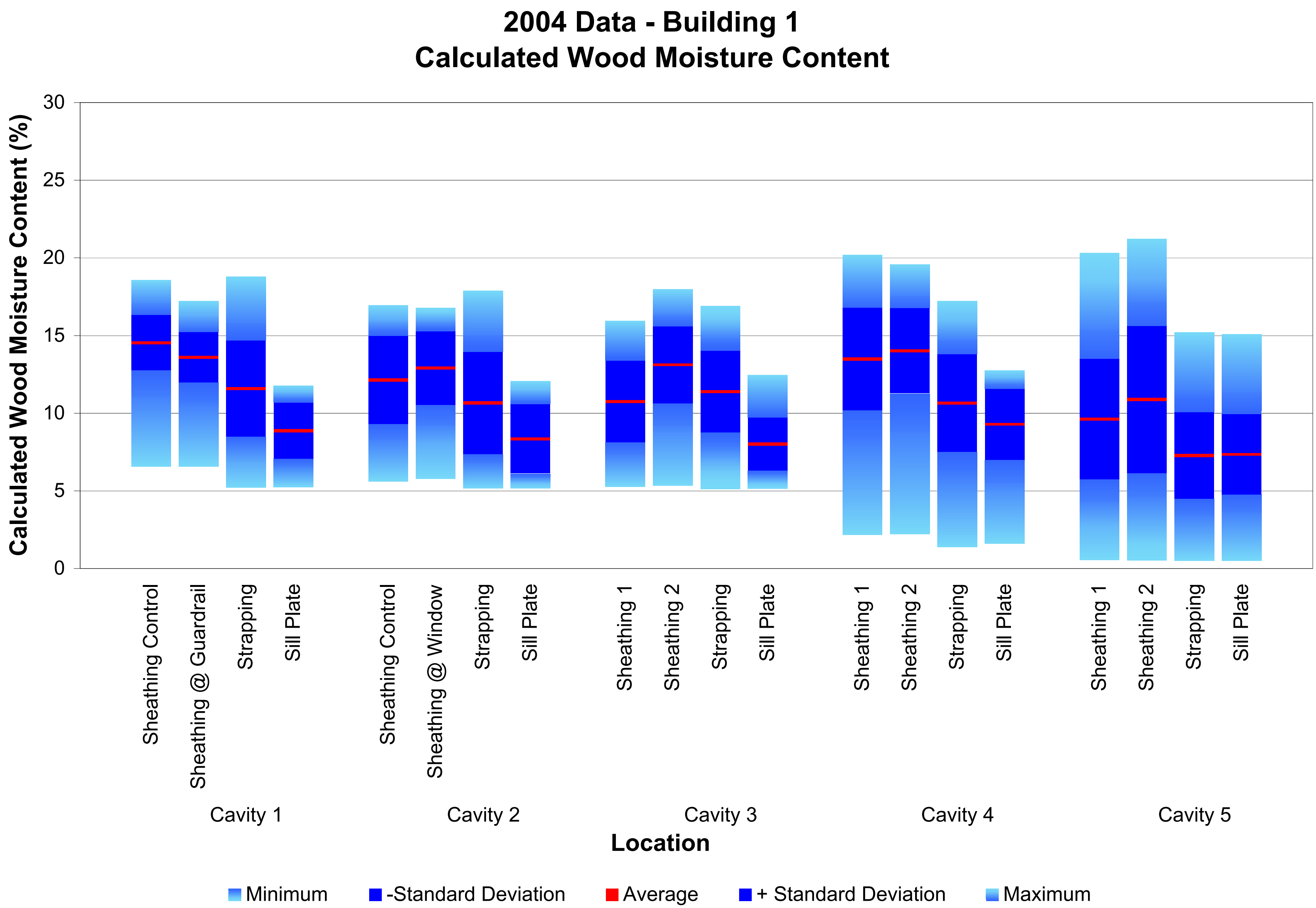
2001 Data - Building 1
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
0
5
10
15
20
25
30
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

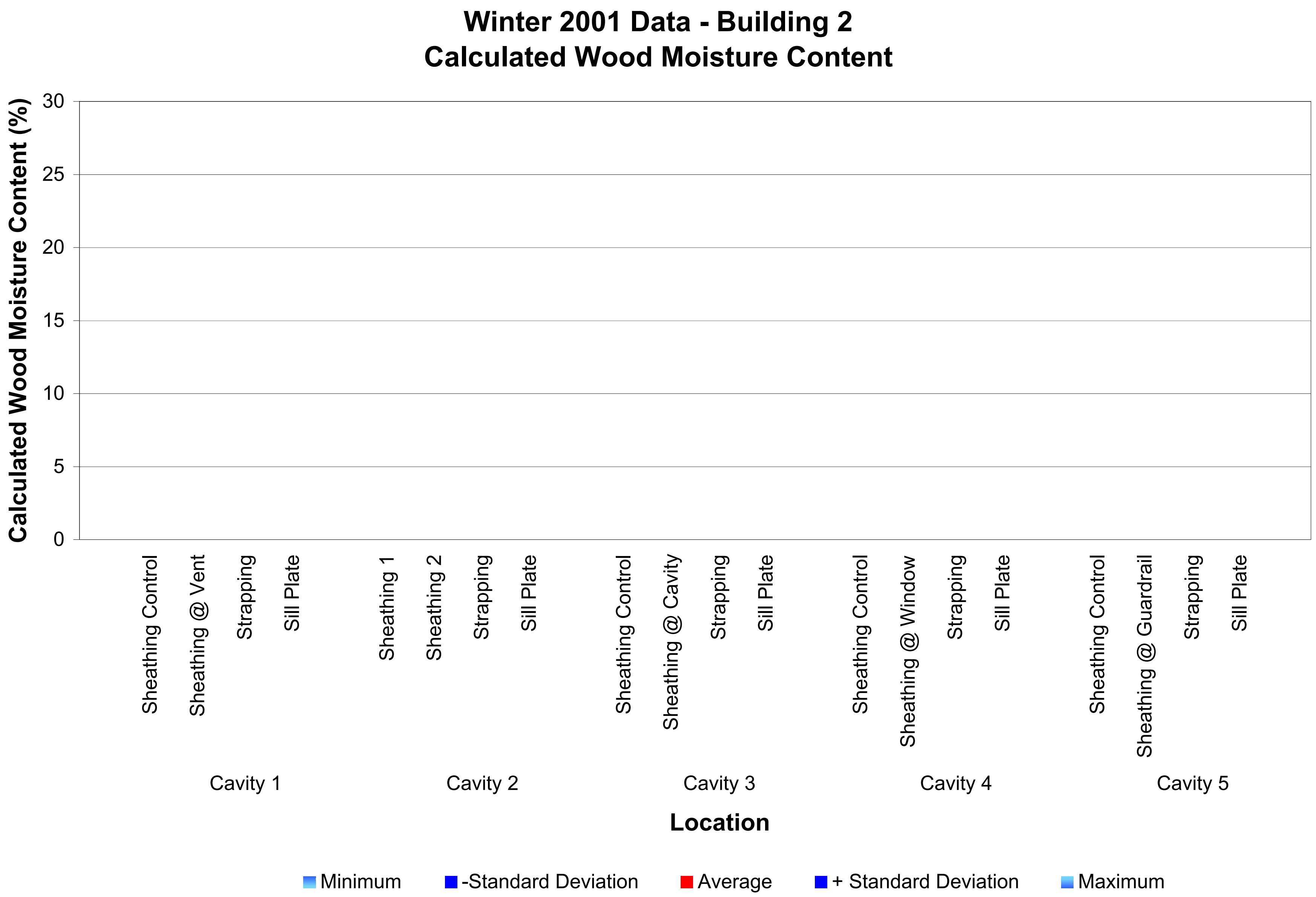


2002 Data - Building 1
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

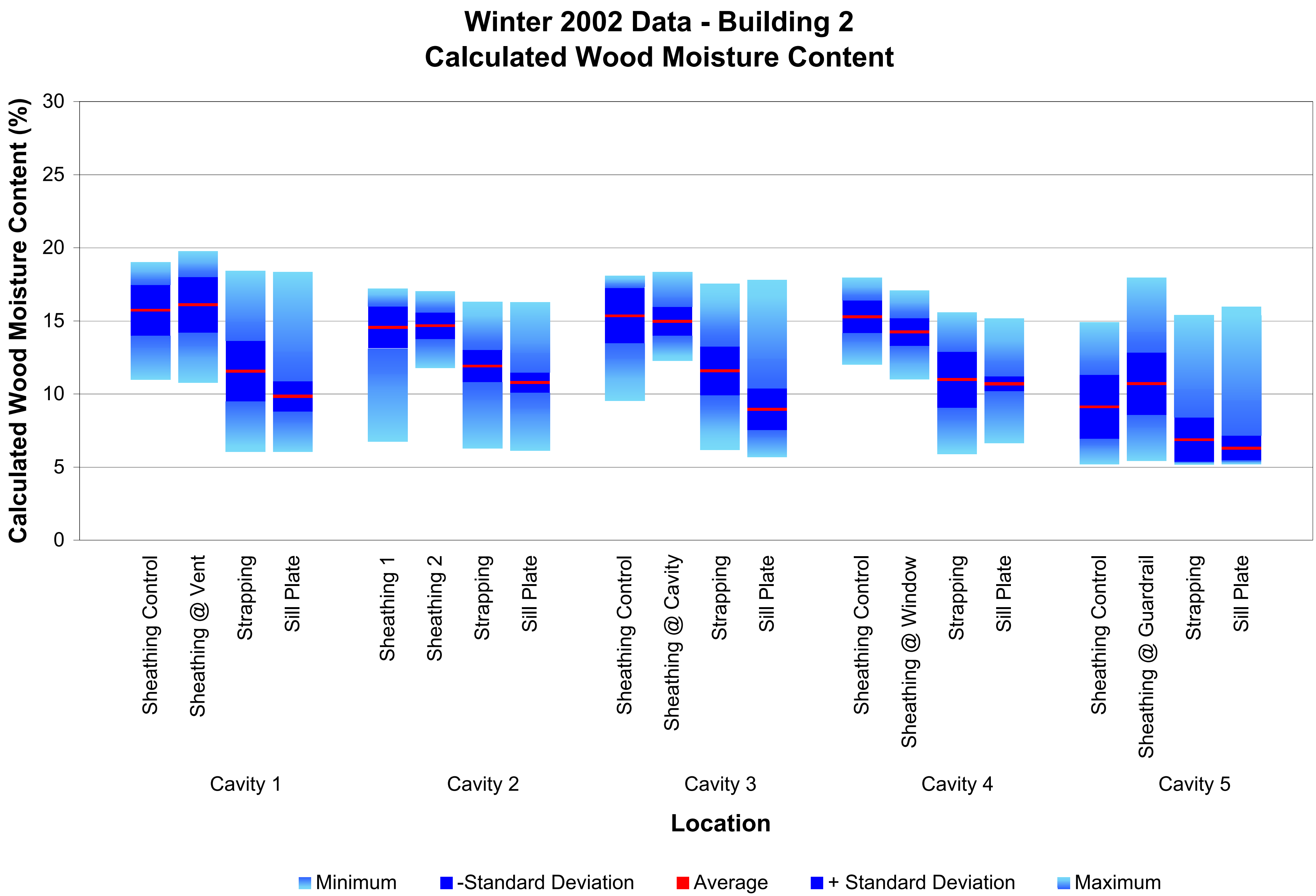


2003 Data - Building 1
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
0
5
10
15
20
25
30
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

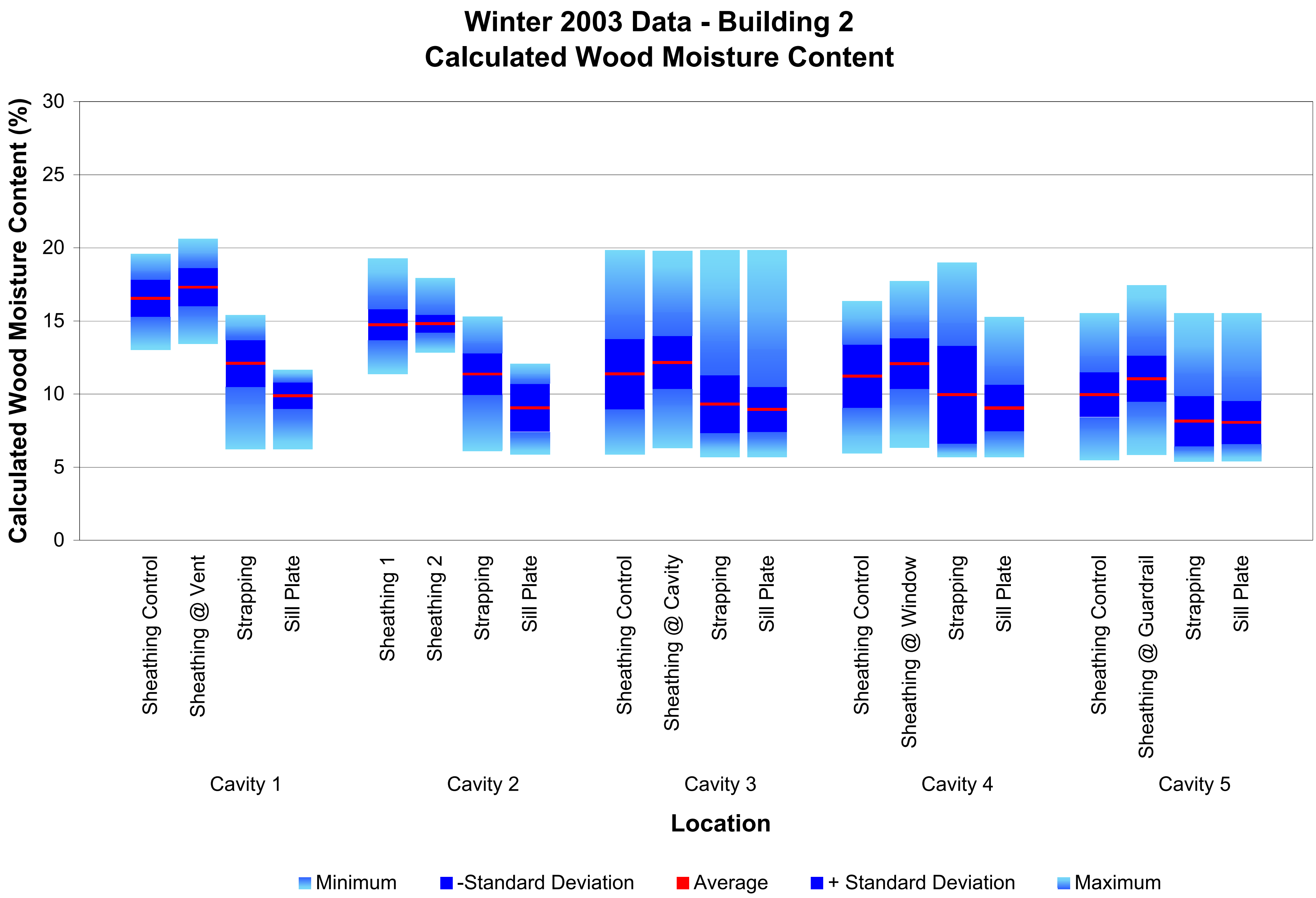

2004 Data - Building 1
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



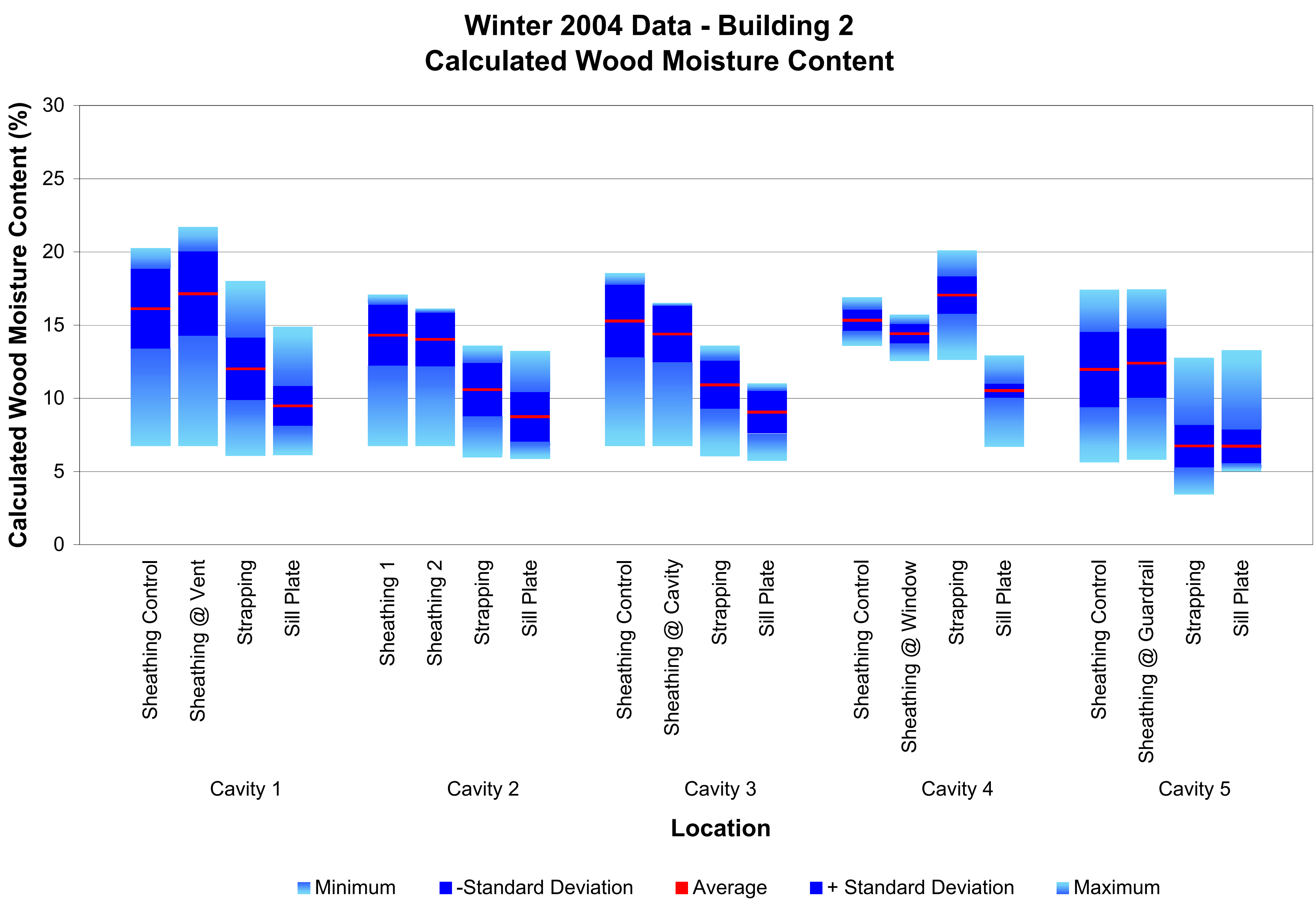
Winter 2001 Data - Building 2
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Vent
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Cavity
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



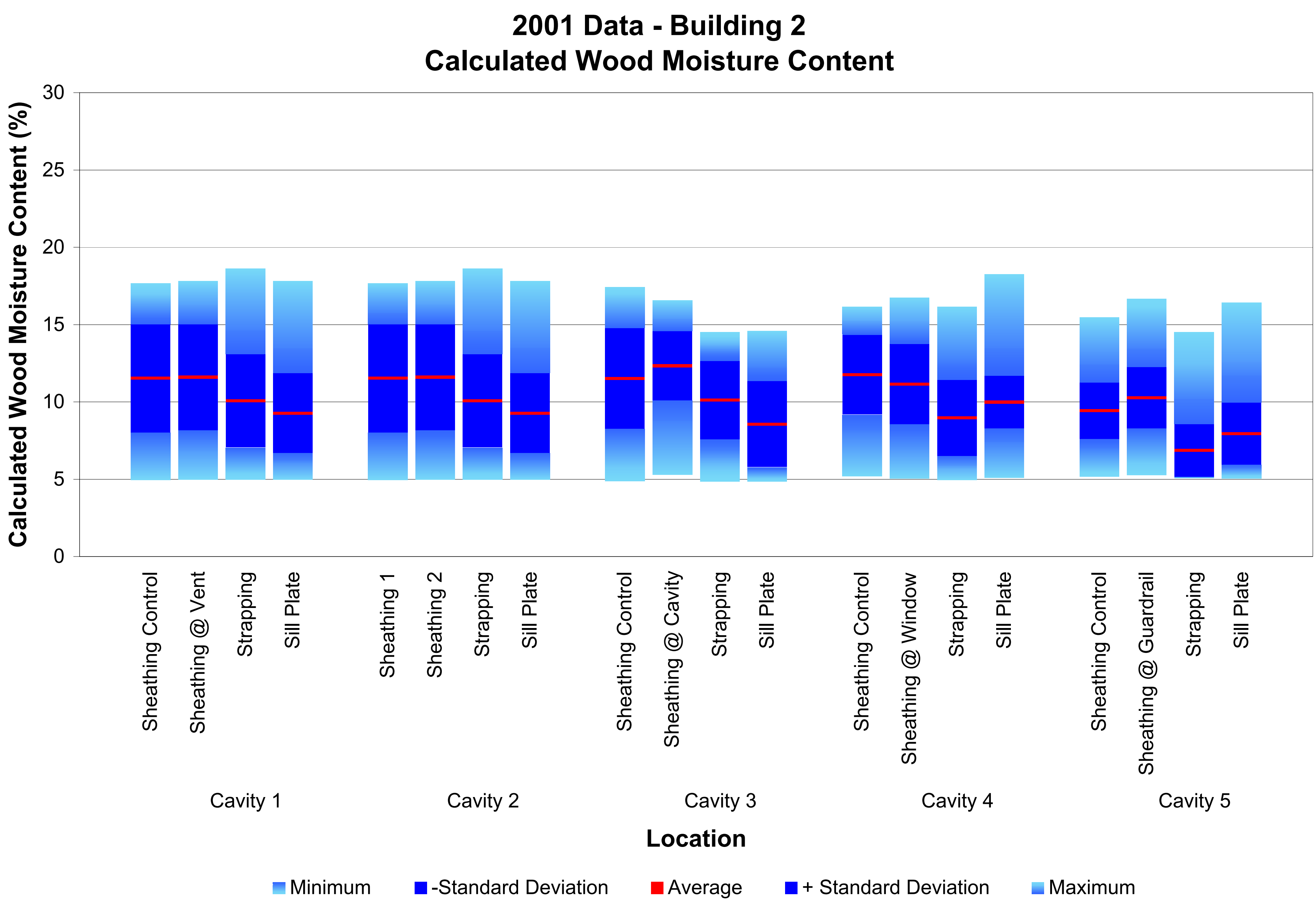
Winter 2002 Data - Building 2
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Vent
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Cavity
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

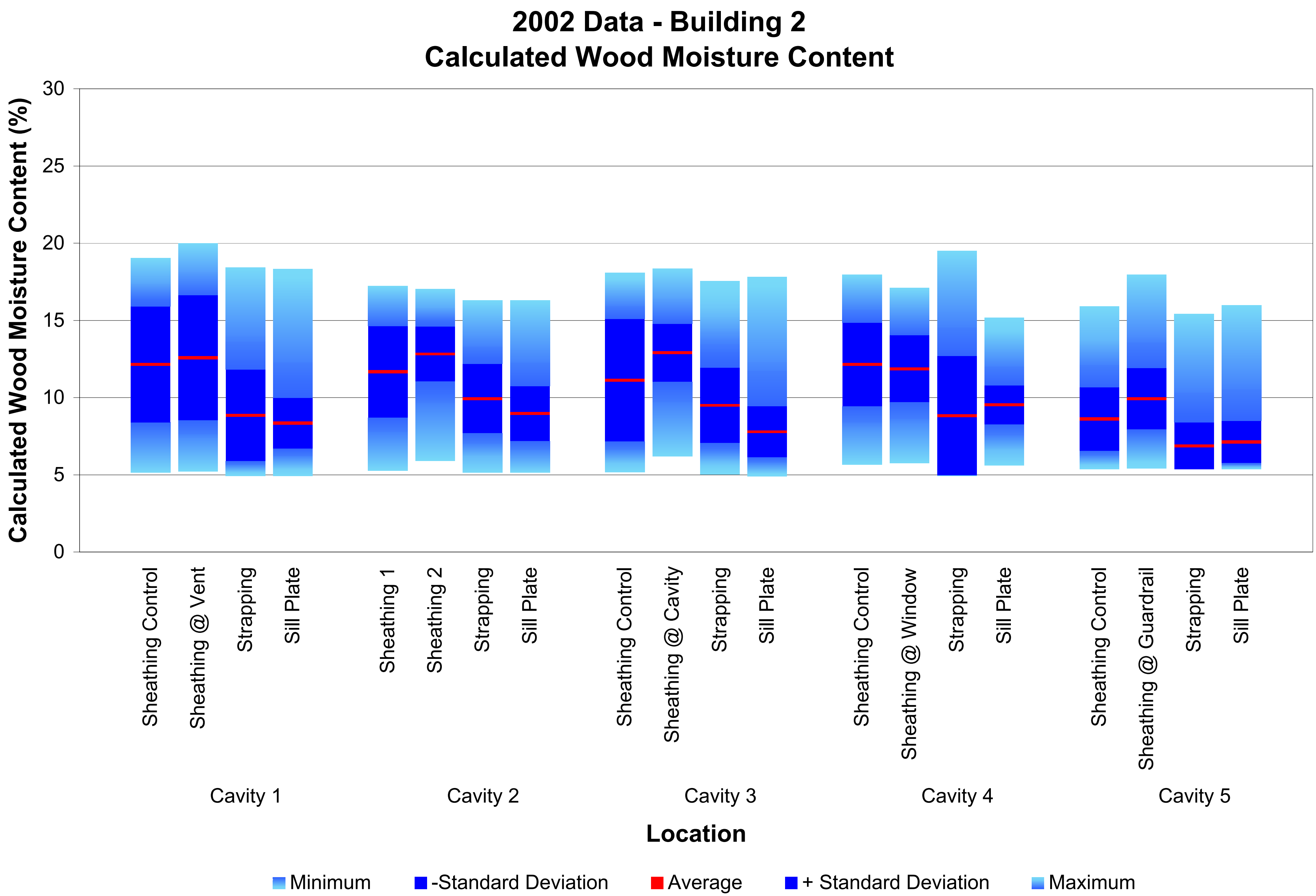


Winter 2003 Data - Building 2
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Vent
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Cavity
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

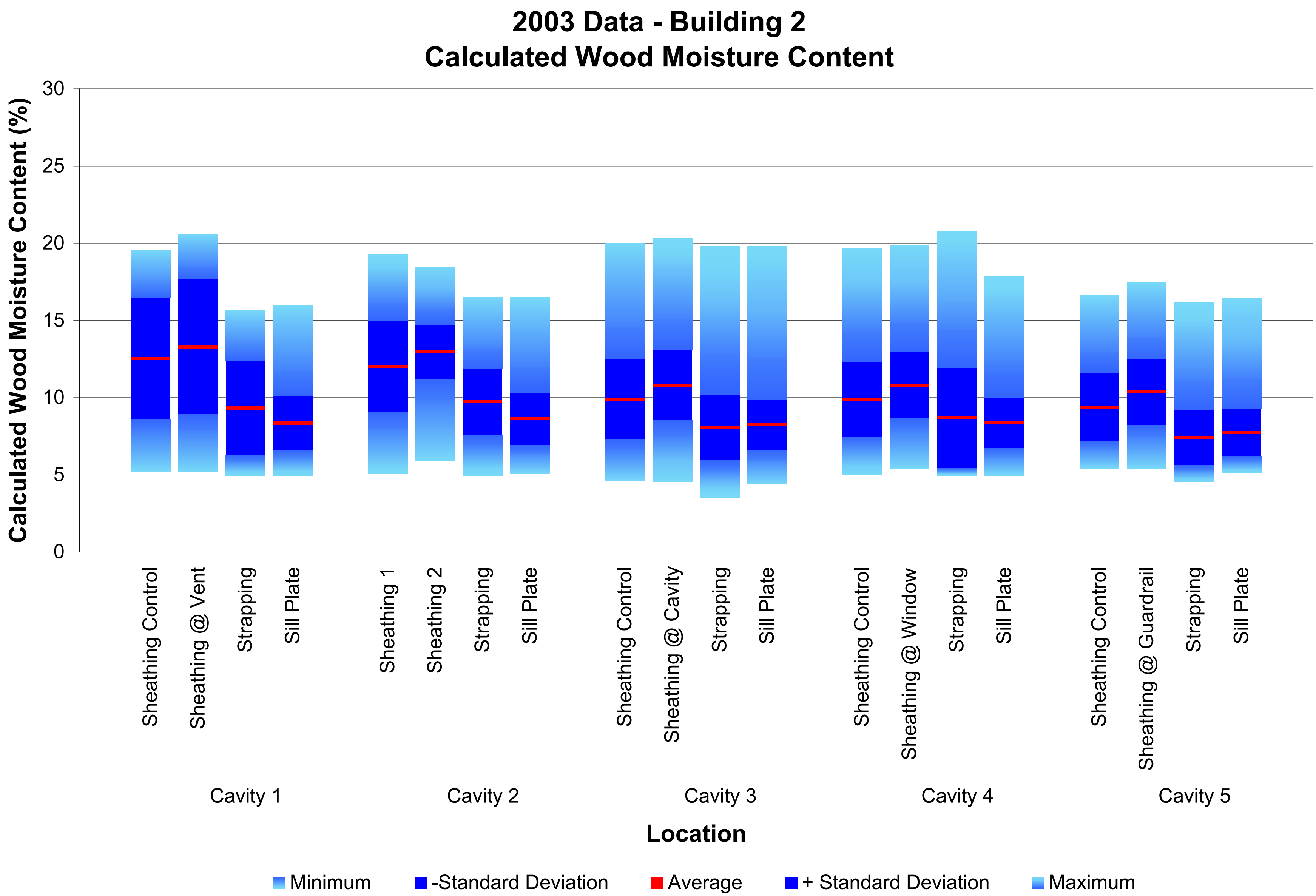


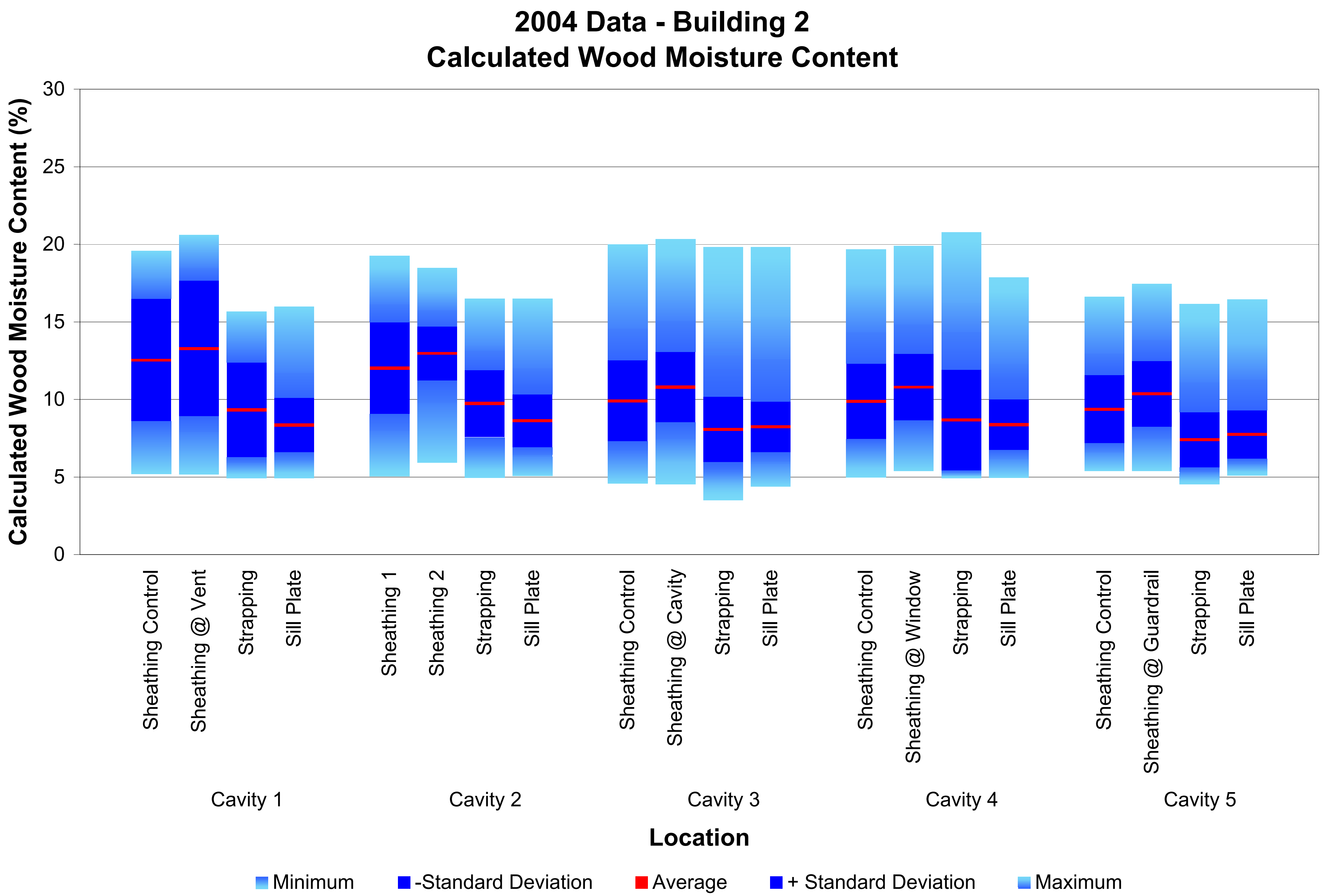
Winter 2004 Data - Building 2
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Vent
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Cavity
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


2001 Data - Building 2
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
0
5
10
15
20
25
30
Sheathing Control
Sheathing @ Vent
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Cavity
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

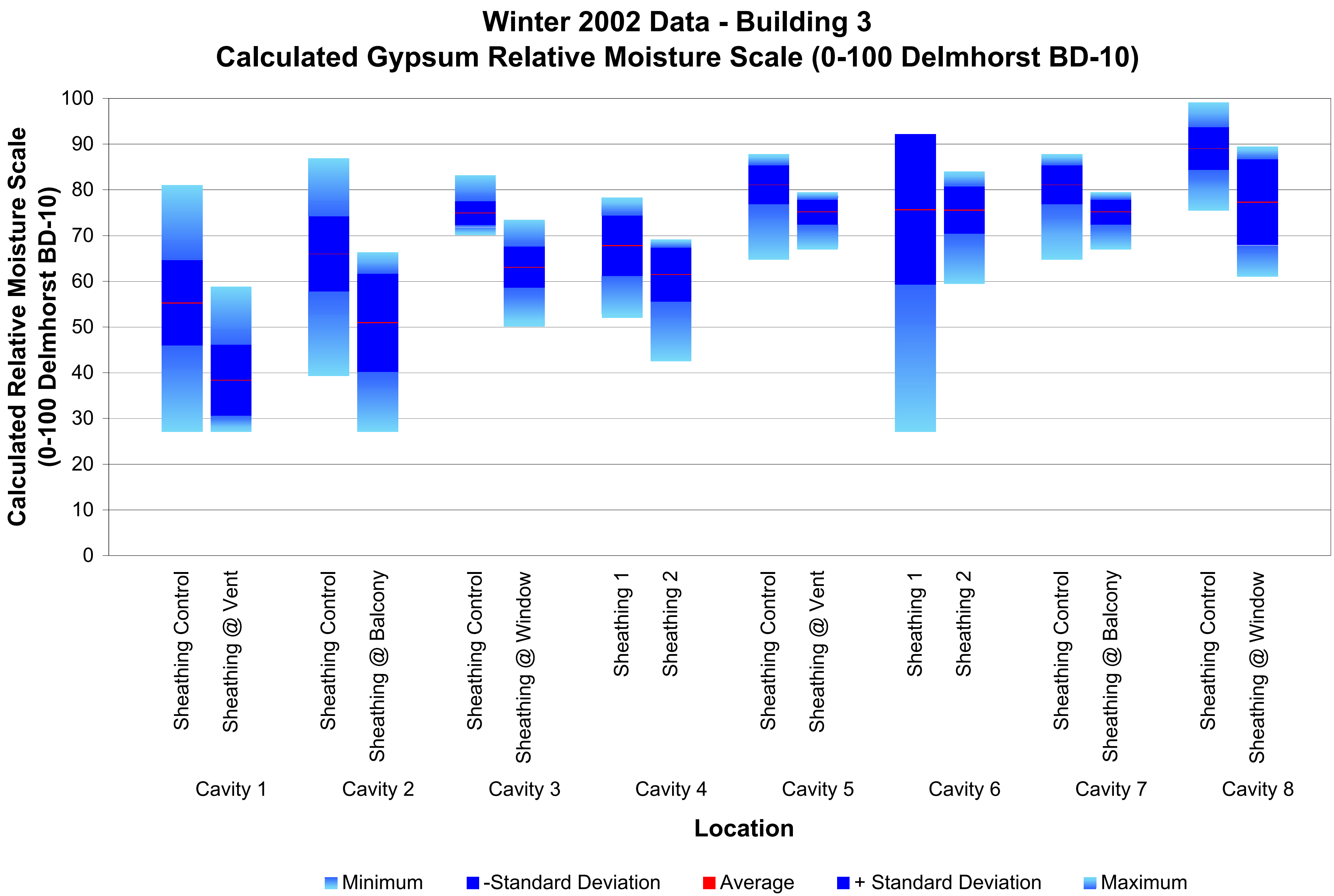


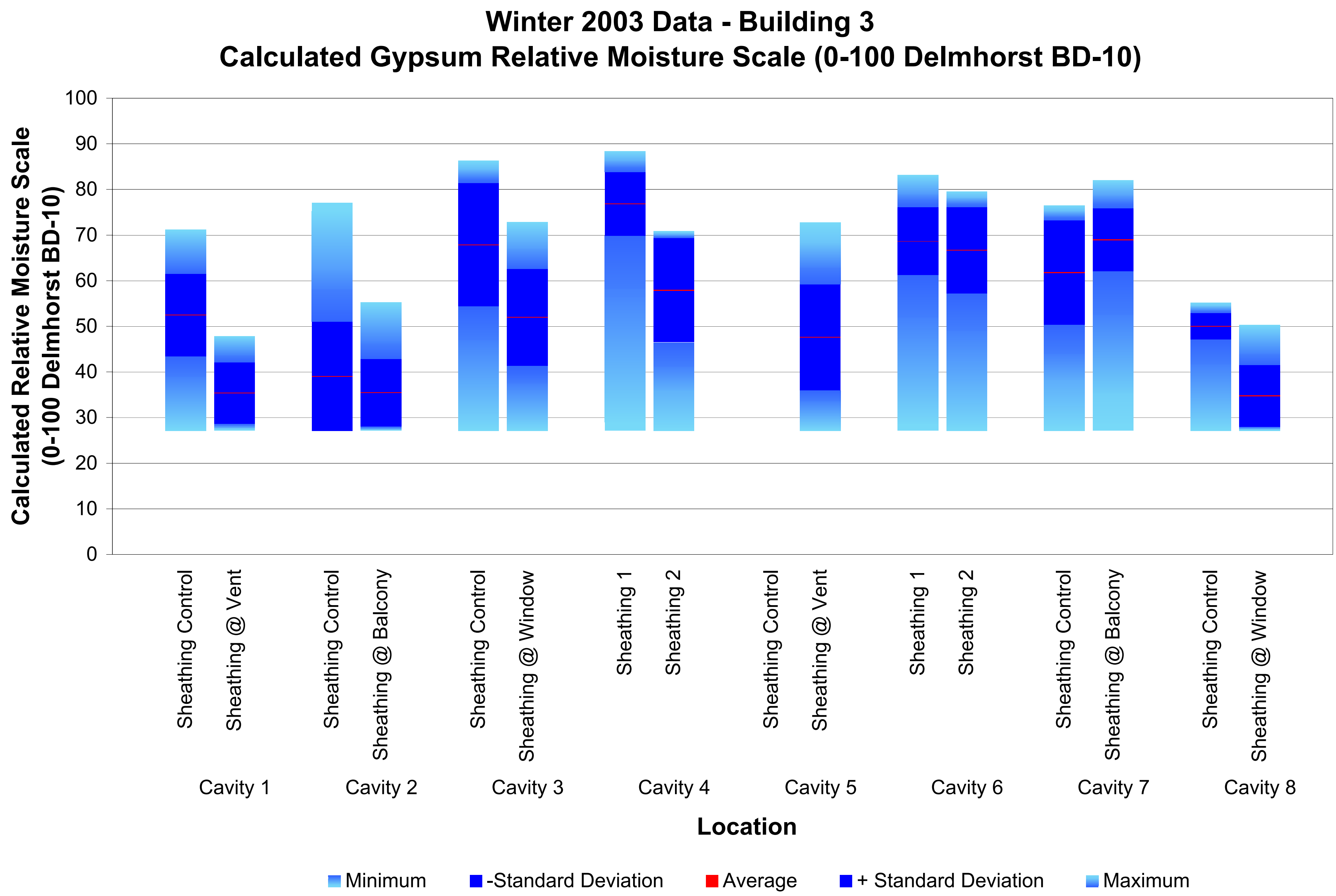
2002 Data - Building 2
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Vent
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Cavity
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


2003 Data - Building 2
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
0
5
10
15
20
25
30
Sheathing Control
Sheathing @ Vent
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Cavity
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

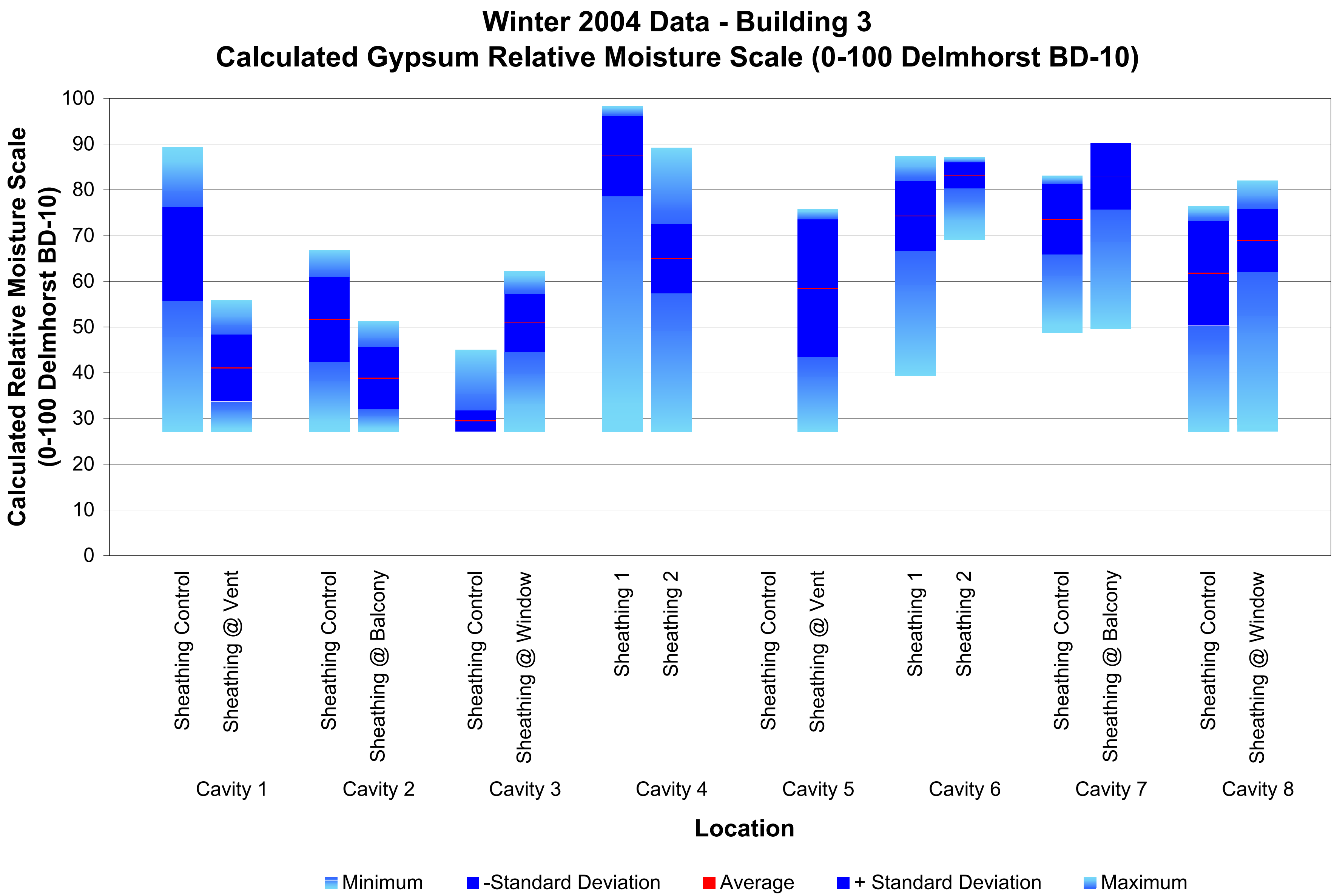


2004 Data - Building 2
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
0
5
10
15
20
25
30
Sheathing Control
Sheathing @ Vent
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Cavity
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing Control
Sheathing @ Guardrail
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

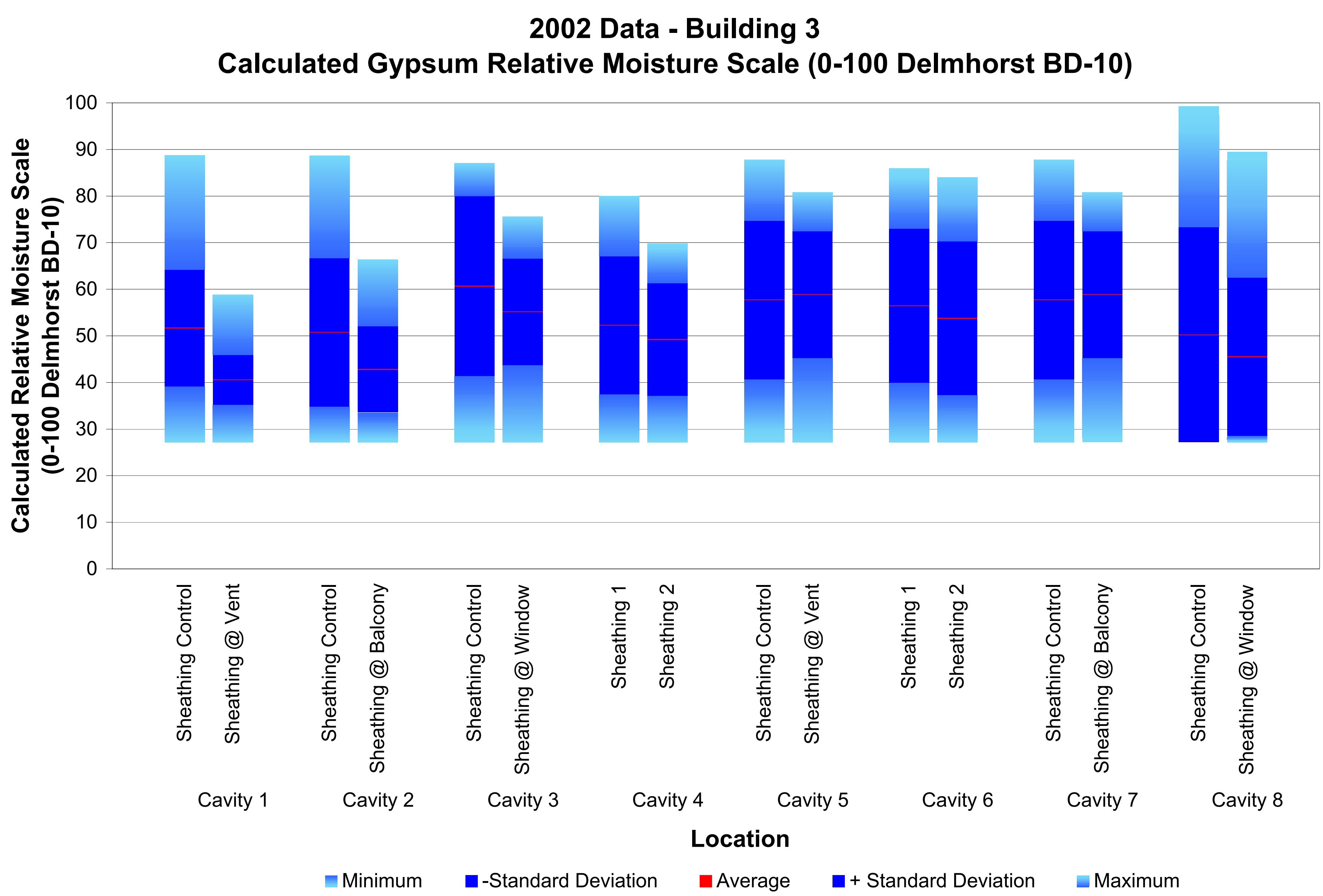

Winter 2002 Data - Building 3
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale (0-100 Delmhorst BD-10)
100
90
80
70
60
50
40
30
20
10
0
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



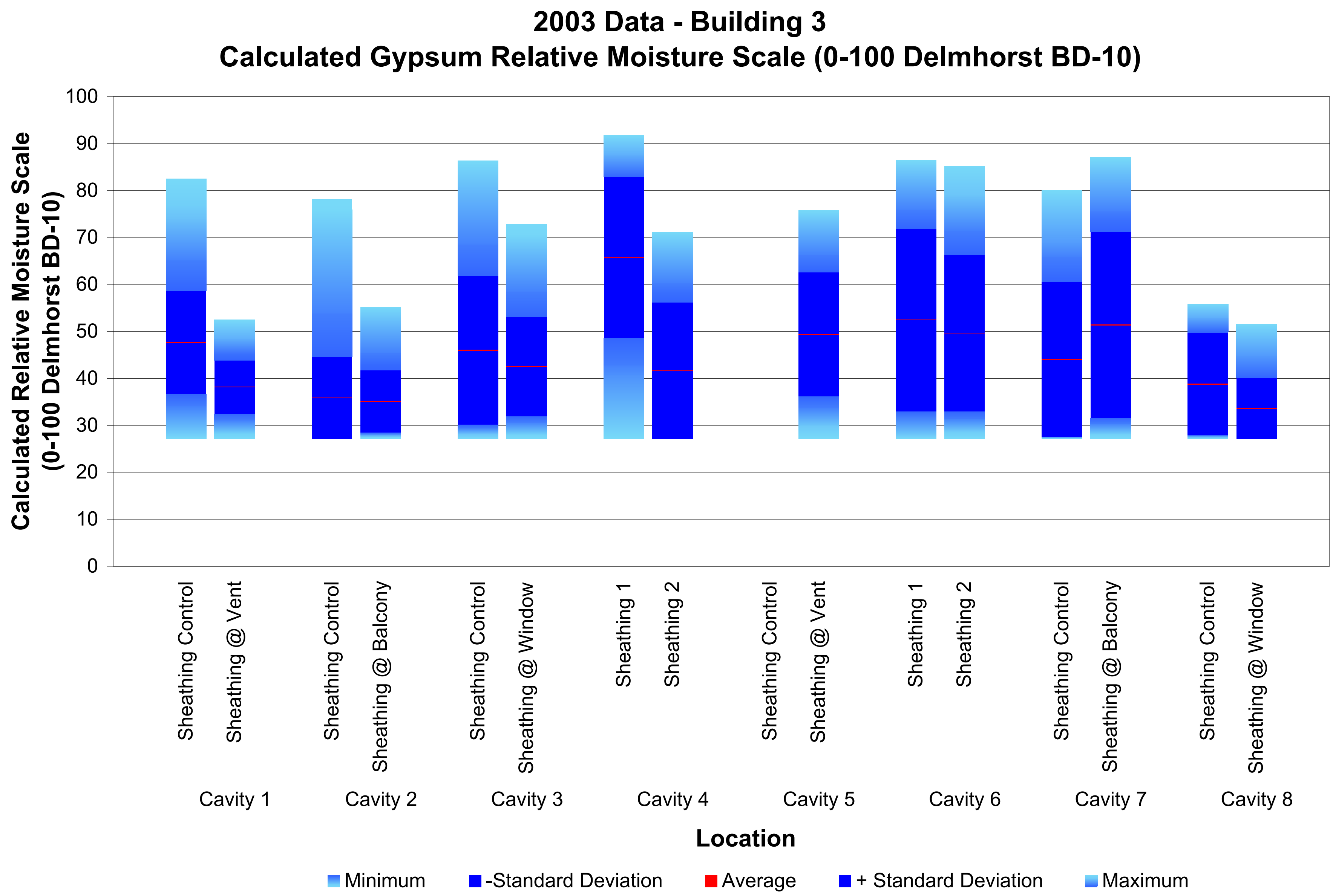
Winter 2003 Data - Building 3
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale (0-100 Delmhorst BD-10)
100
90
80
70
60
50
40
30
20
10
0
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



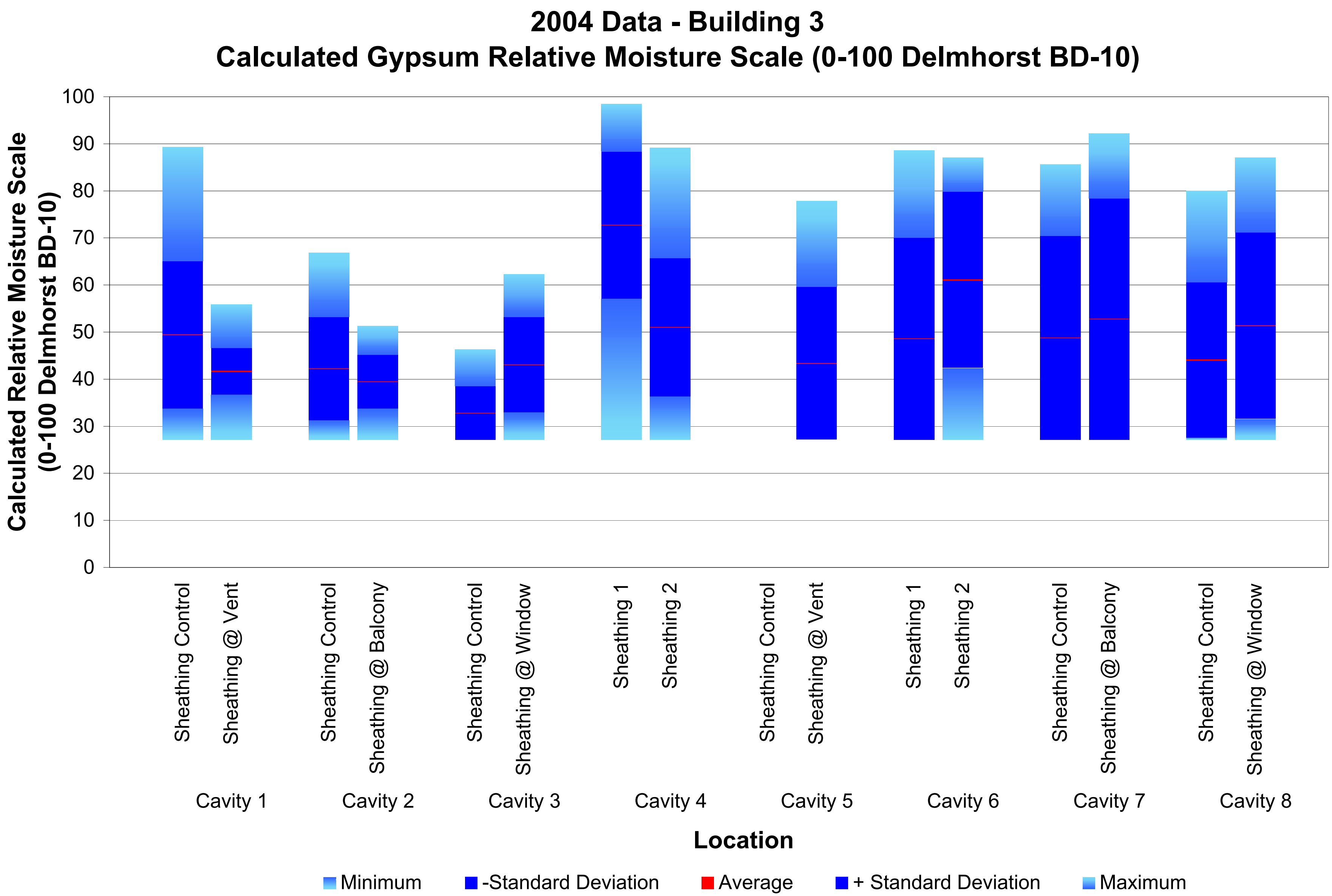
Winter 2004 Data - Building 3
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale (0-100 Delmhorst BD-10)
0
10
20
30
40
50
60
70
80
90
100
Sheathing Control
Sheathing @ Vent
Cavity 1
Sheathing Control
Sheathing @ Balcony
Cavity 2
Sheathing Control
Sheathing @ Window
Cavity 3
Sheathing 1
Sheathing 2
Cavity 4
Sheathing Control
Sheathing @ Vent
Cavity 5
Sheathing 1
Sheathing 2
Cavity 6
Sheathing Control
Sheathing @ Balcony
Cavity 7
Sheathing Control
Sheathing @ Window
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

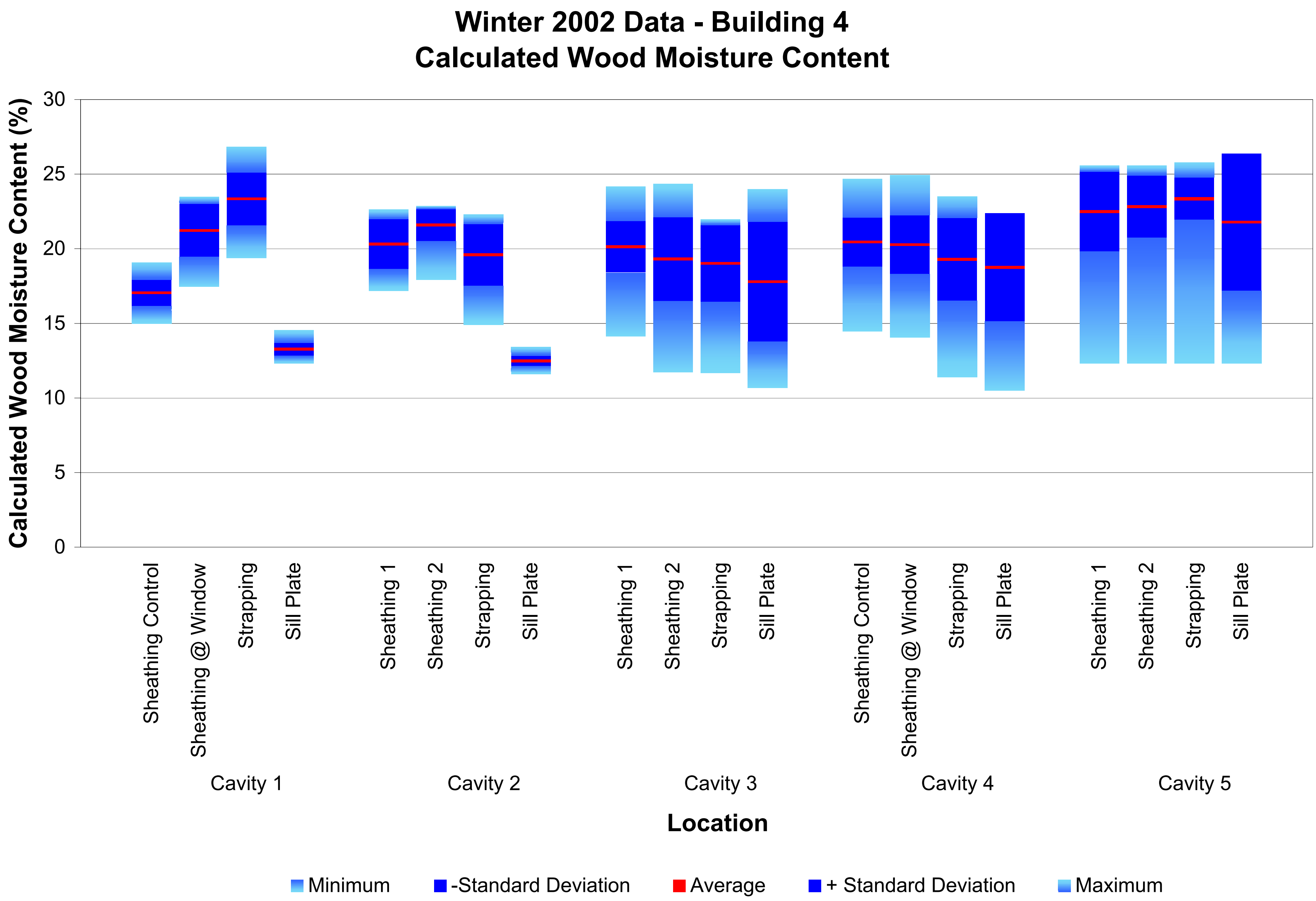


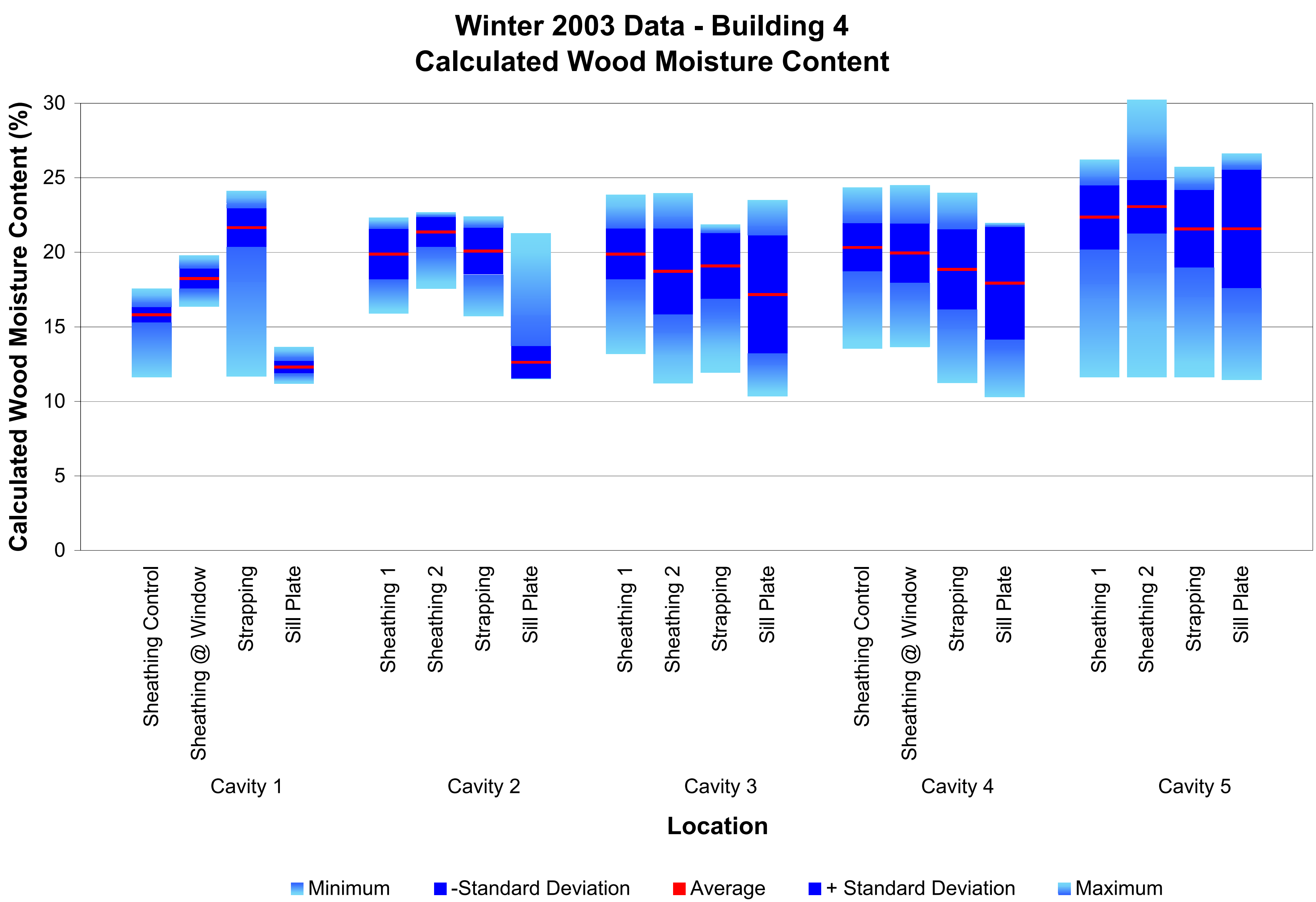
2002 Data - Building 3
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale
(0-100 Delmhorst BD-10)
100
90
80
70
60
50
40
30
20
10
0
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

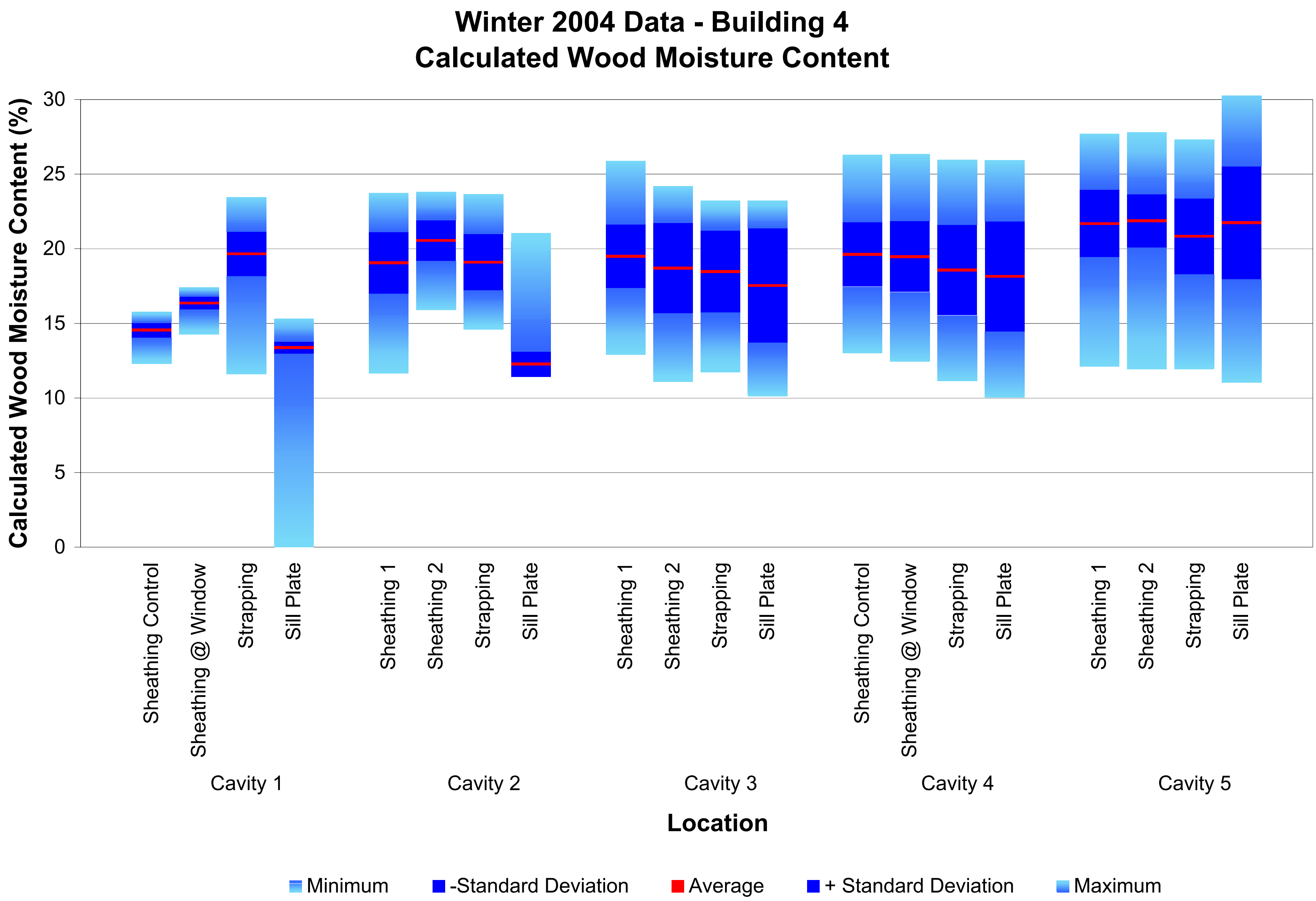


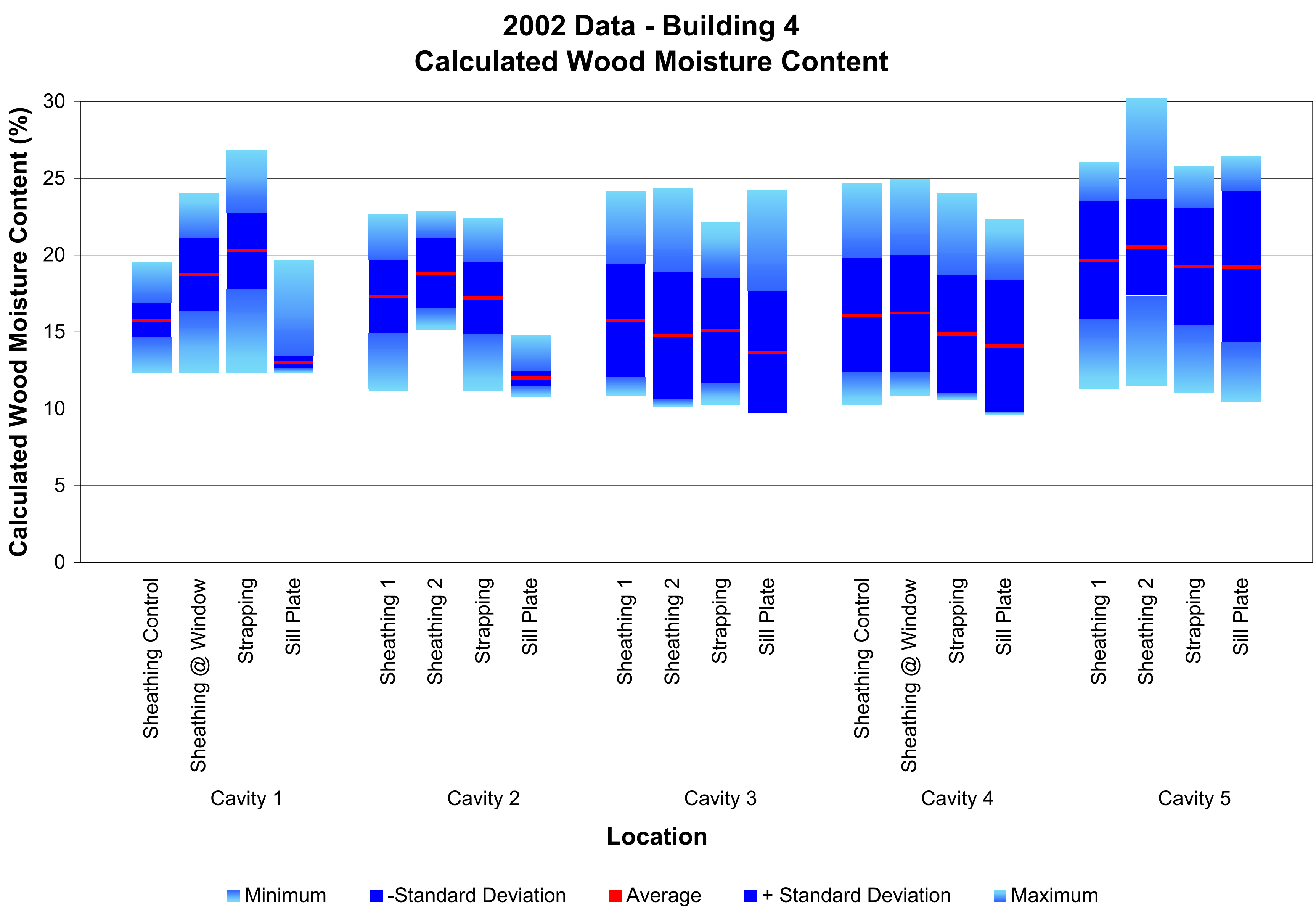
2003 Data - Building 3
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale (0-100 Delmhorst BD-10)
0
10
20
30
40
50
60
70
80
90
100
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

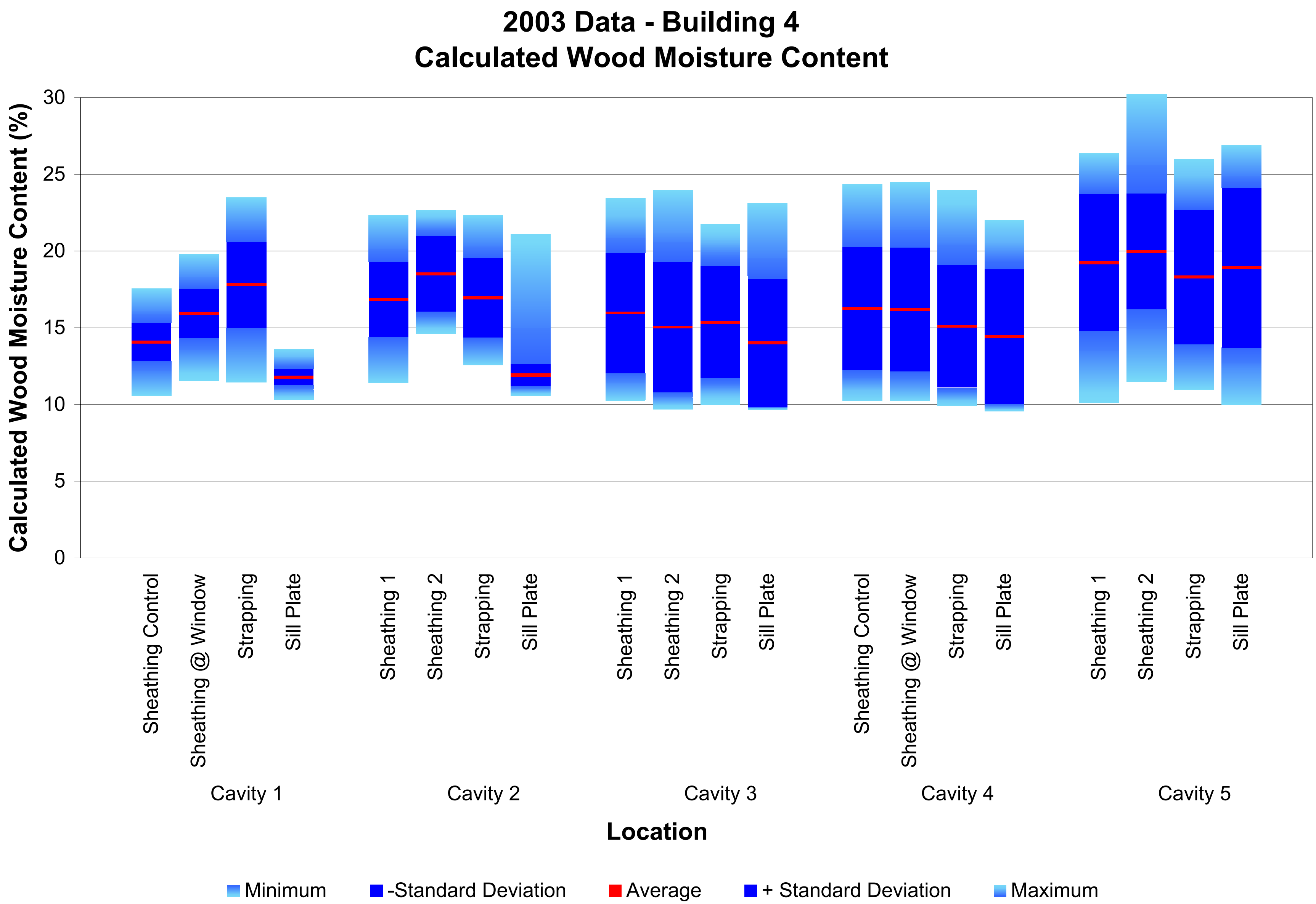

2004 Data - Building 3
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale
(0-100 Delmhorst BD-10)
100
90
80
70
60
50
40
30
20
10
0
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Window
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


Winter 2002 Data - Building 4
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Cavity 1
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 2
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 3
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Cavity 4
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

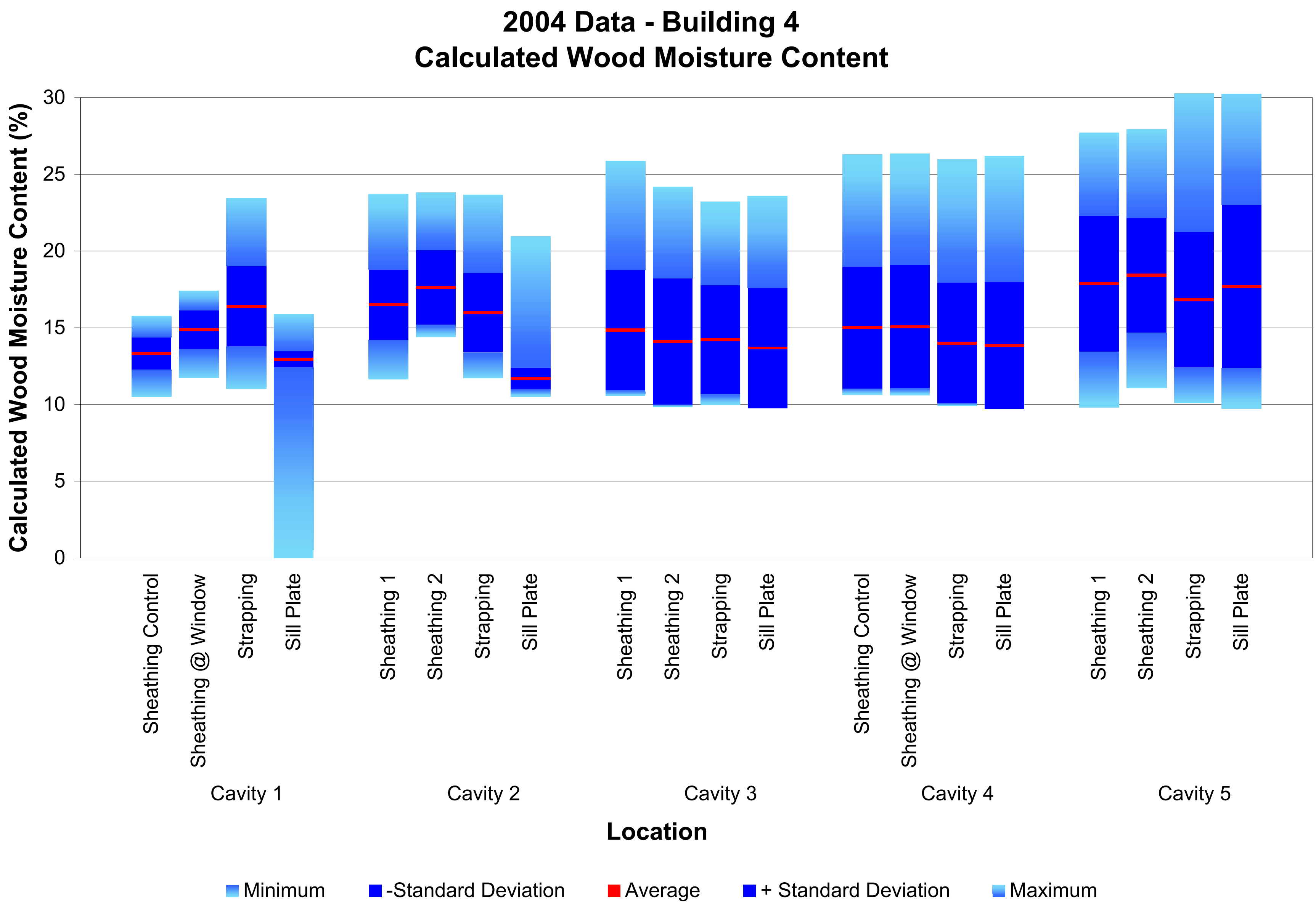

Winter 2003 Data - Building 4
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Cavity 1
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 2
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 3
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Cavity 4
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


Winter 2004 Data - Building 4
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

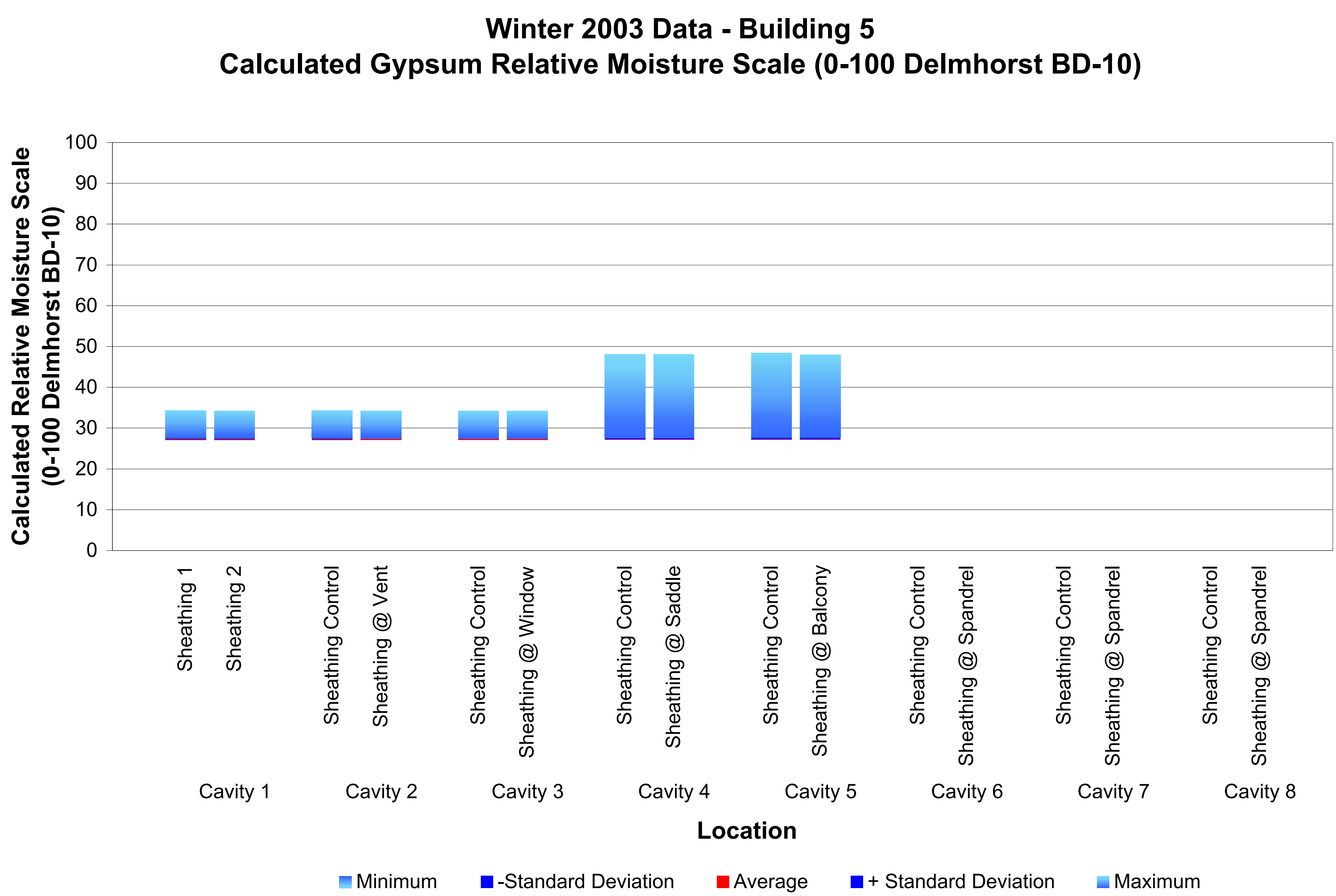

2002 Data - Building 4
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
0
5
10
15
20
25
30
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



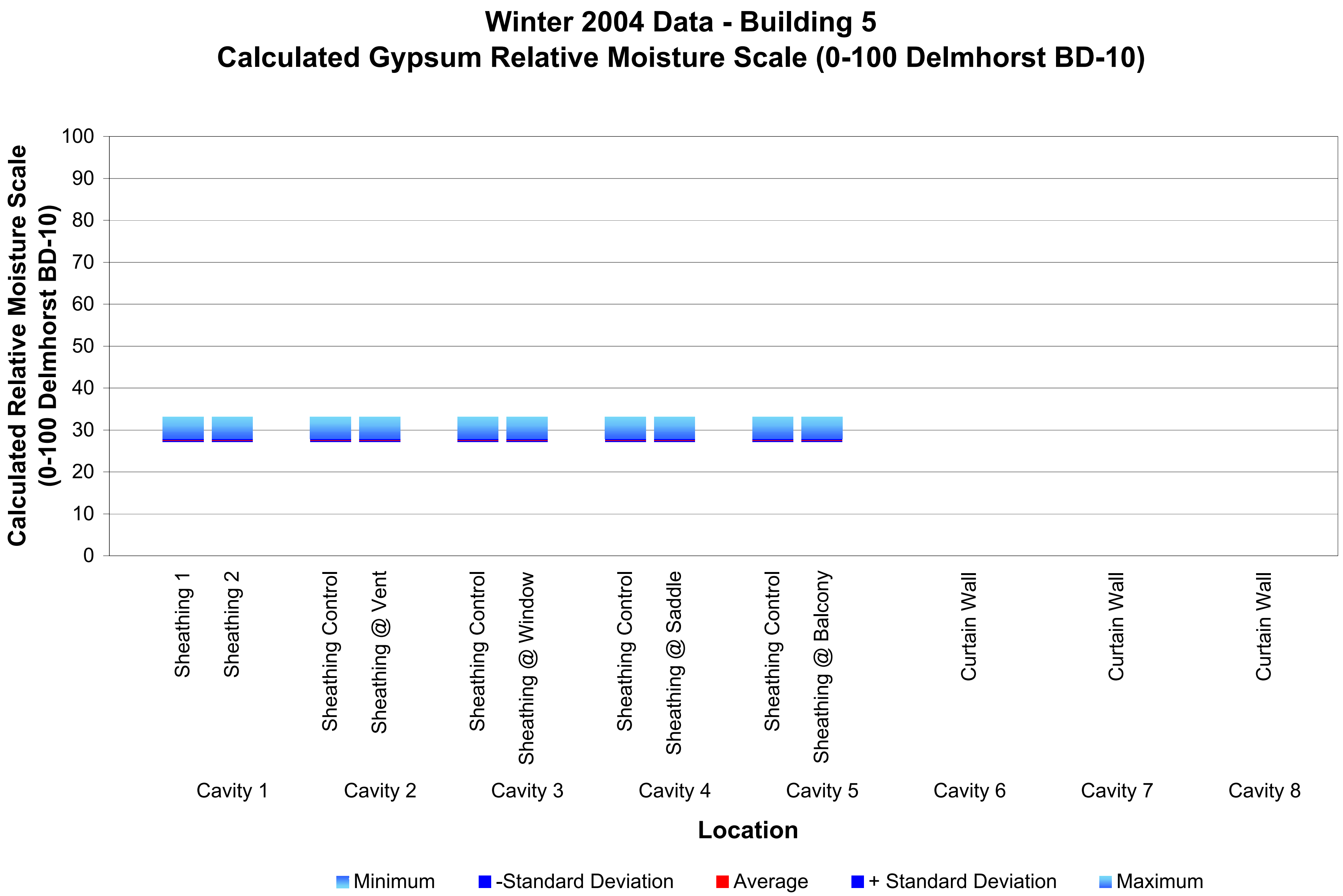
2003 Data - Building 4
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



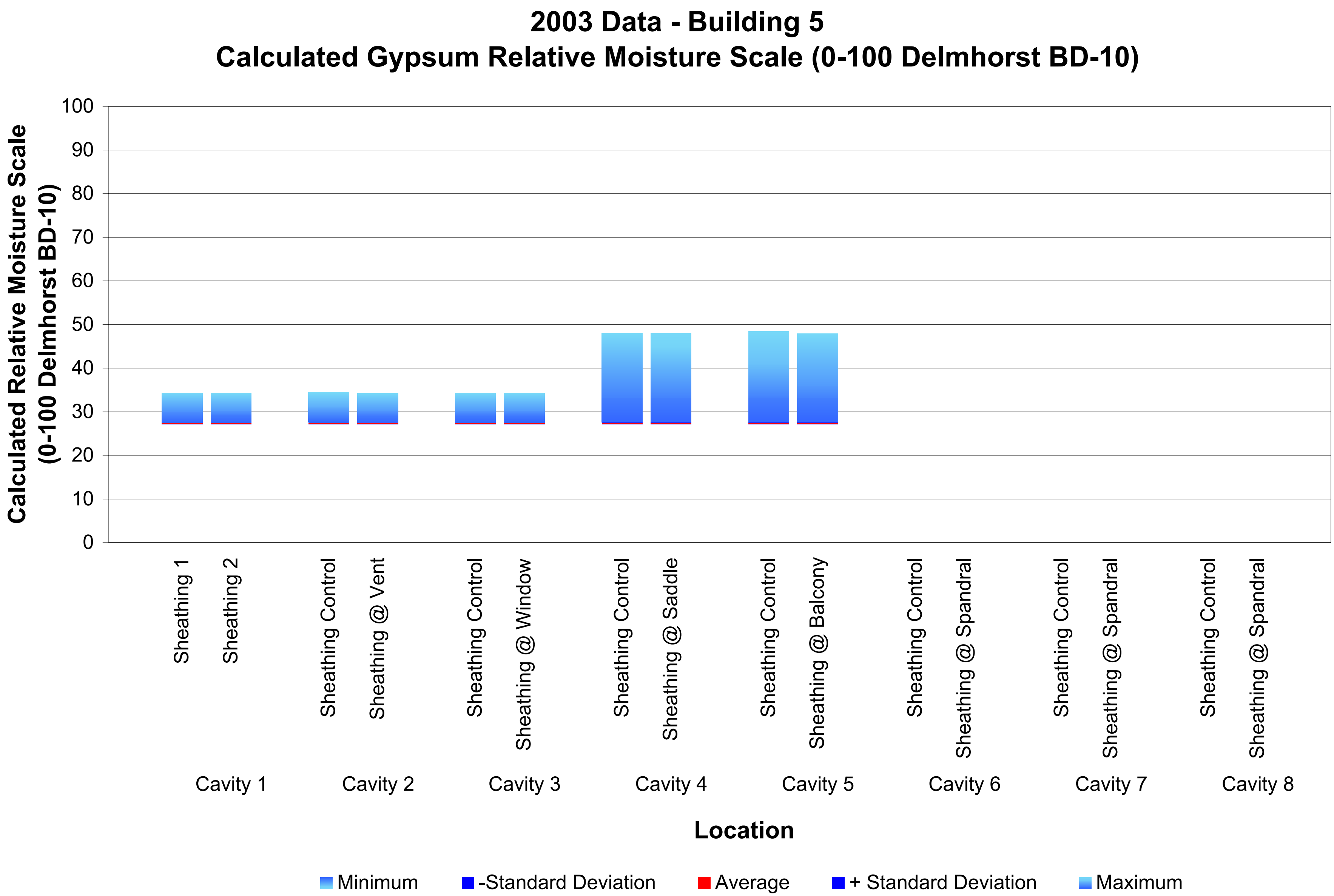
2004 Data - Building 4
Calculated Wood Moisture Content
Calculated Wood Moisture Content (%)
30
25
20
15
10
5
0
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Cavity 1
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 2
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 3
Sheathing Control
Sheathing @ Window
Strapping
Sill Plate
Cavity 4
Sheathing 1
Sheathing 2
Strapping
Sill Plate
Cavity 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



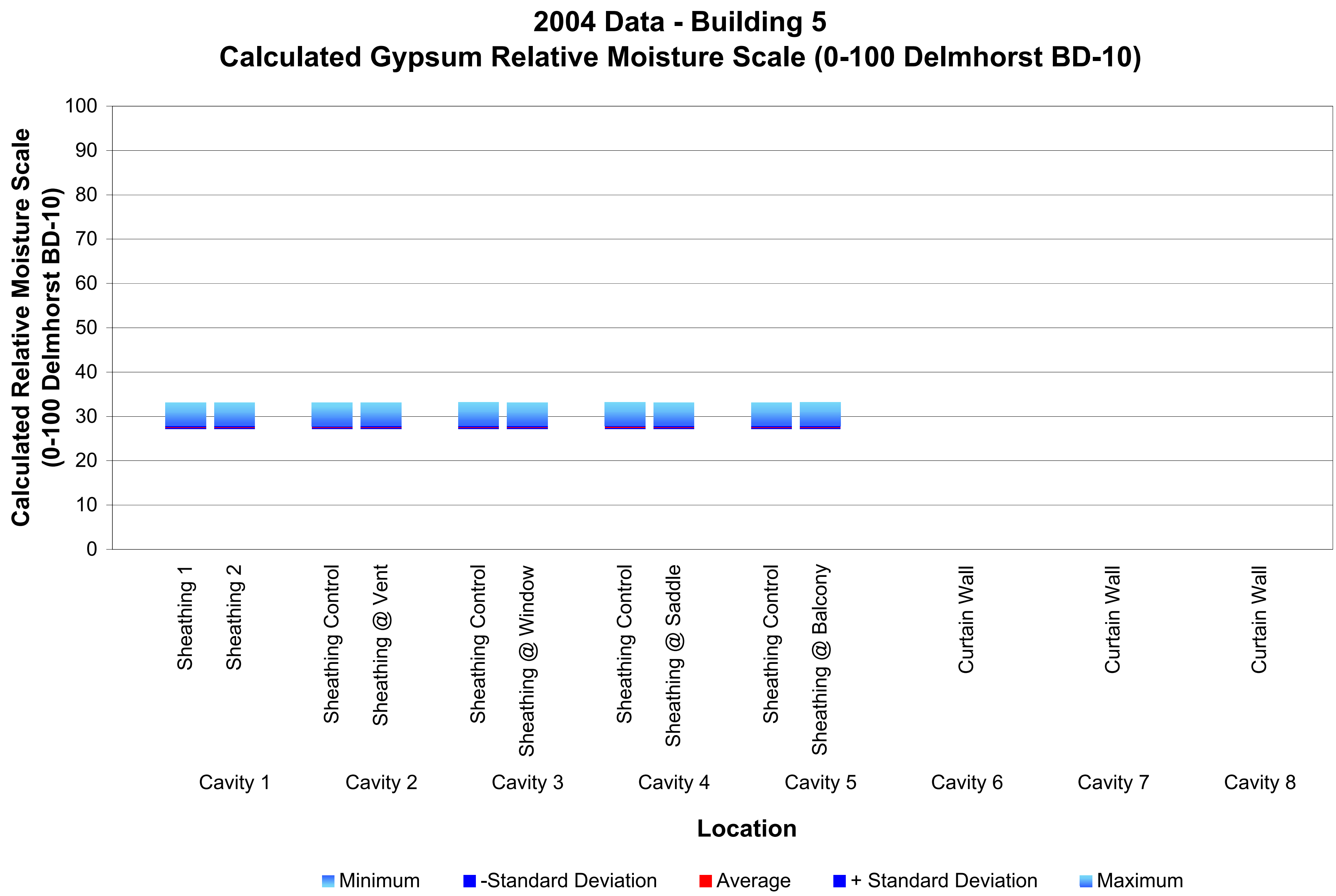
Winter 2003 Data - Building 5
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale
(0-100 Delmhorst BD-10)
100
90
80
70
60
50
40
30
20
10
0
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Window
Sheathing Control
Sheathing @ Saddle
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Spandrel
Sheathing Control
Sheathing @ Spandrel
Sheathing Control
Sheathing @ Spandrel
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



Winter 2004 Data - Building 5
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale
(0-100 Delmhorst BD-10)
100
90
80
70
60
50
40
30
20
10
0
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Window
Sheathing Control
Sheathing @ Saddle
Sheathing Control
Sheathing @ Balcony
Curtain Wall
Curtain Wall
Curtain Wall
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

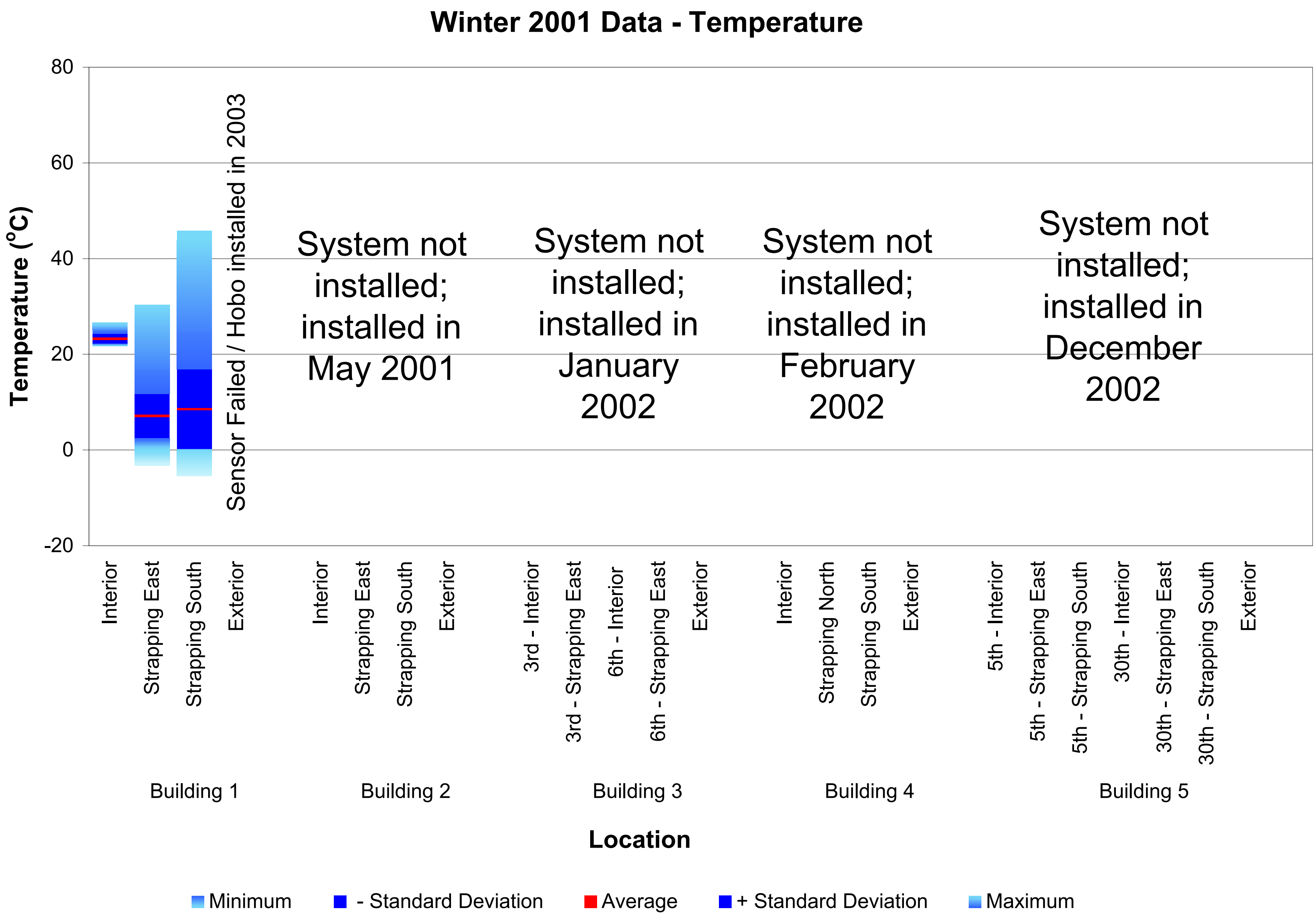


2003 Data - Building 5
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale (0-100 Delmhorst BD-10)
100
90
80
70
60
50
40
30
20
10
0
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Window
Sheathing Control
Sheathing @ Saddle
Sheathing Control
Sheathing @ Balcony
Sheathing Control
Sheathing @ Spandral
Sheathing Control
Sheathing @ Spandral
Sheathing Control
Sheathing @ Spandral
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

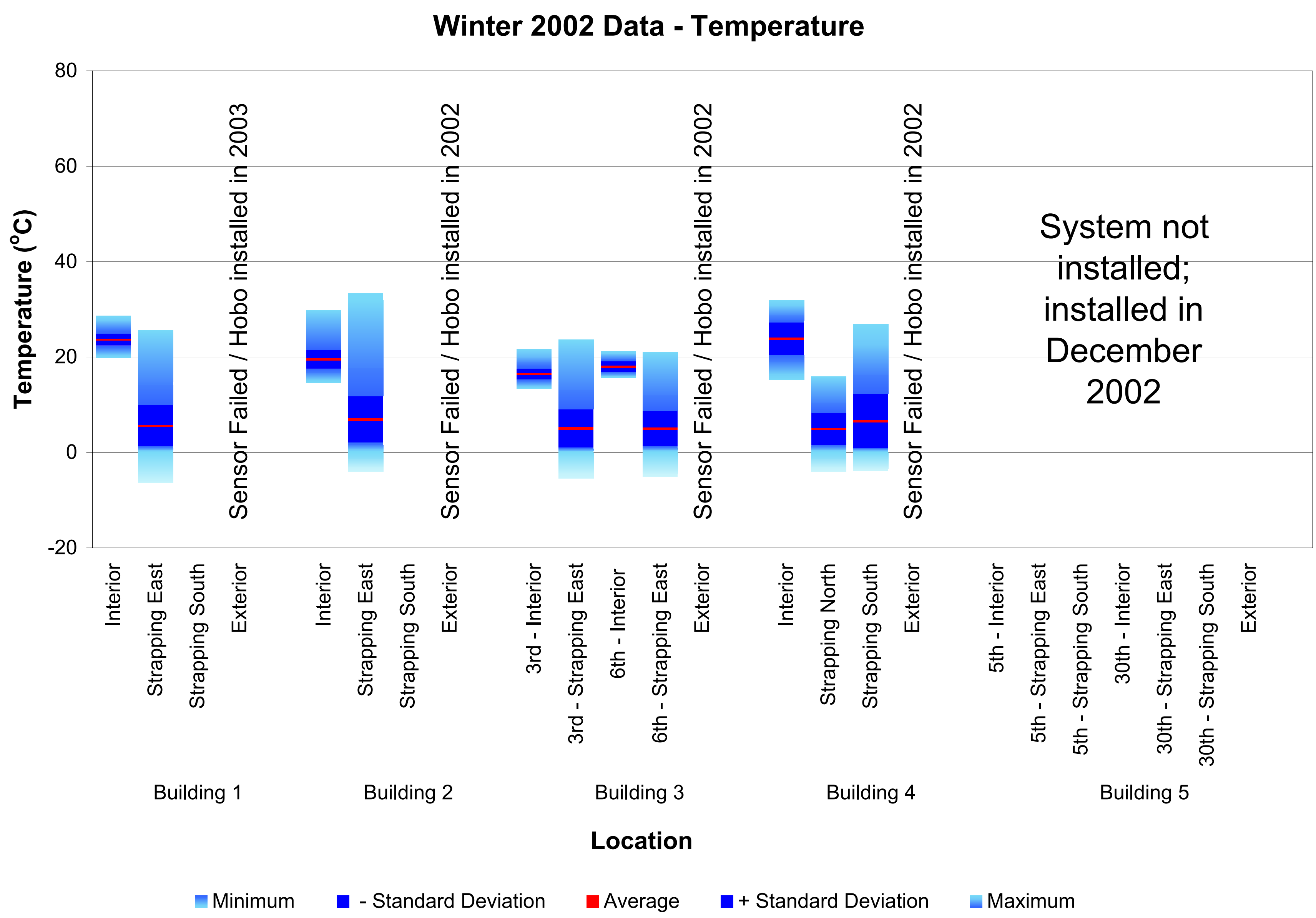

2004 Data - Building 5
Calculated Gypsum Relative Moisture Scale (0-100 Delmhorst BD-10)
Calculated Relative Moisture Scale (0-100 Delmhorst BD-10)
100
90
80
70
60
50
40
30
20
10
0
Sheathing 1
Sheathing 2
Sheathing Control
Sheathing @ Vent
Sheathing Control
Sheathing @ Window
Sheathing Control
Sheathing @ Saddle
Sheathing Control
Sheathing @ Balcony
Curtain Wall
Curtain Wall
Curtain Wall
Cavity 1
Cavity 2
Cavity 3
Cavity 4
Cavity 5
Cavity 6
Cavity 7
Cavity 8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

APPENDIX D

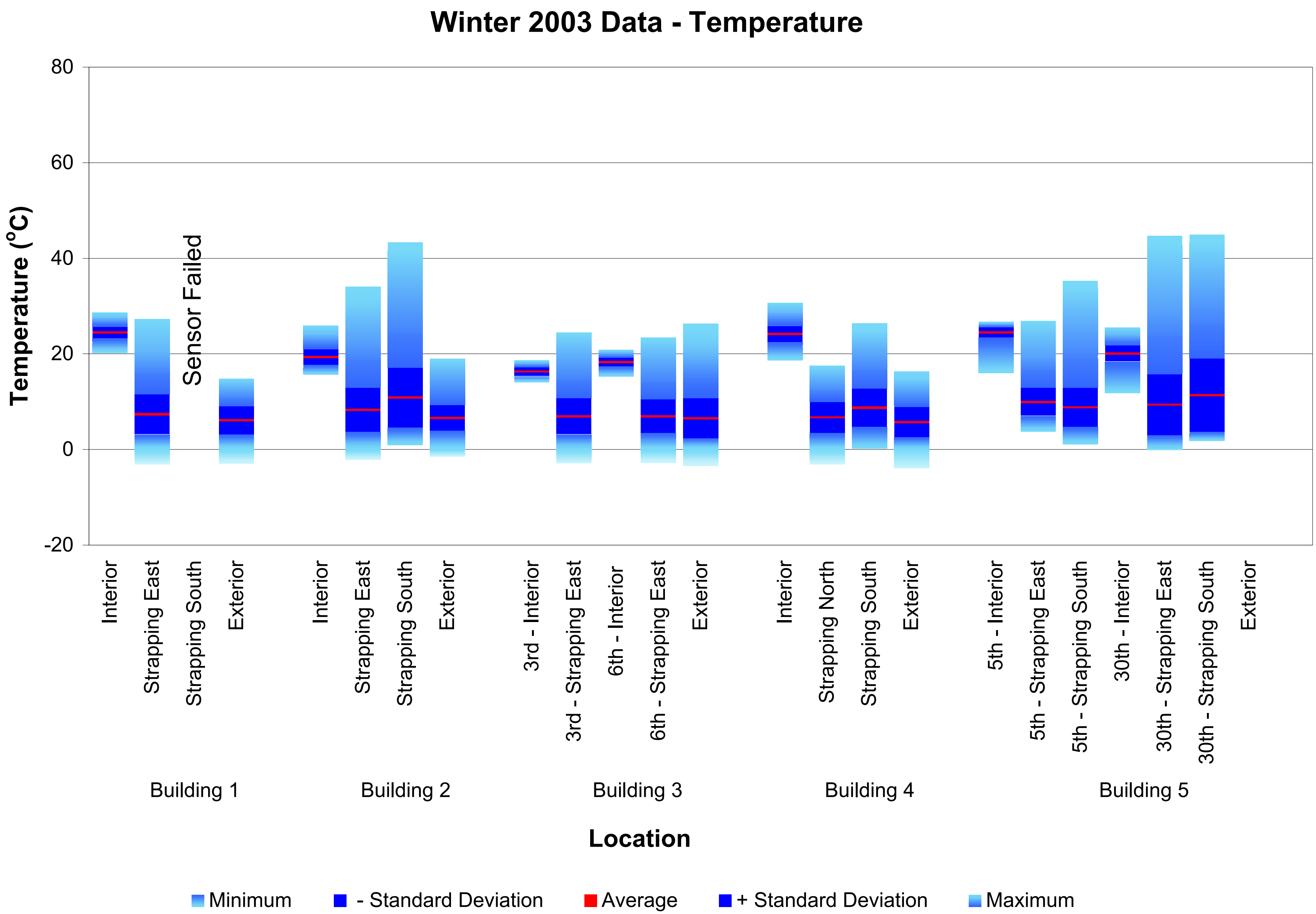
Temperature Summary



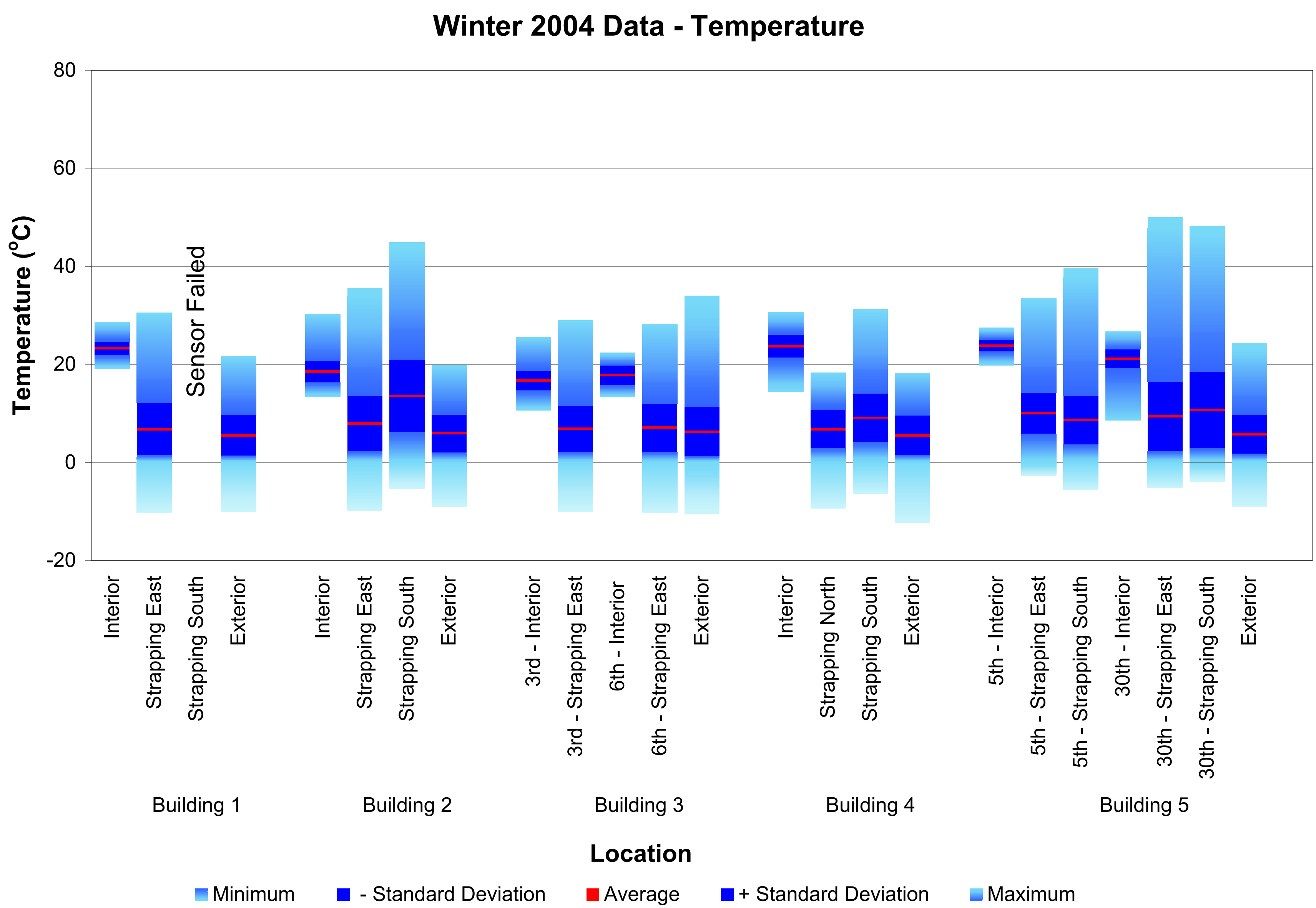
Winter 2001 Data - Temperature
80
60
40
20
0
-20
Temperature (°C)
Sensor Failed / Hobo installed in 2003
System not installed; installed in May 2001
System not installed; installed in January 2002
System not installed; installed in February 2002
System not installed; installed in December 2002
Interior
Strapping East
Strapping South
Exterior
Interior
Strapping East
Strapping South
Exterior
3rd - Interior
3rd - Strapping East
6th - Interior
6th - Strapping East
Exterior
Interior
Strapping North
Strapping South
Exterior
5th - Interior
5th - Strapping East
5th - Strapping South
30th - Interior
30th - Strapping East
30th - Strapping South
Exterior
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum



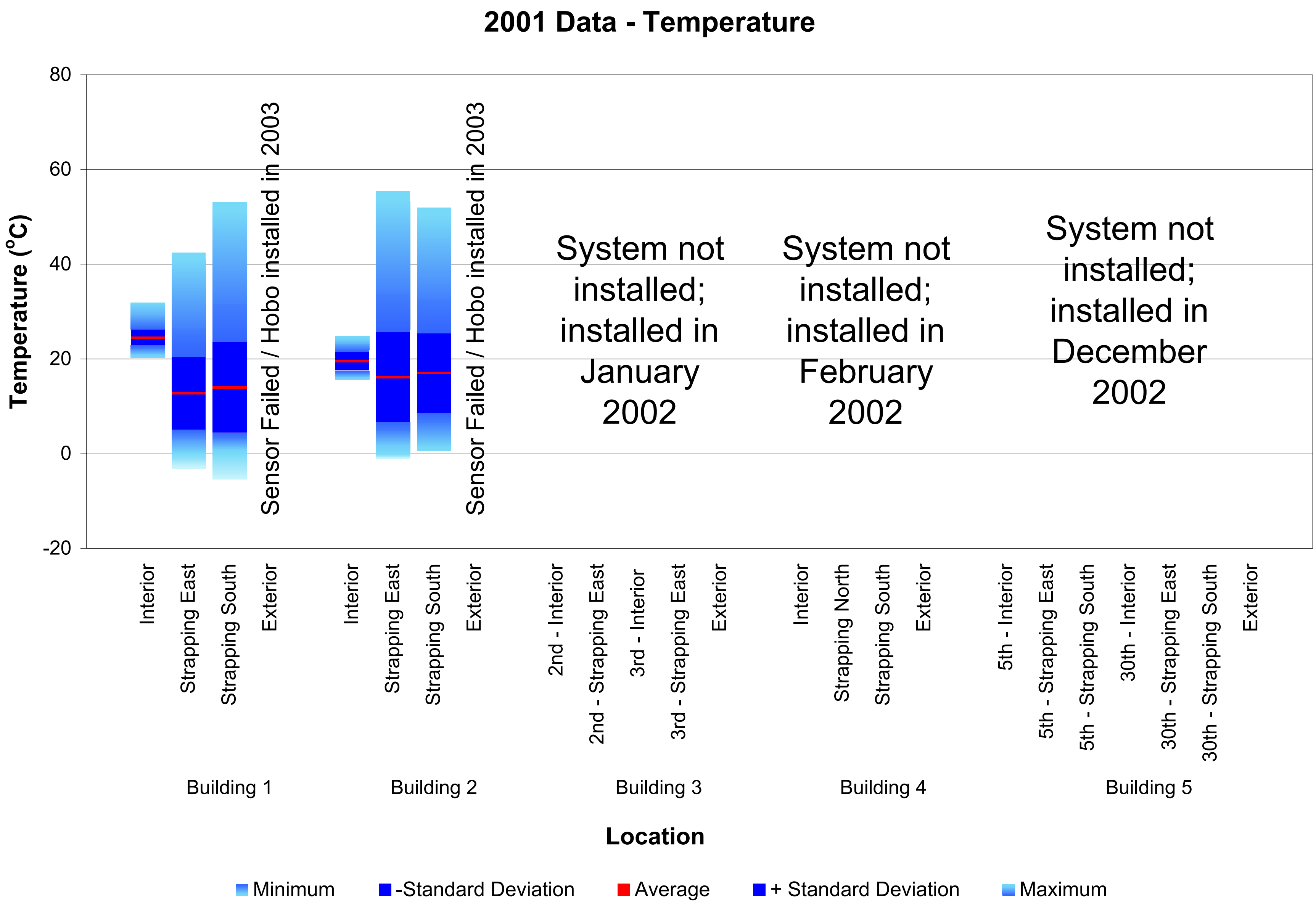
Winter 2002 Data - Temperature
Temperature (°C)
80
60
40
20
0
-20
Sensor Failed / Hobo installed in 2003
Sensor Failed / Hobo installed in 2002
Sensor Failed / Hobo installed in 2002
Sensor Failed / Hobo installed in 2002
System not installed; installed in December 2002
Interior
Strapping East
Strapping South
Exterior
Interior
Strapping East
Strapping South
Exterior
3rd - Interior
3rd - Strapping East
6th - Interior
6th - Strapping East
Exterior
Interior
Strapping North
Strapping South
Exterior
5th - Interior
5th - Strapping East
5th - Strapping South
30th - Interior
30th - Strapping East
30th - Strapping South
Exterior
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

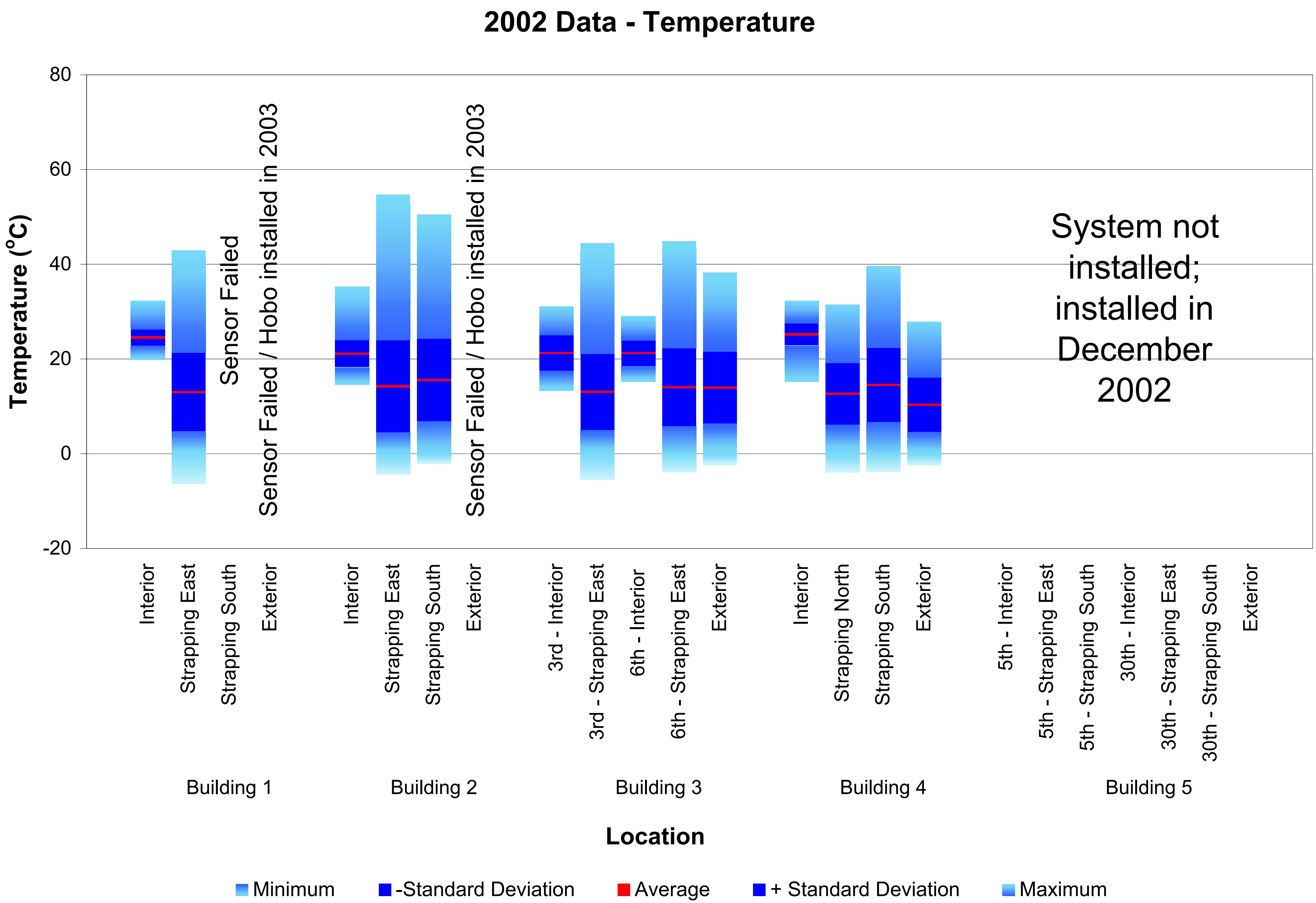


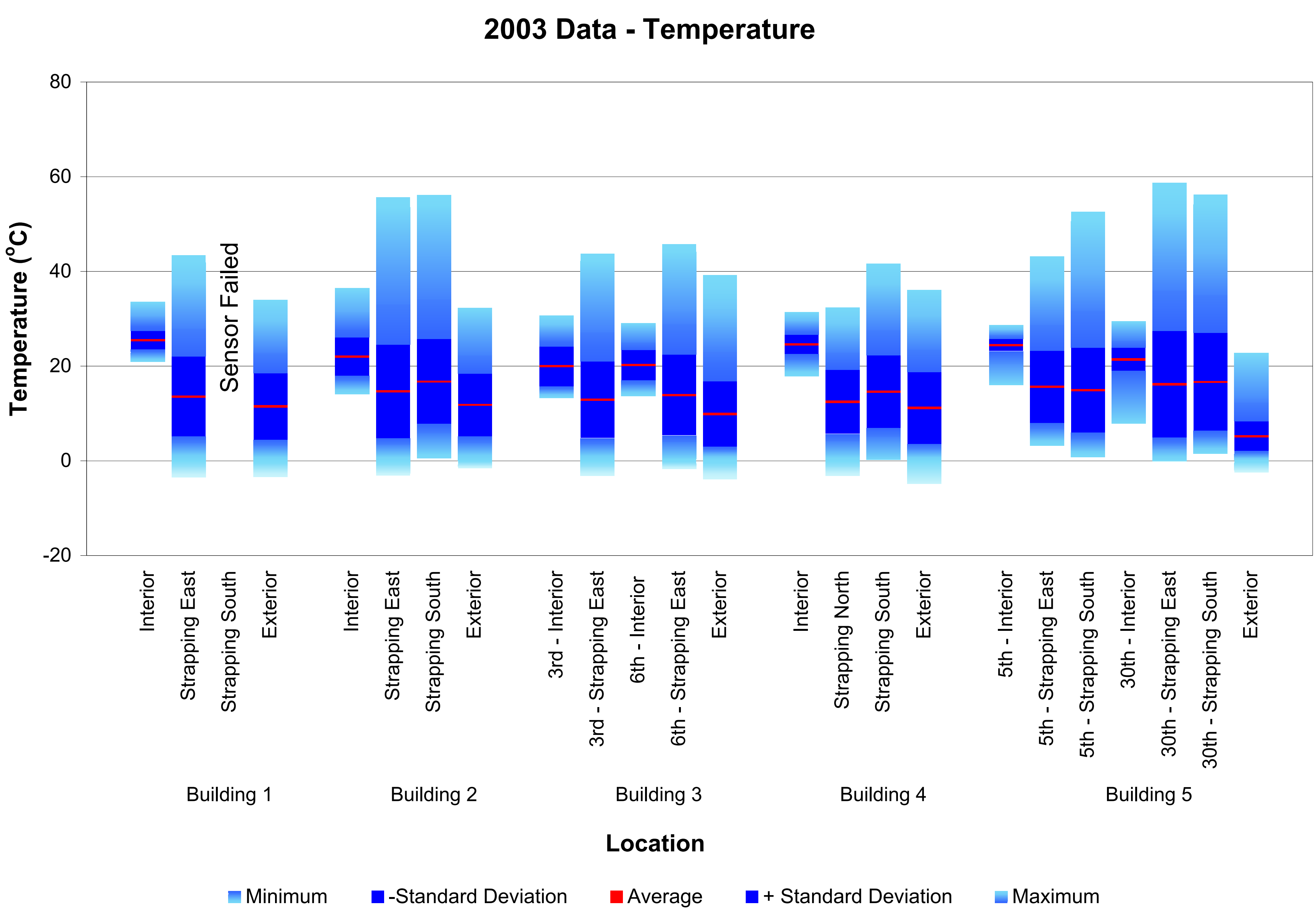
Winter 2003 Data - Temperature
Temperature (°C)
80
60
40
20
0
-20
Sensor Failed
Interior
Strapping East
Strapping South
Exterior
Interior
Strapping East
Strapping South
Exterior
3rd - Interior
3rd - Strapping East
6th - Interior
6th - Strapping East
Exterior
Interior
Strapping North
Strapping South
Exterior
5th - Interior
5th - Strapping East
5th - Strapping South
30th - Interior
30th - Strapping East
30th - Strapping South
Exterior
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

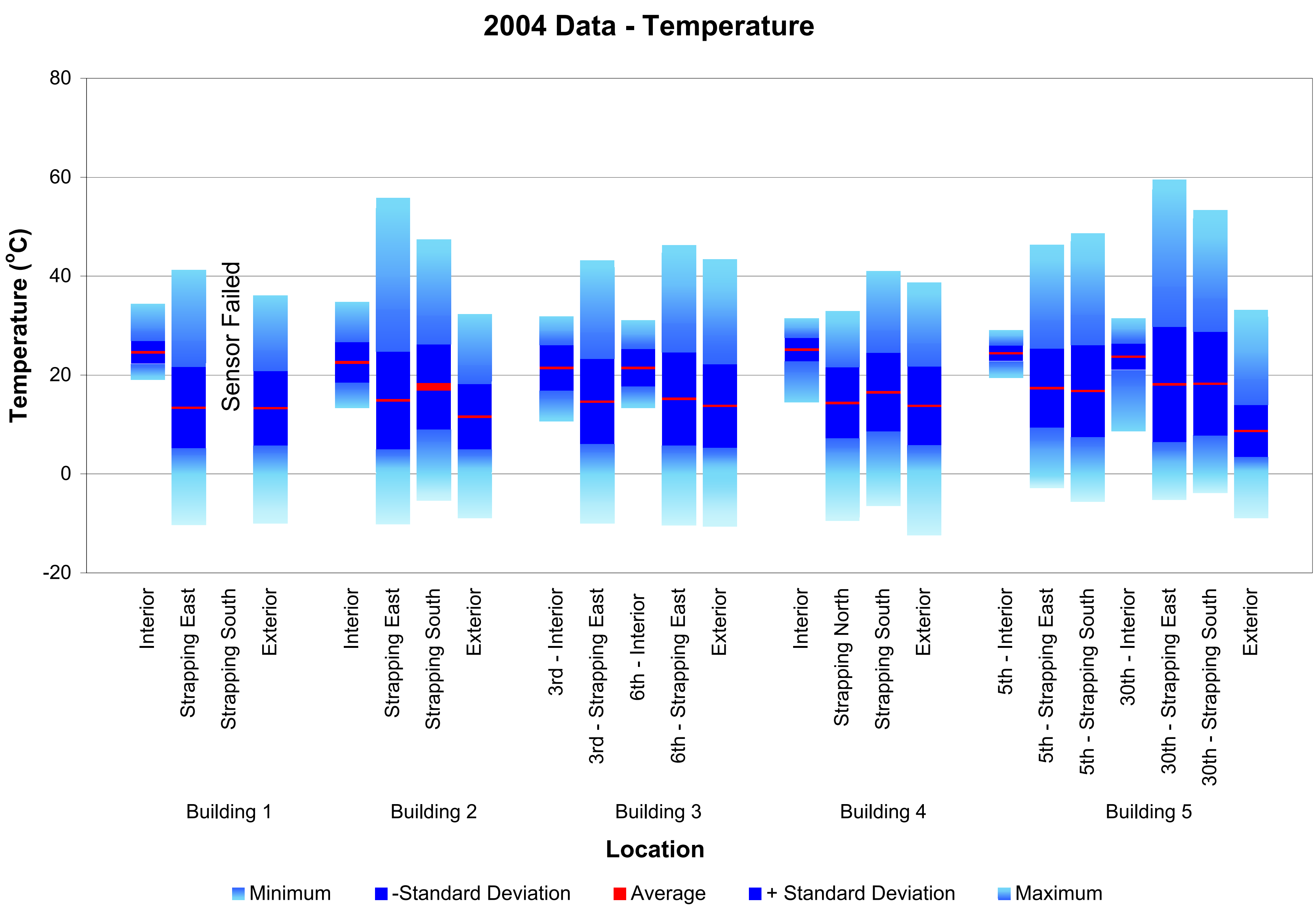


Winter 2004 Data - Temperature
Temperature (°C)
80
60
40
20
0
-20
Sensor Failed
Interior
Strapping East
Strapping South
Exterior
Interior
Strapping East
Strapping South
Exterior
3rd - Interior
3rd - Strapping East
6th - Interior
6th - Strapping East
Exterior
Interior
Strapping North
Strapping South
Exterior
5th - Interior
5th - Strapping East
5th - Strapping South
30th - Interior
30th - Strapping East
30th - Strapping South
Exterior
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum


2001 Data - Temperature
Temperature (°C)
80
60
40
20
0
-20
Sensor Failed / Hobo installed in 2003
Sensor Failed / Hobo installed in 2003
System not installed; installed in January 2002
System not installed; installed in February 2002
System not installed; installed in December 2002
Interior
Strapping East
Strapping South
Exterior
Interior
Strapping East
Strapping South
Exterior
2nd - Interior
2nd - Strapping East
3rd - Interior
3rd - Strapping East
Exterior
Interior
Strapping North
Strapping South
Exterior
5th - Interior
5th - Strapping East
5th - Strapping South
30th - Interior
30th - Strapping East
30th - Strapping South
Exterior
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

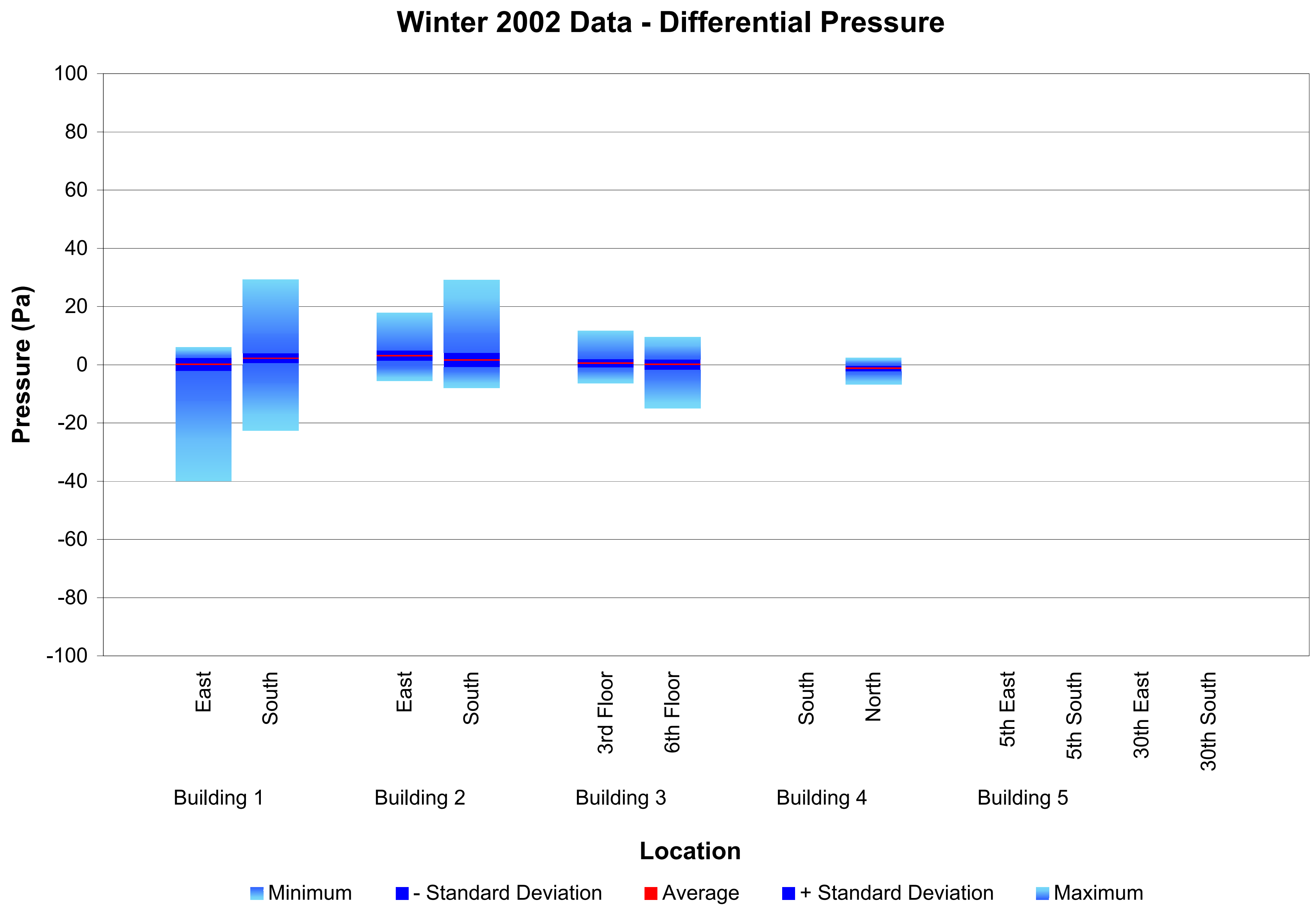

2002 Data - Temperature
80
60
40
20
0
-20
Temperature (°C)
Sensor Failed
Sensor Failed / Hobo installed in 2003
Sensor Failed / Hobo installed in 2003
System not installed; installed in December 2002
Interior
Strapping East
Strapping South
Exterior
Interior
Strapping East
Strapping South
Exterior
3rd - Interior
3rd - Strapping East
6th - Interior
6th - Strapping East
Exterior
Interior
Strapping North
Strapping South
Exterior
5th - Interior
5th - Strapping East
5th - Strapping South
30th - Interior
30th - Strapping East
30th - Strapping South
Exterior
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


2003 Data - Temperature
Temperature (°C)
80
60
40
20
0
-20
Sensor Failed
Interior
Strapping East
Strapping South
Exterior
Interior
Strapping East
Strapping South
Exterior
3rd - Interior
3rd - Strapping East
6th - Interior
6th - Strapping East
Exterior
Interior
Strapping North
Strapping South
Exterior
5th - Interior
5th - Strapping East
5th - Strapping South
30th - Interior
30th - Strapping East
30th - Strapping South
Exterior
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

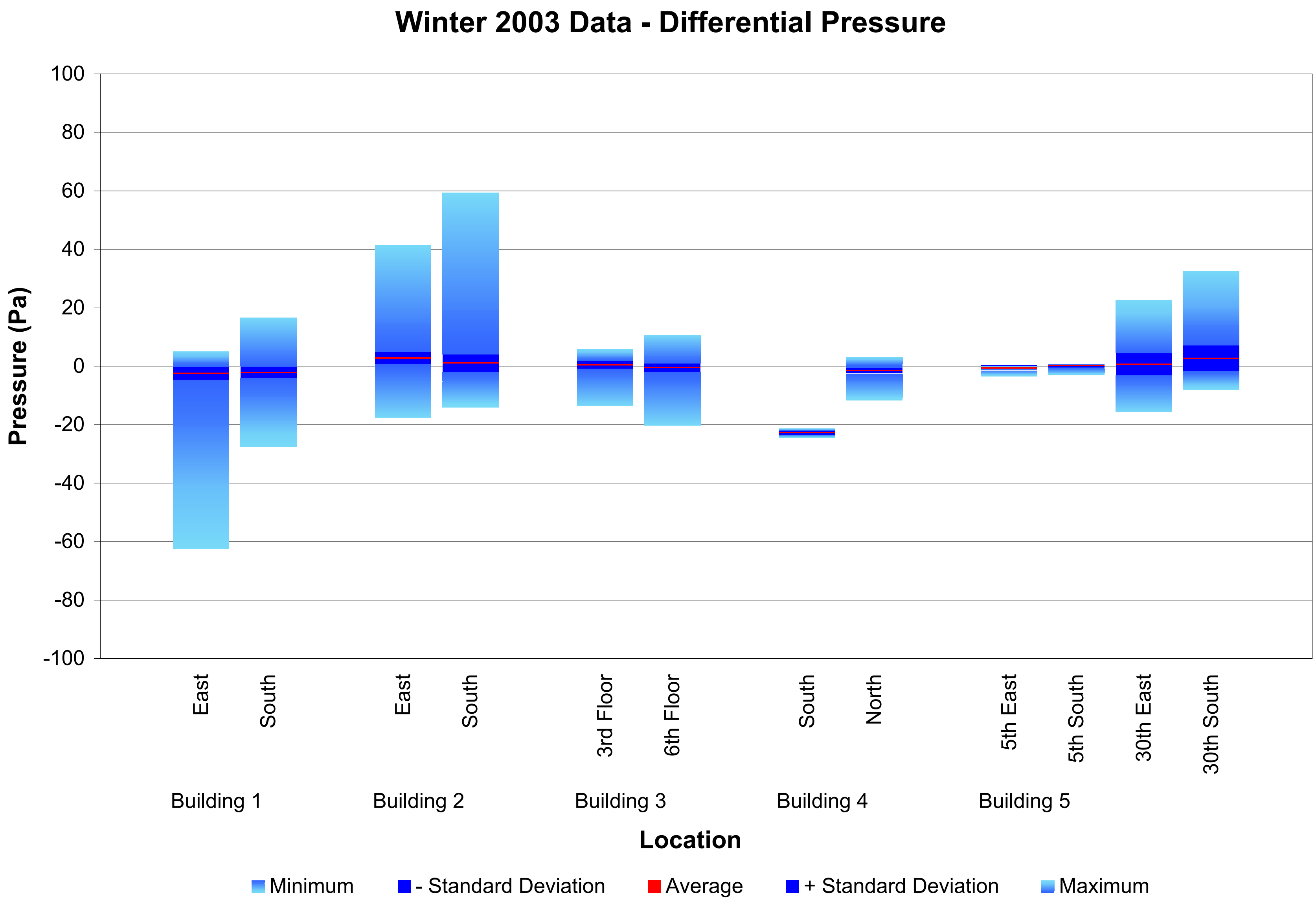

2004 Data - Temperature
Temperature (°C)
80
60
40
20
0
-20
Sensor Failed
Interior
Strapping East
Strapping South
Exterior
Interior
Strapping East
Strapping South
Exterior
3rd - Interior
3rd - Strapping East
6th - Interior
6th - Strapping East
Exterior
Interior
Strapping North
Strapping South
Exterior
5th - Interior
5th - Strapping East
5th - Strapping South
30th - Interior
30th - Strapping East
30th - Strapping South
Exterior
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

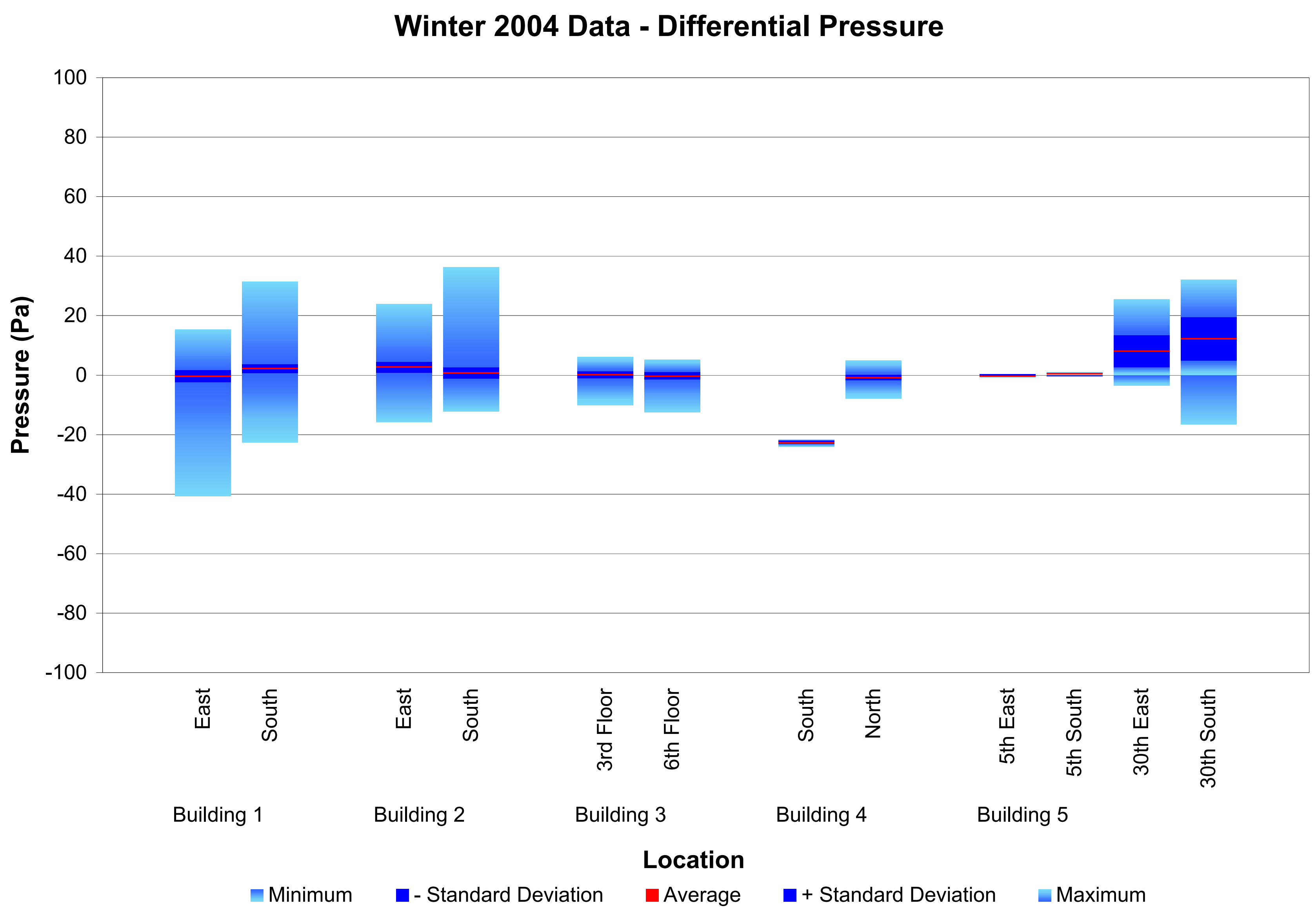
APPENDIX E

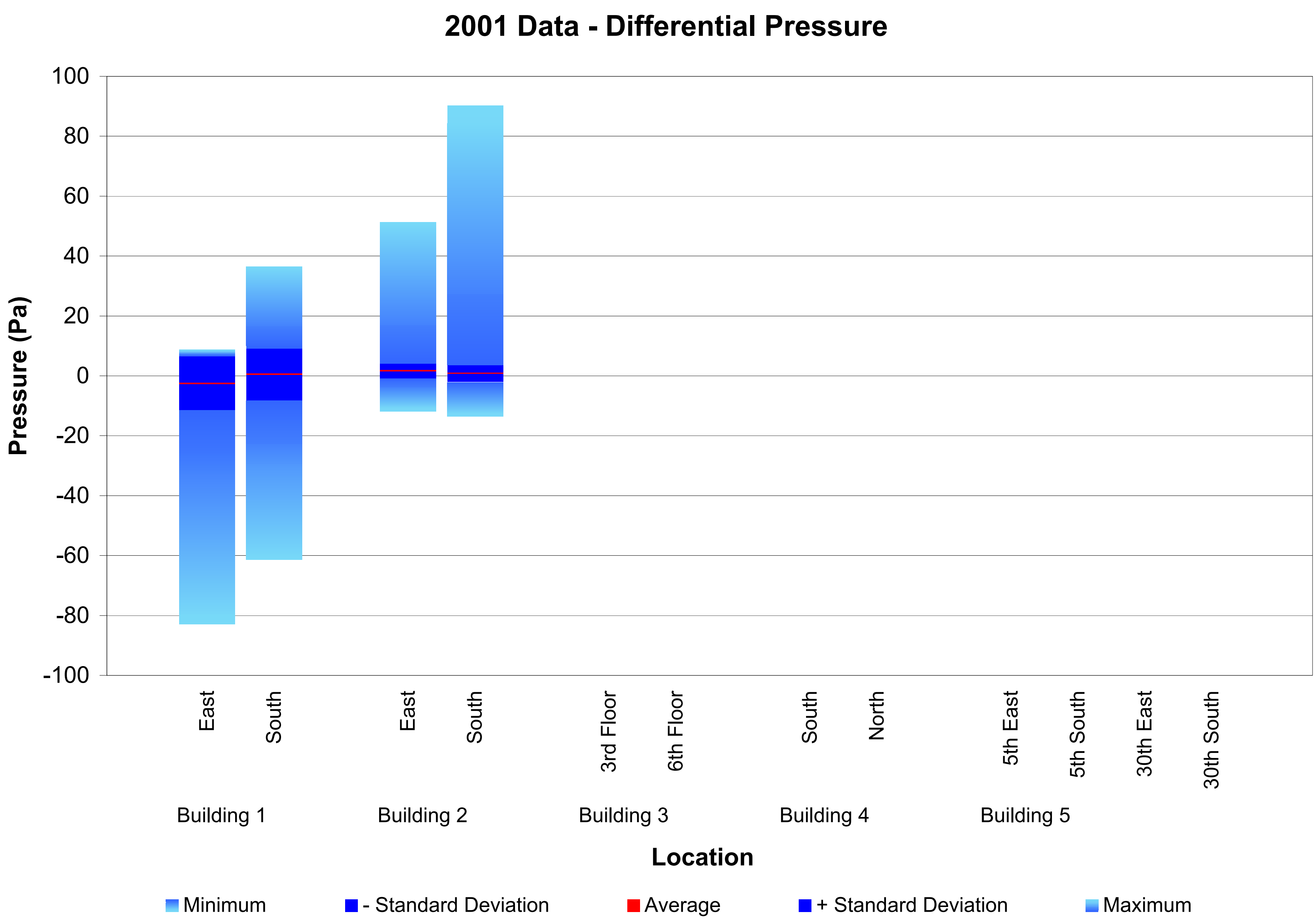
Wind Speed, Direction and Pressurization Data

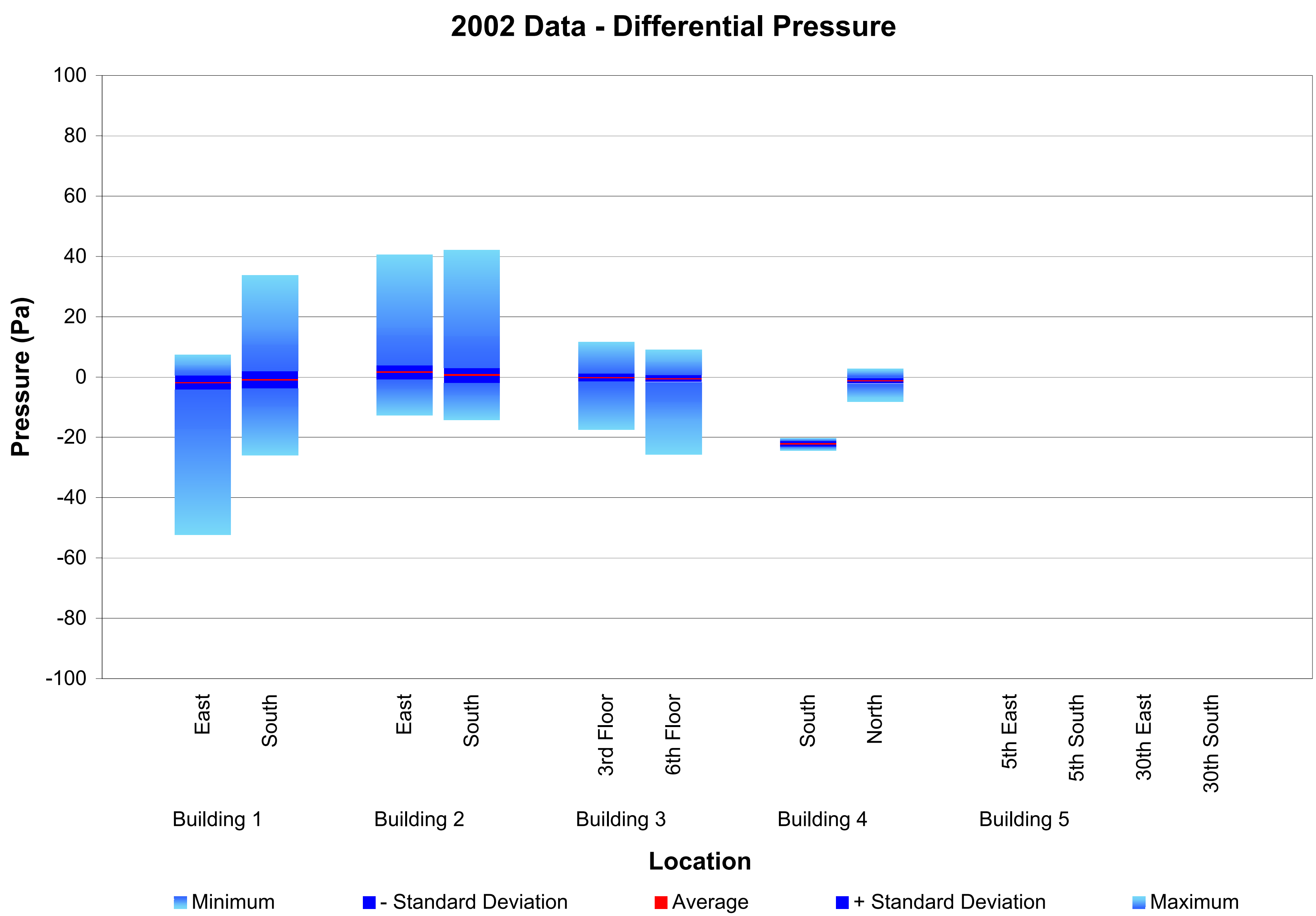


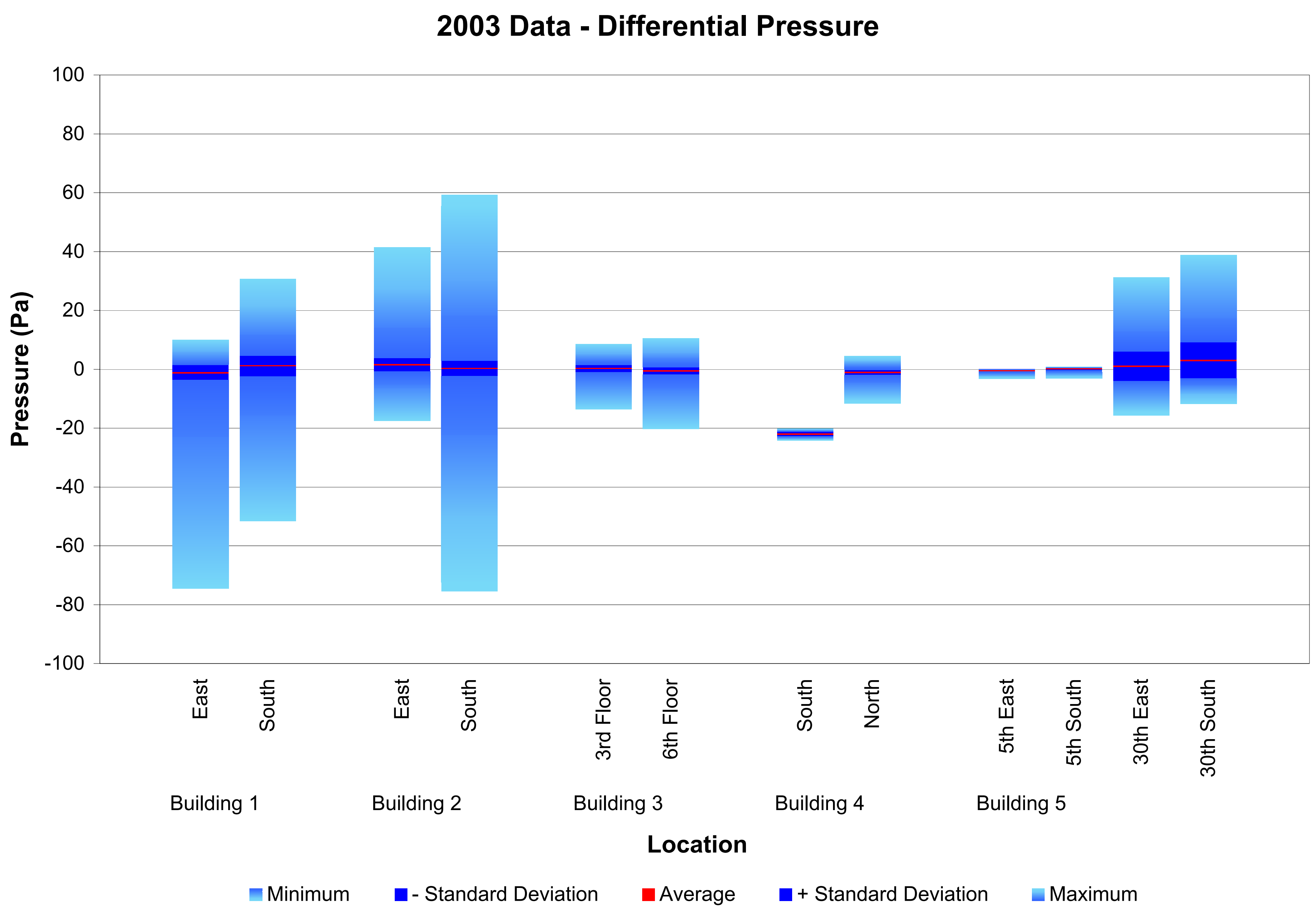
Winter 2002 Data - Differential Pressure
Pressure (Pa)
100
80
60
40
20
0
-20
-40
-60
-80
-100
East
South
East
South
3rd Floor
6th Floor
South
North
5th East
5th South
30th East
30th South
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum


Winter 2003 Data - Differential Pressure
Pressure (Pa)
100
80
60
40
20
0
-20
-40
-60
-80
-100
East
South
East
South
3rd Floor
6th Floor
South
North
5th East
5th South
30th East
30th South
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

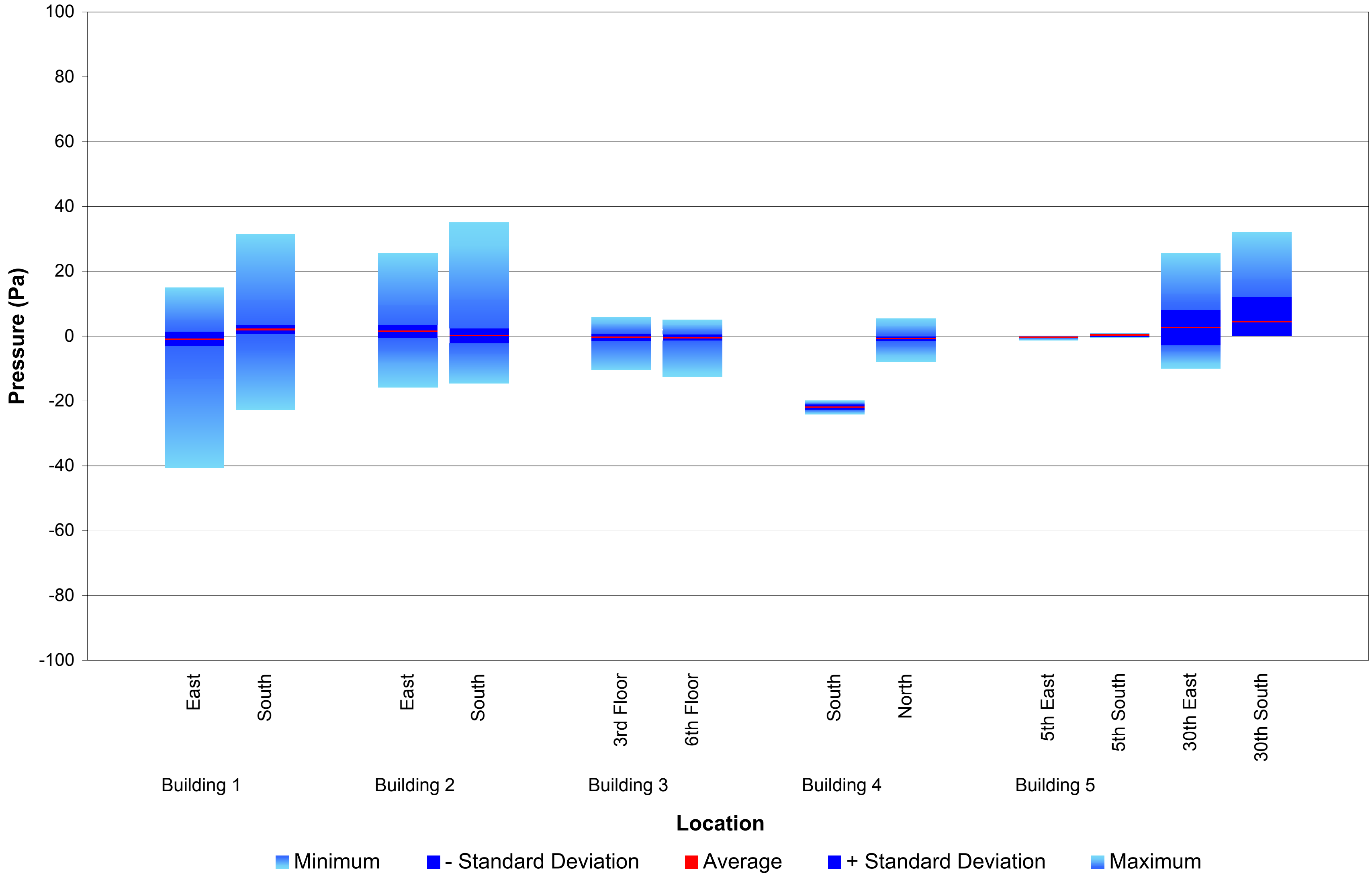

Winter 2004 Data - Differential Pressure
Pressure (Pa)
100
80
60
40
20
0
-20
-40
-60
-80
-100
East
South
East
South
3rd Floor
6th Floor
South
North
5th East
5th South
30th East
30th South
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

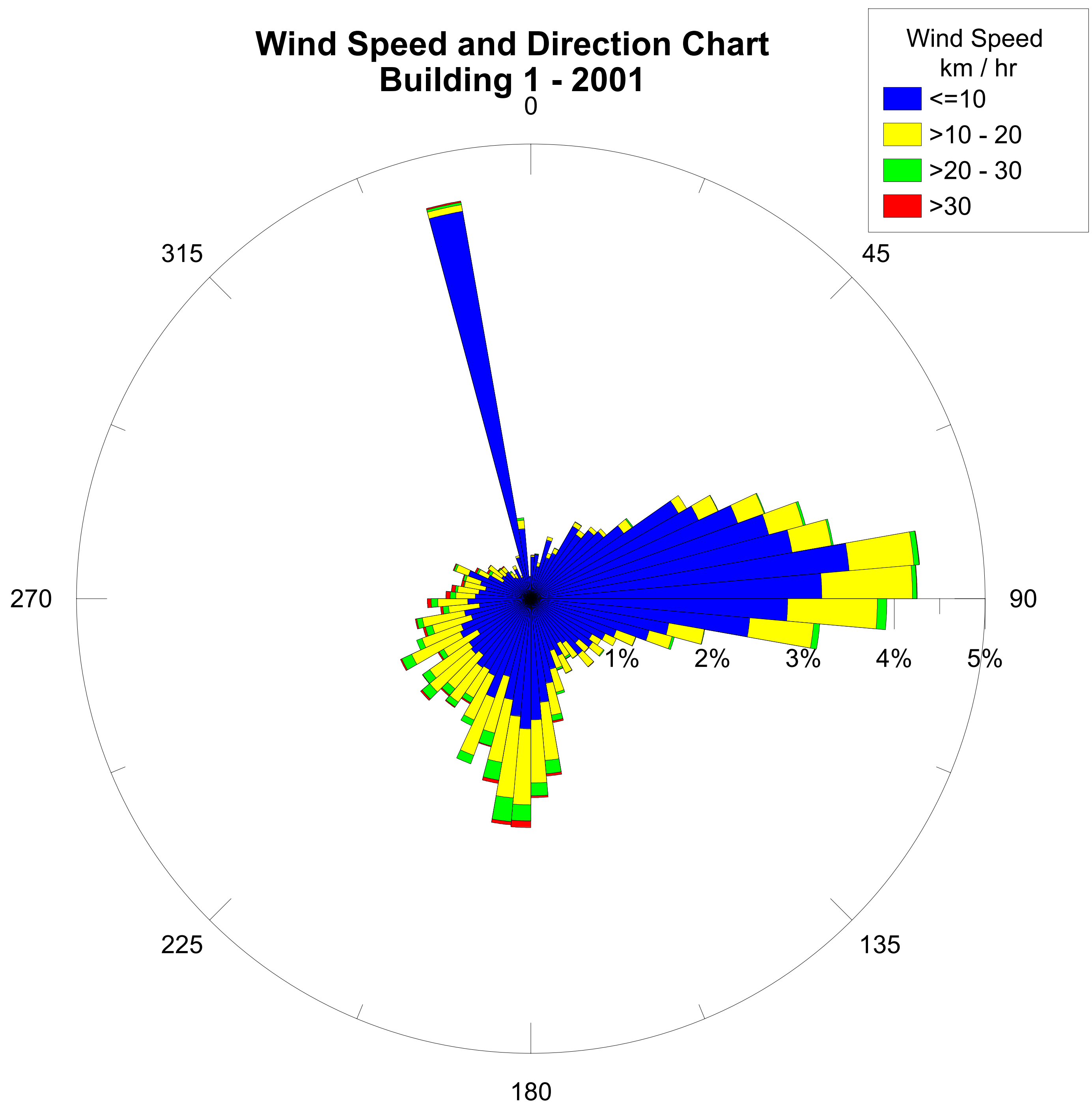

2001 Data - Differential Pressure
Pressure (Pa)
100
80
60
40
20
0
-20
-40
-60
-80
-100
East
South
East
South
3rd Floor
6th Floor
South
North
5th East
5th South
30th East
30th South
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum


2002 Data - Differential Pressure
Pressure (Pa)
100
80
60
40
20
0
-20
-40
-60
-80
-100
East
South
East
South
3rd Floor
6th Floor
South
North
5th East
5th South
30th East
30th South
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

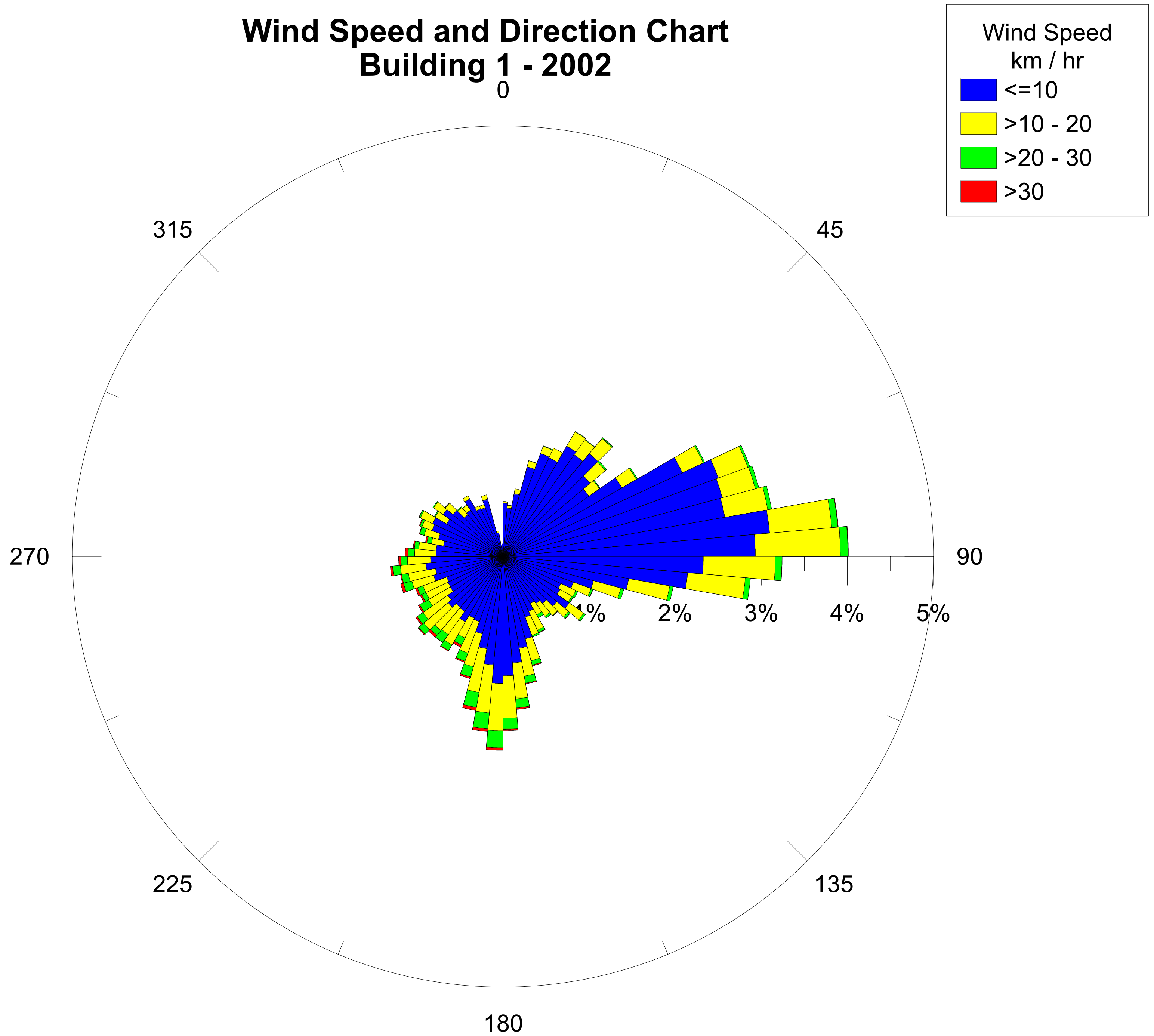

2003 Data - Differential Pressure
100
80
60
40
20
0
-20
-40
-60
-80
-100
Pressure (Pa)
East
South
East
South
3rd Floor
6th Floor
South
North
5th East
5th South
30th East
30th South
Building 1
Building 2
Building 3
Building 4
Building 5
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

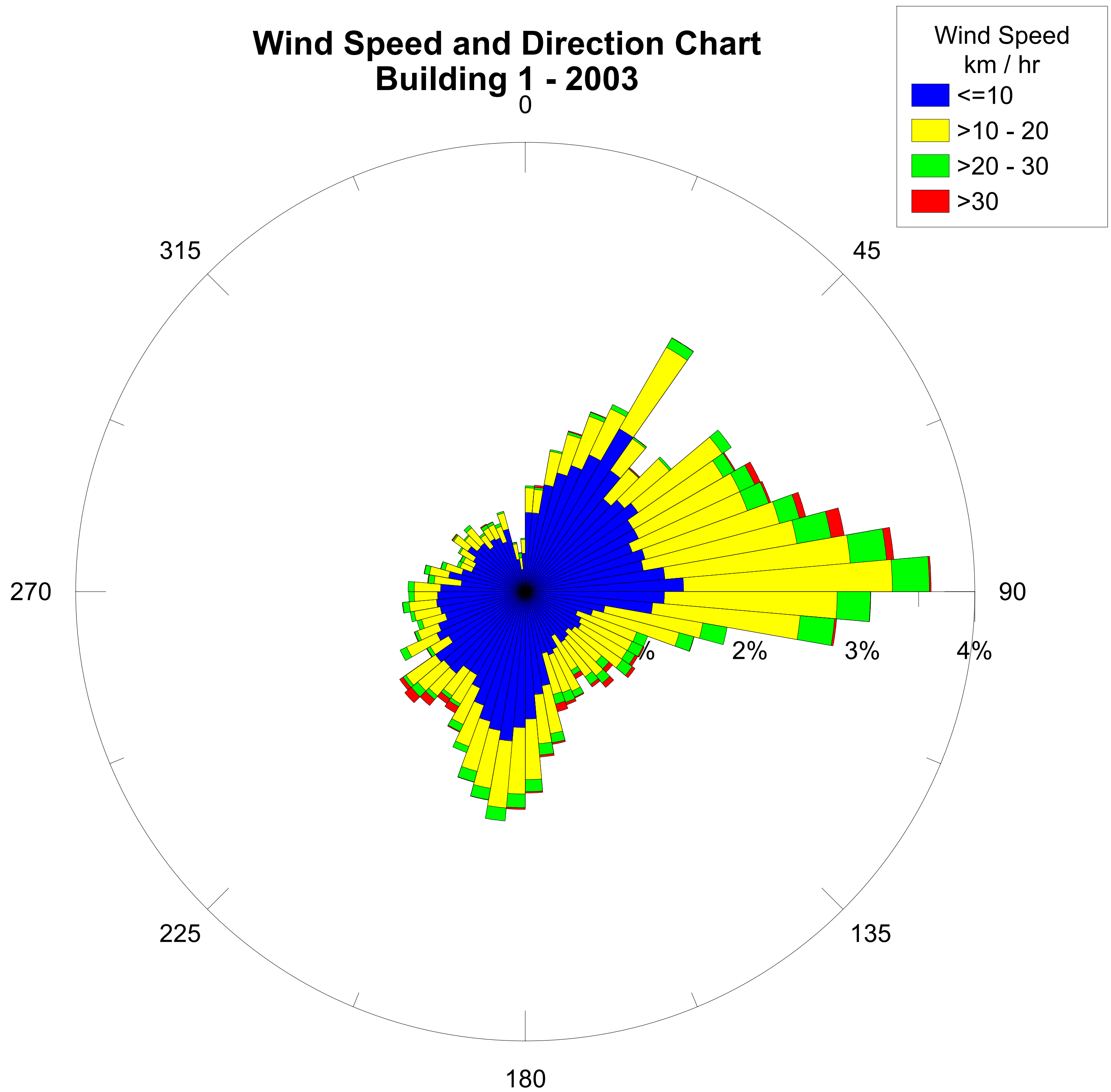
2004 Data - Differential Pressure



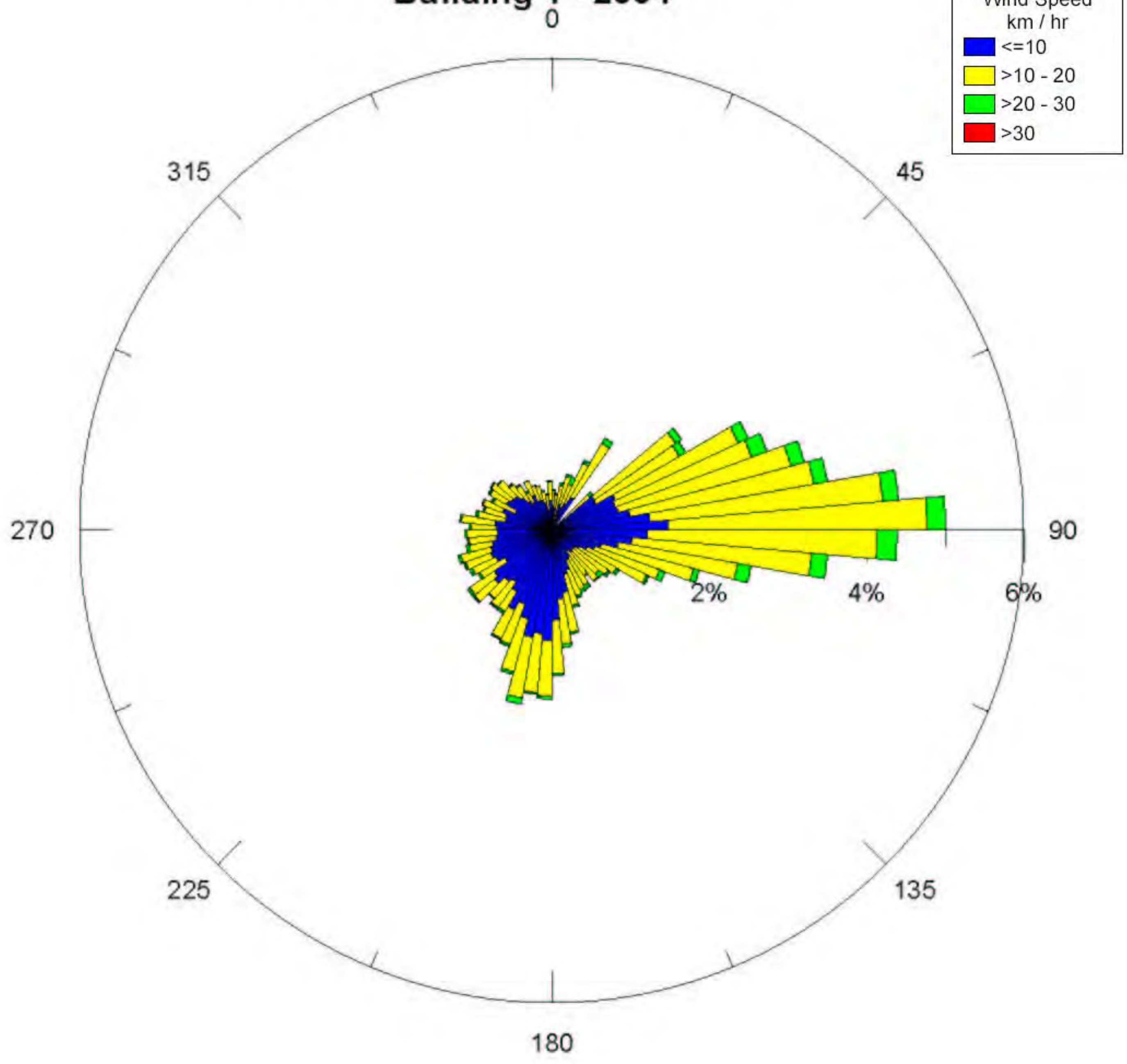


Wind Speed and Direction Chart
Building 1 - 2001
Wind Speed
km / hr
<=10
>10 - 20
>20 - 30
>30
0
45
90
135
180
225
270
315
1%
2%
3%
4%
5%

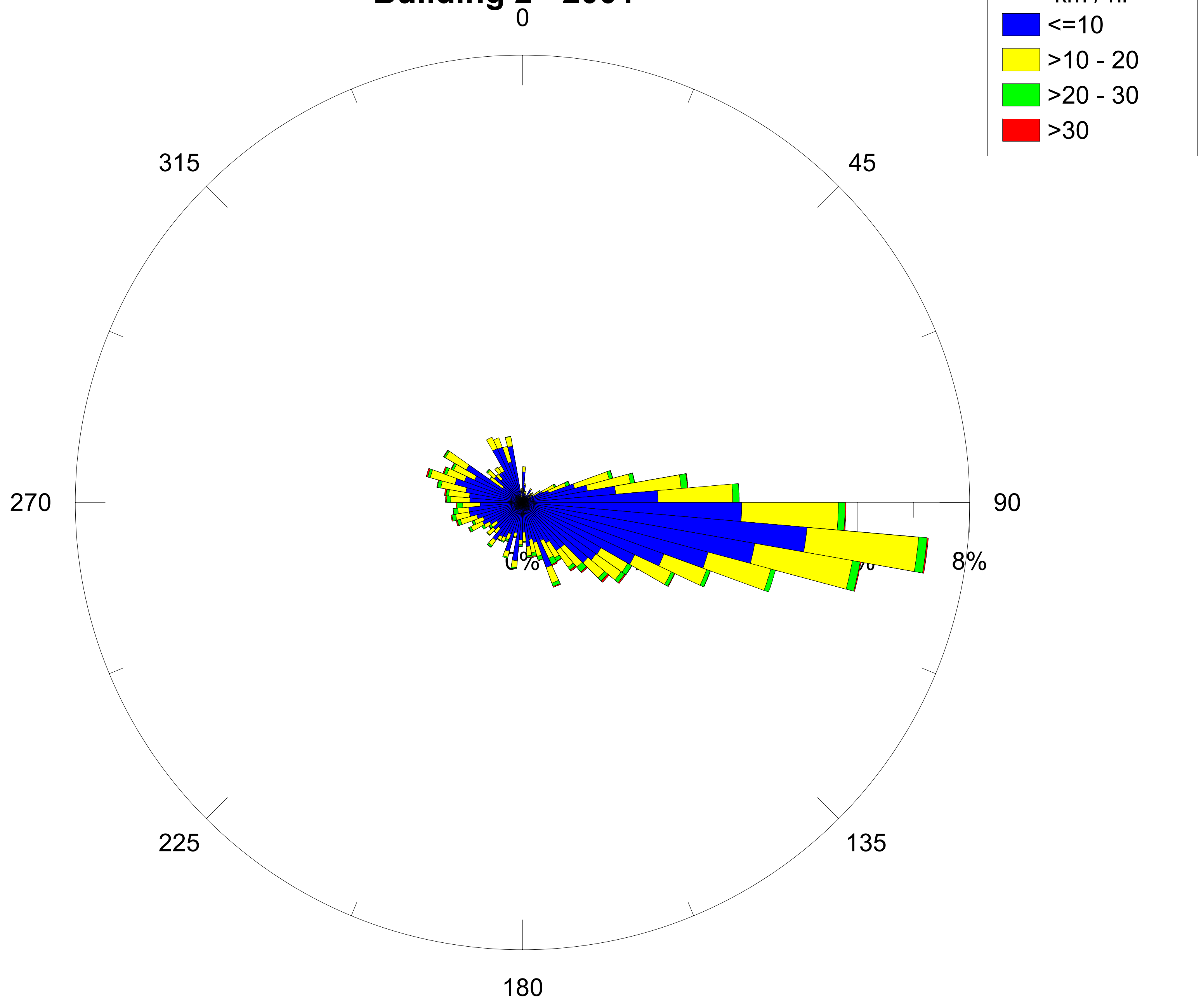

Wind Speed and Direction Chart
Building 1 - 2002
0
45
90
135
180
225
270
315
1%
2%
3%
4%
5%
Wind Speed
km / hr
<=10
>10 - 20
>20 - 30
>30

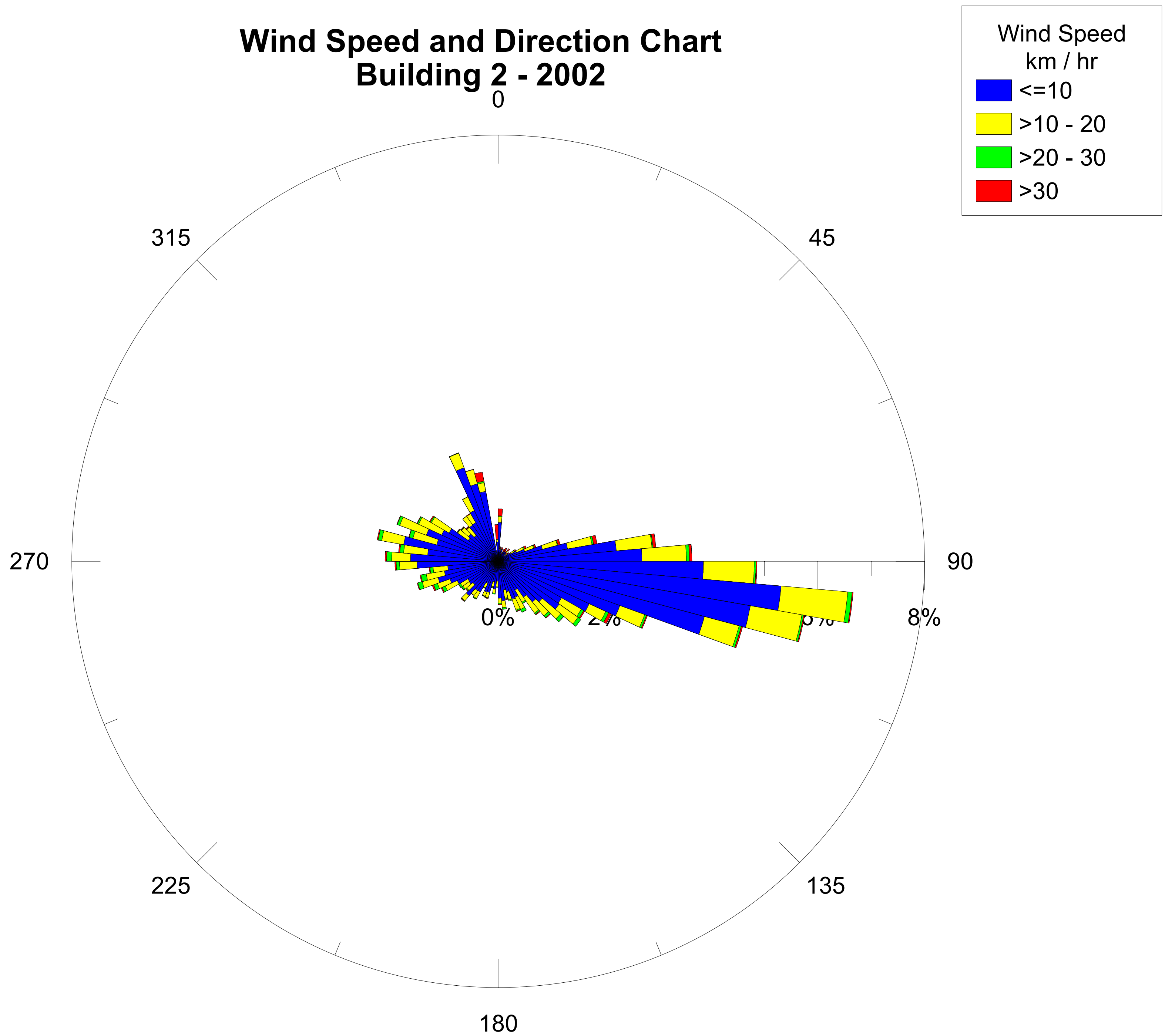

Wind Speed and Direction Chart
Building 1 - 2003
Wind Speed
km / hr
<=10
>10 - 20
>20 - 30
>30
0
45
90
135
180
225
270
315
2%
3%
4%

Wind Speed and Direction Chart
Building 1 - 2004

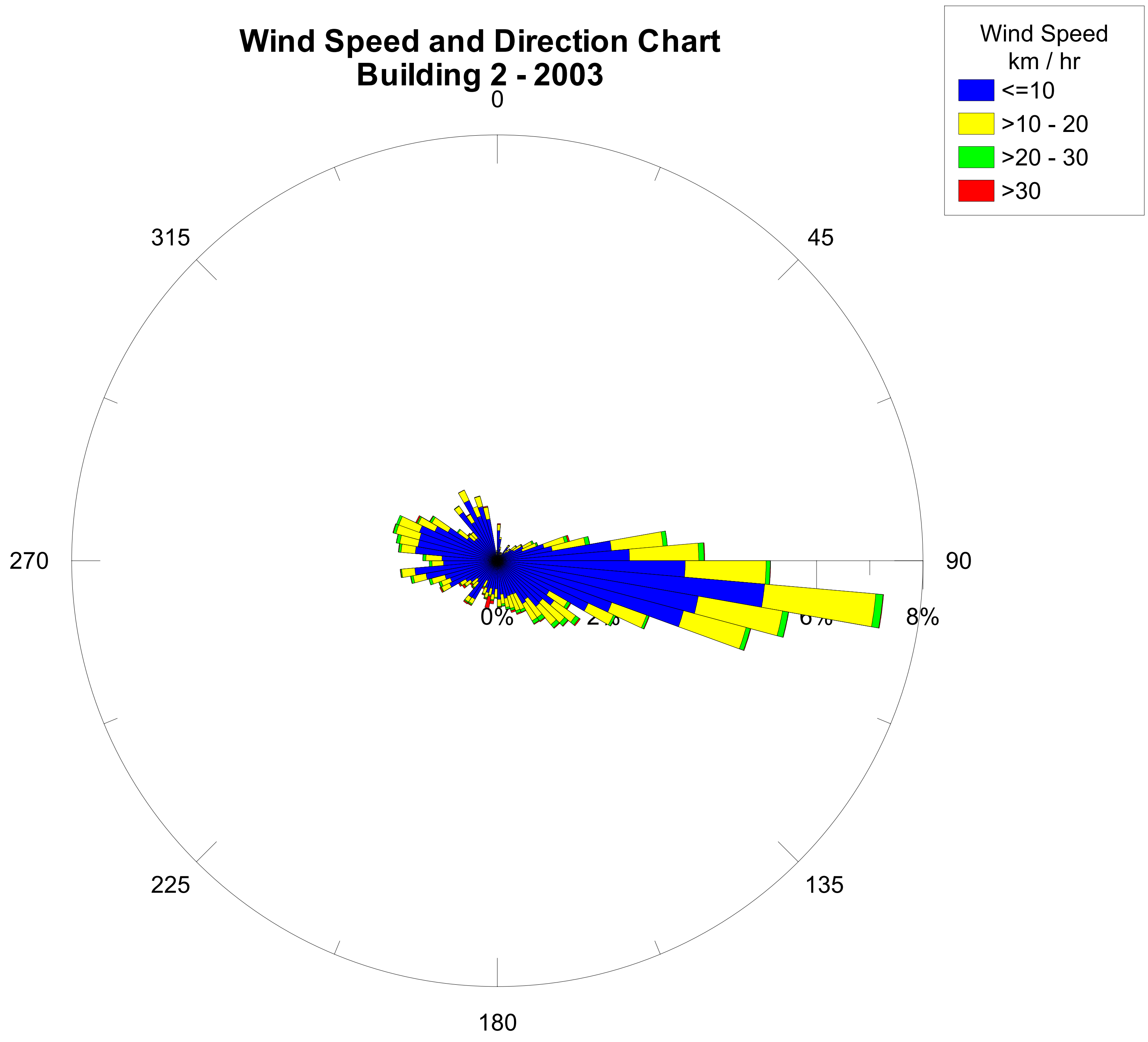


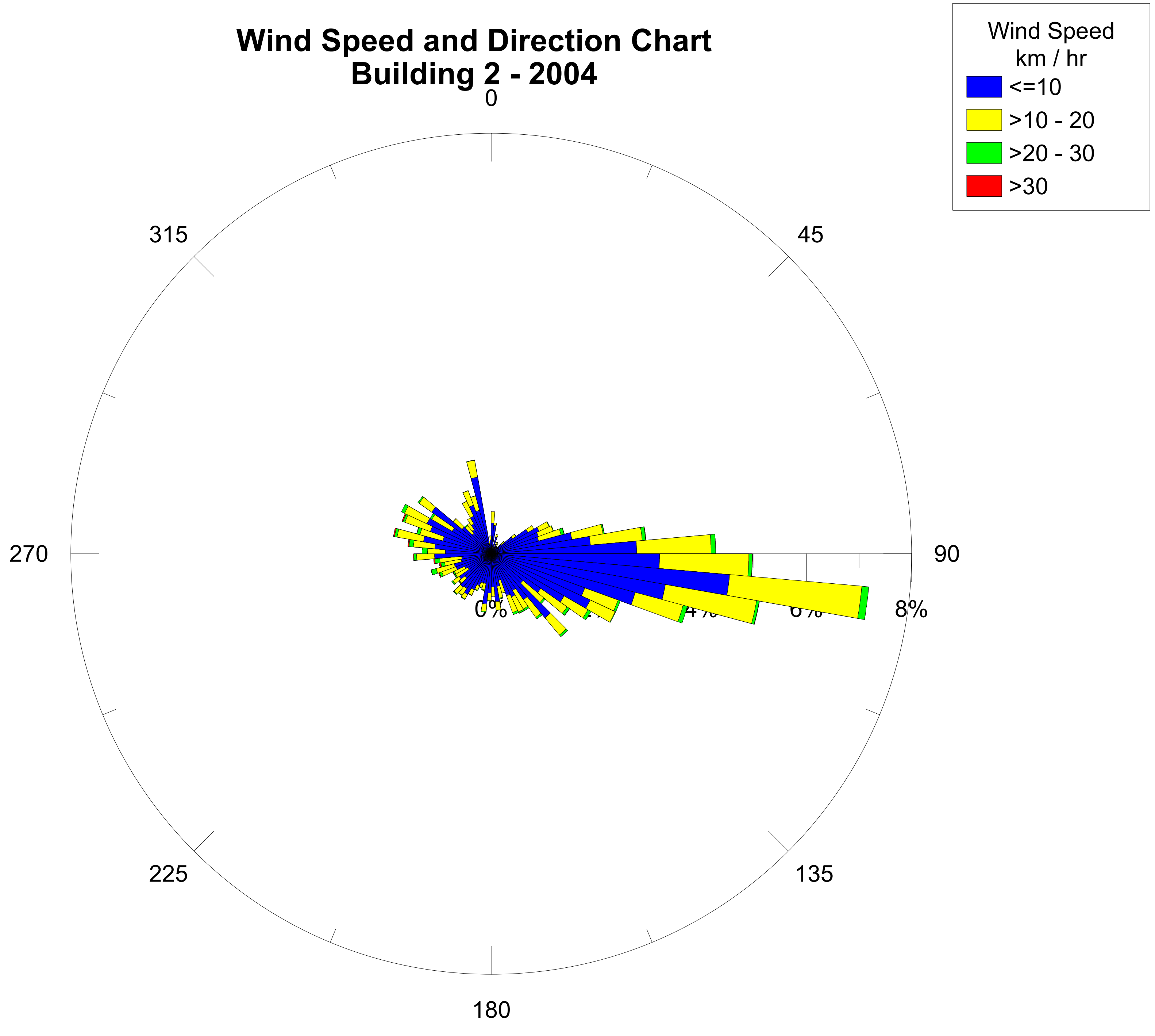
Wind Speed and Direction Chart
Building 2 - 2001




Wind Speed and Direction Chart
Building 2 - 2002
Wind Speed
km / hr
<=10
>10 - 20
>20 - 30
>30
0
45
90
135
180
225
270
315
0%
8%

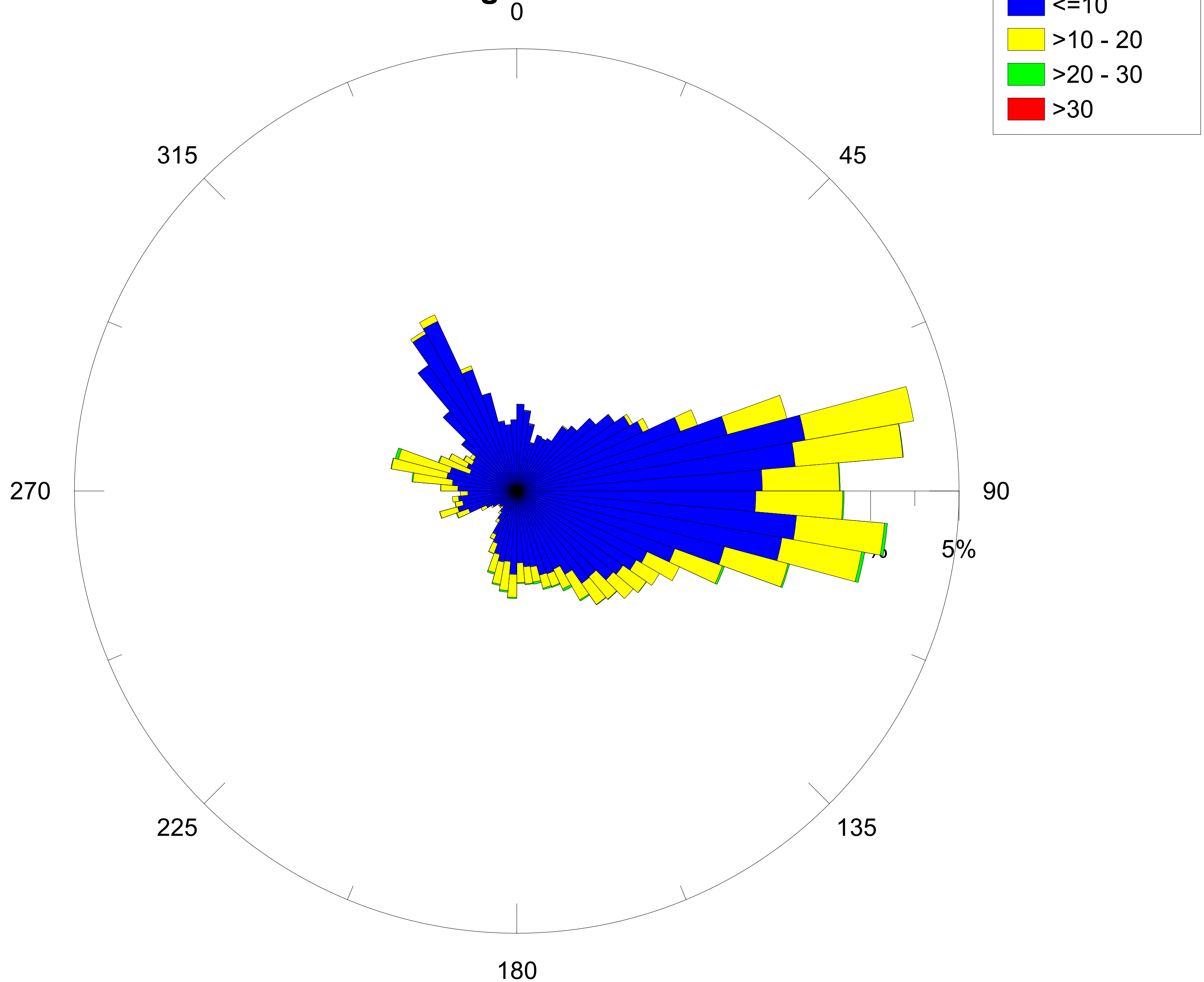
Wind Speed and Direction Chart
Building 2 - 2003



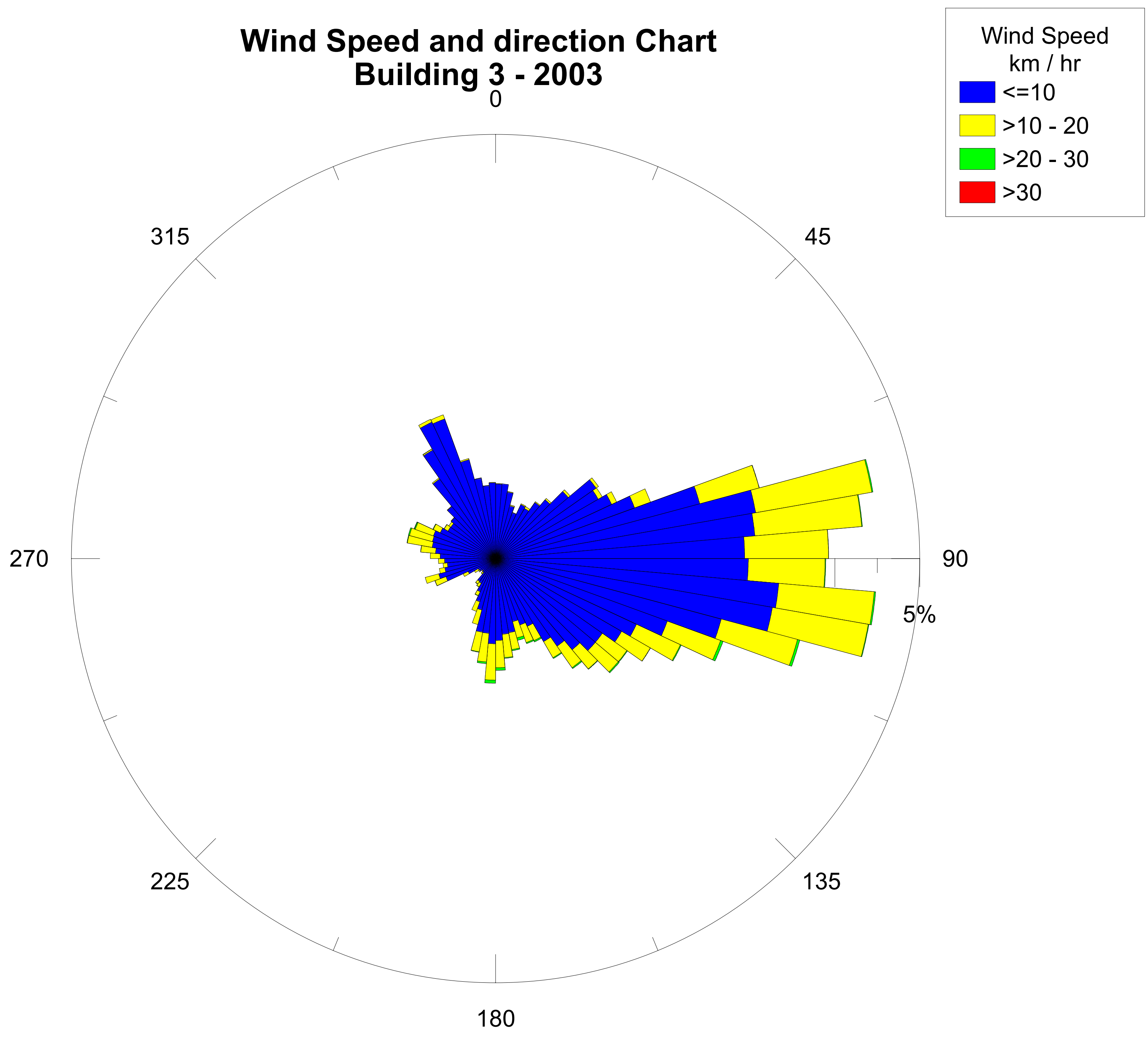


Wind Speed and Direction Chart
Building 2 - 2004
0
45
90
135
180
225
270
315
0%
8%
Wind Speed
km / hr
<=10
>10 - 20
>20 - 30
>30

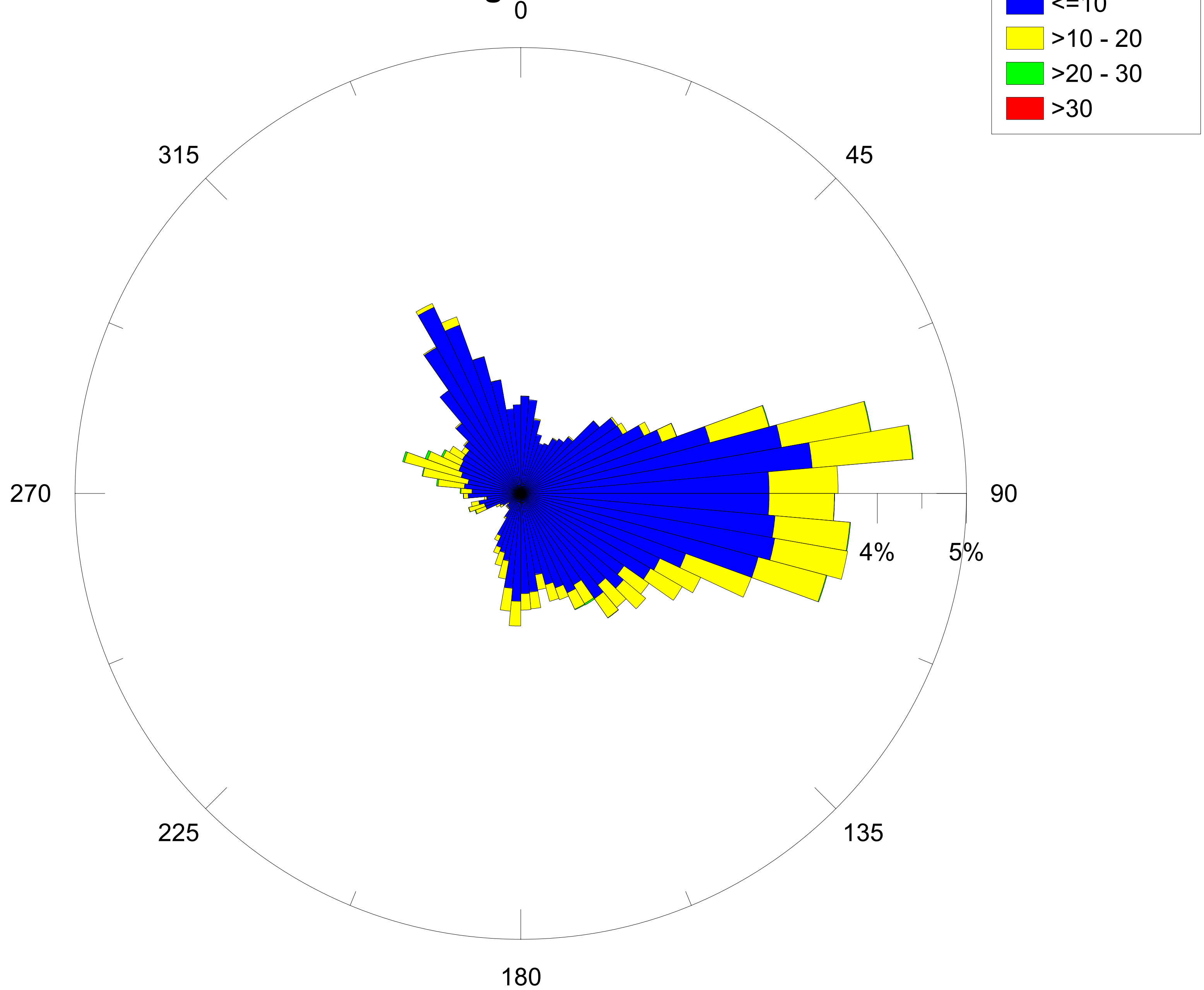
Wind Speed and Direction Chart
Building 3 - 2002

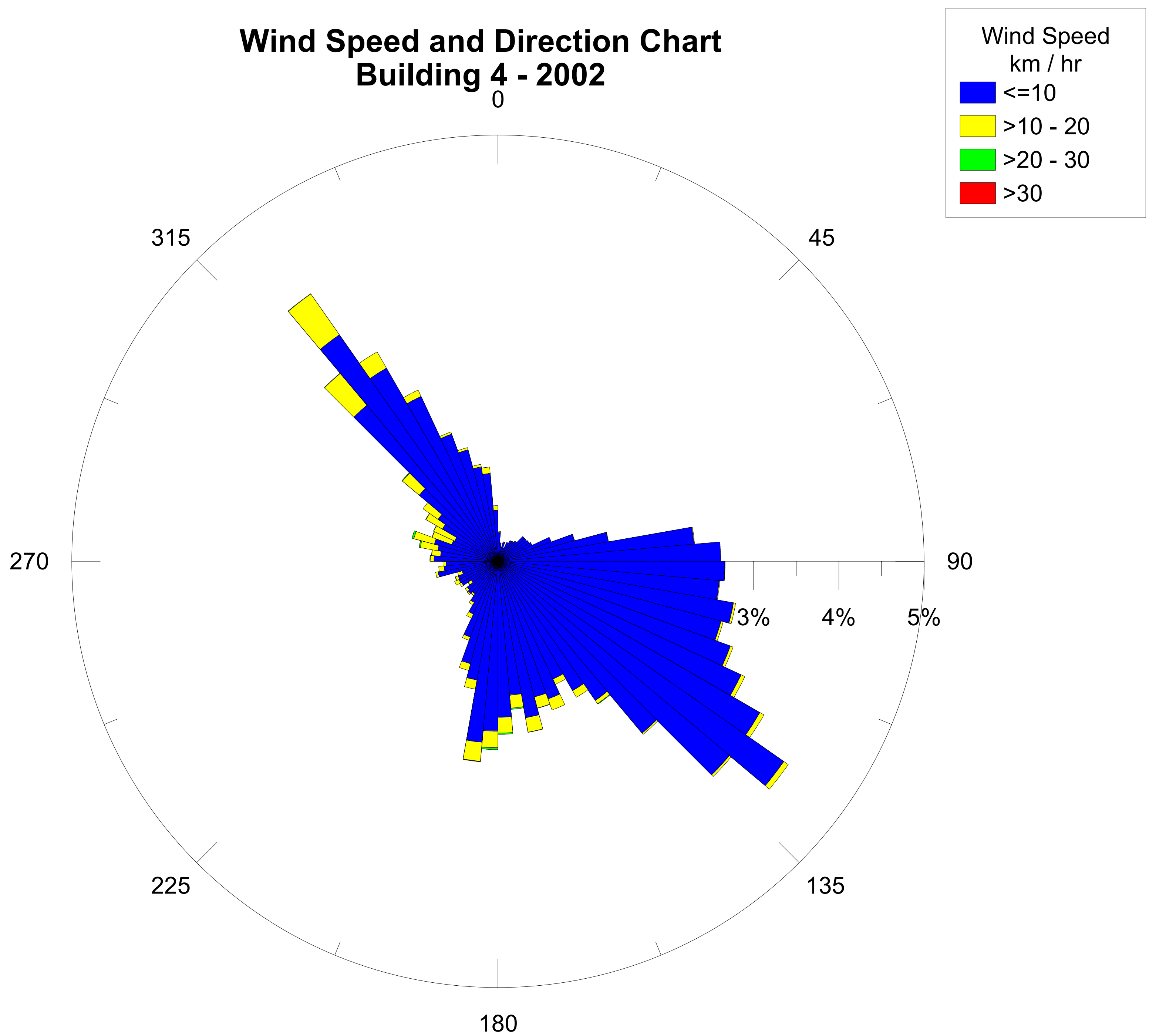


Wind Speed and direction Chart
Building 3 - 2003

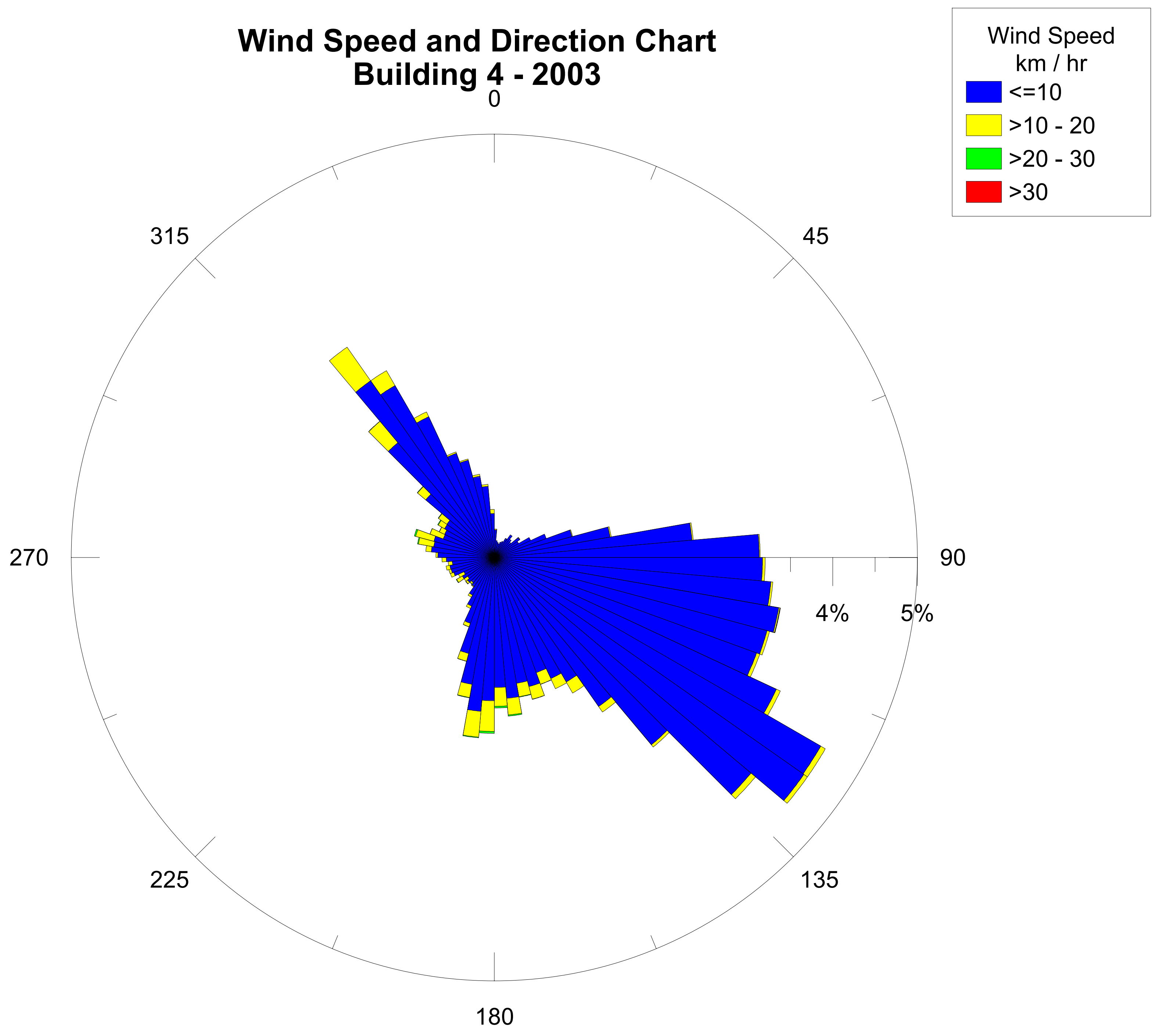


Wind Speed and Direction Chart
Building 3 - 2004

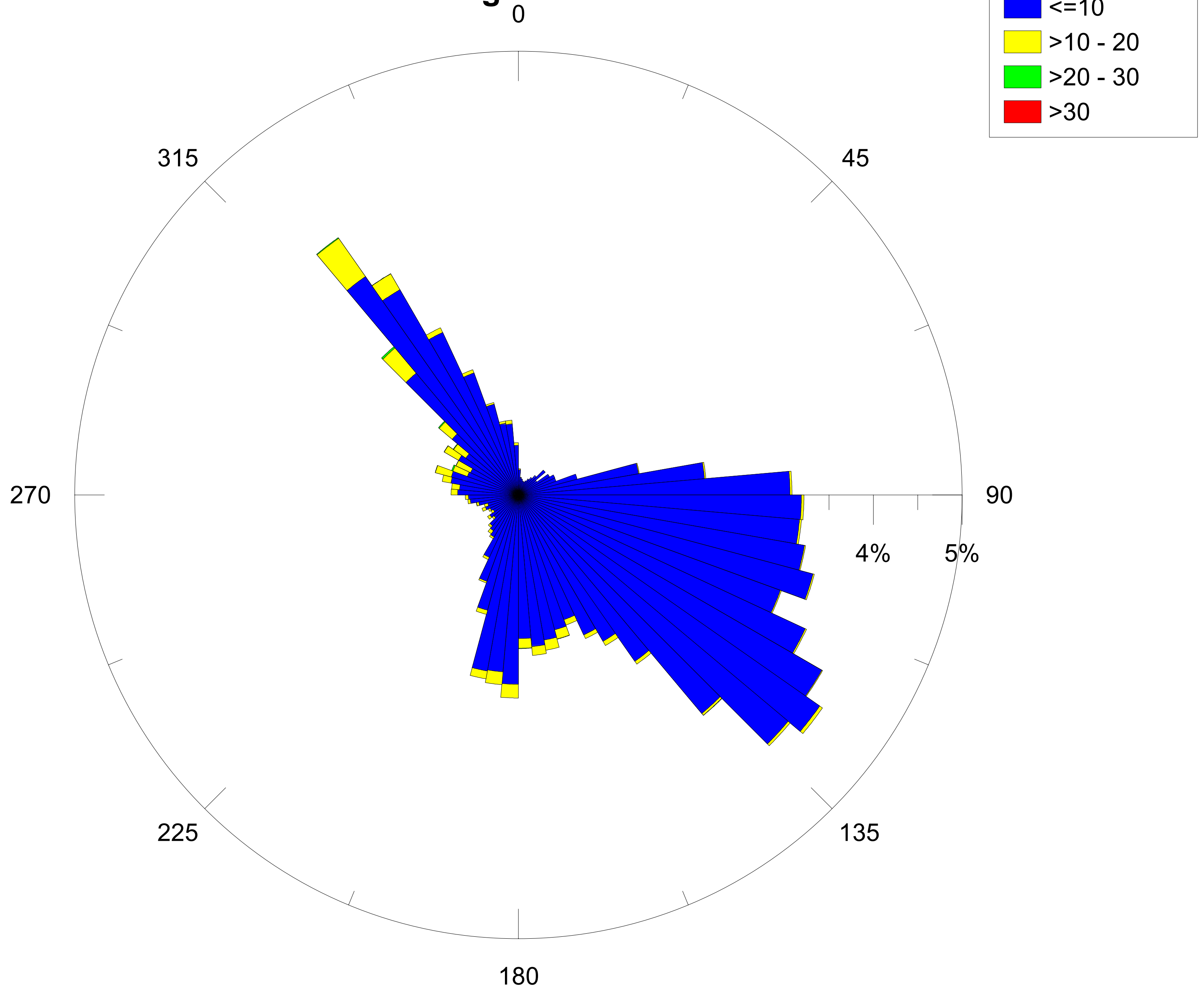




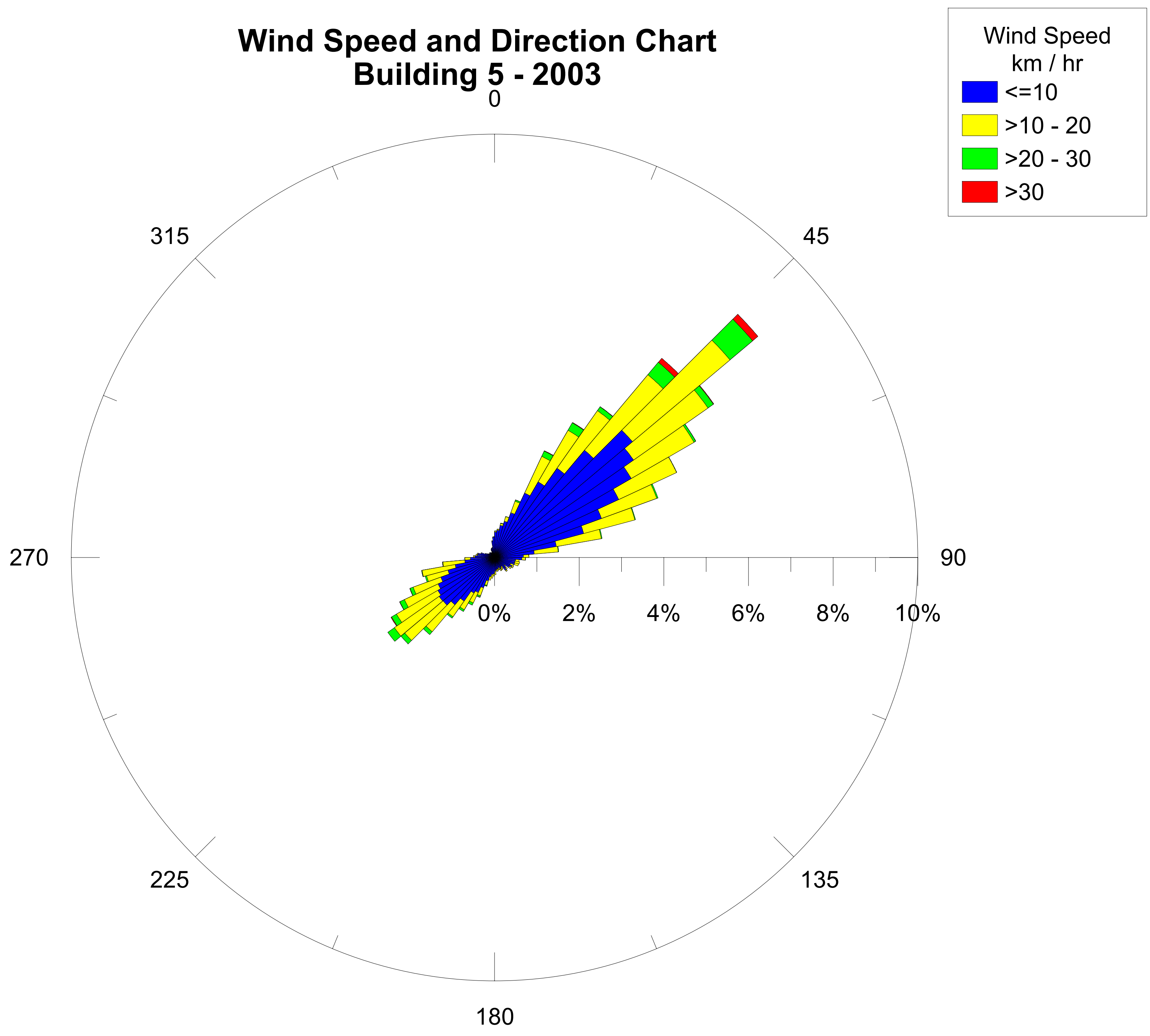
Wind Speed and Direction Chart
Building 4 - 2002
0
45
90
135
180
225
270
315
3%
4%
5%
Wind Speed
km / hr
<=10
>10 - 20
>20 - 30
>30

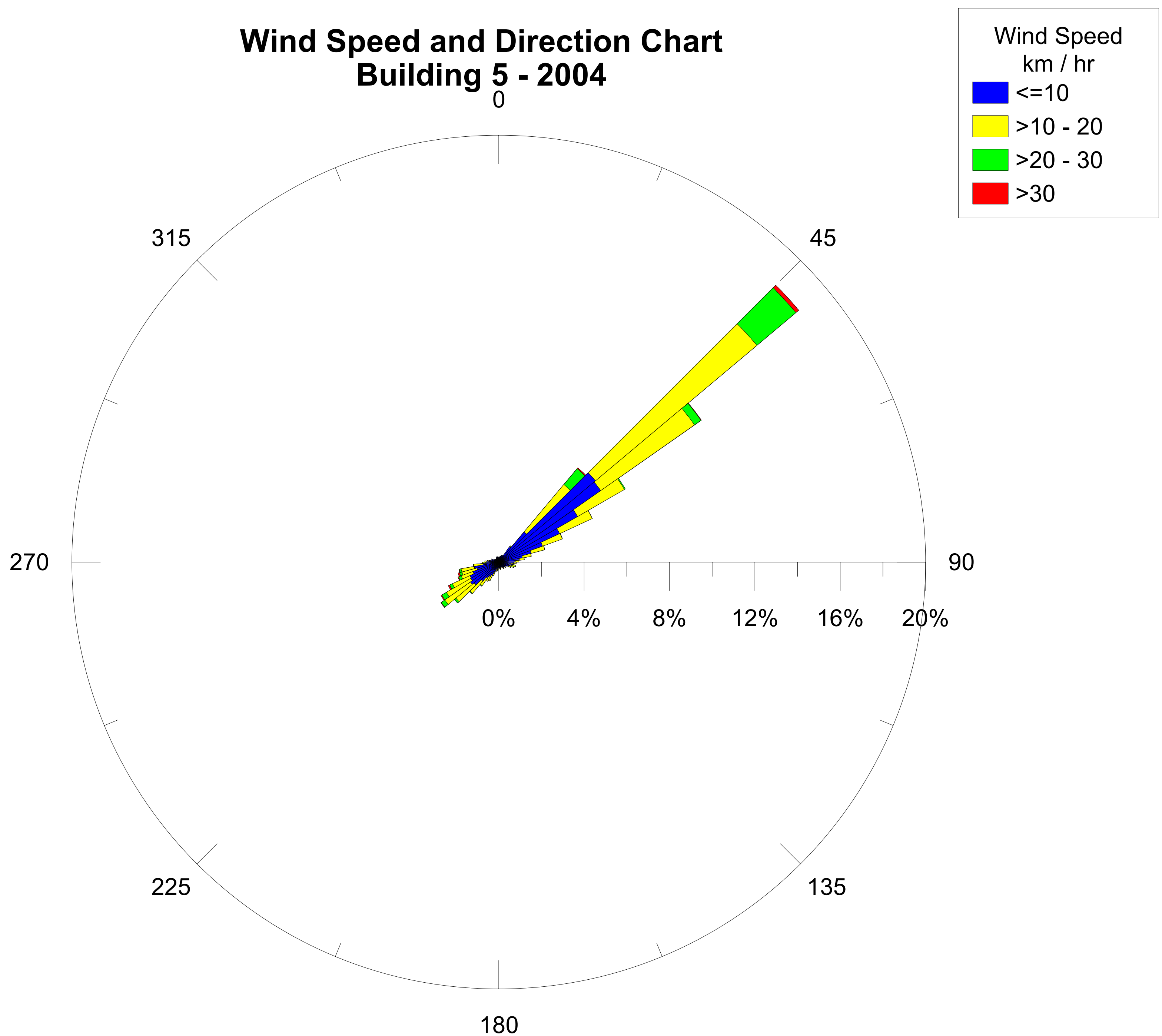

Wind Speed and Direction Chart
Building 4 - 2003
0
45
90
135
180
225
270
315
4%
5%
Wind Speed
km / hr
<=10
>10 - 20
>20 - 30
>30

Wind Speed and Direction Chart
Building 4 - 2004



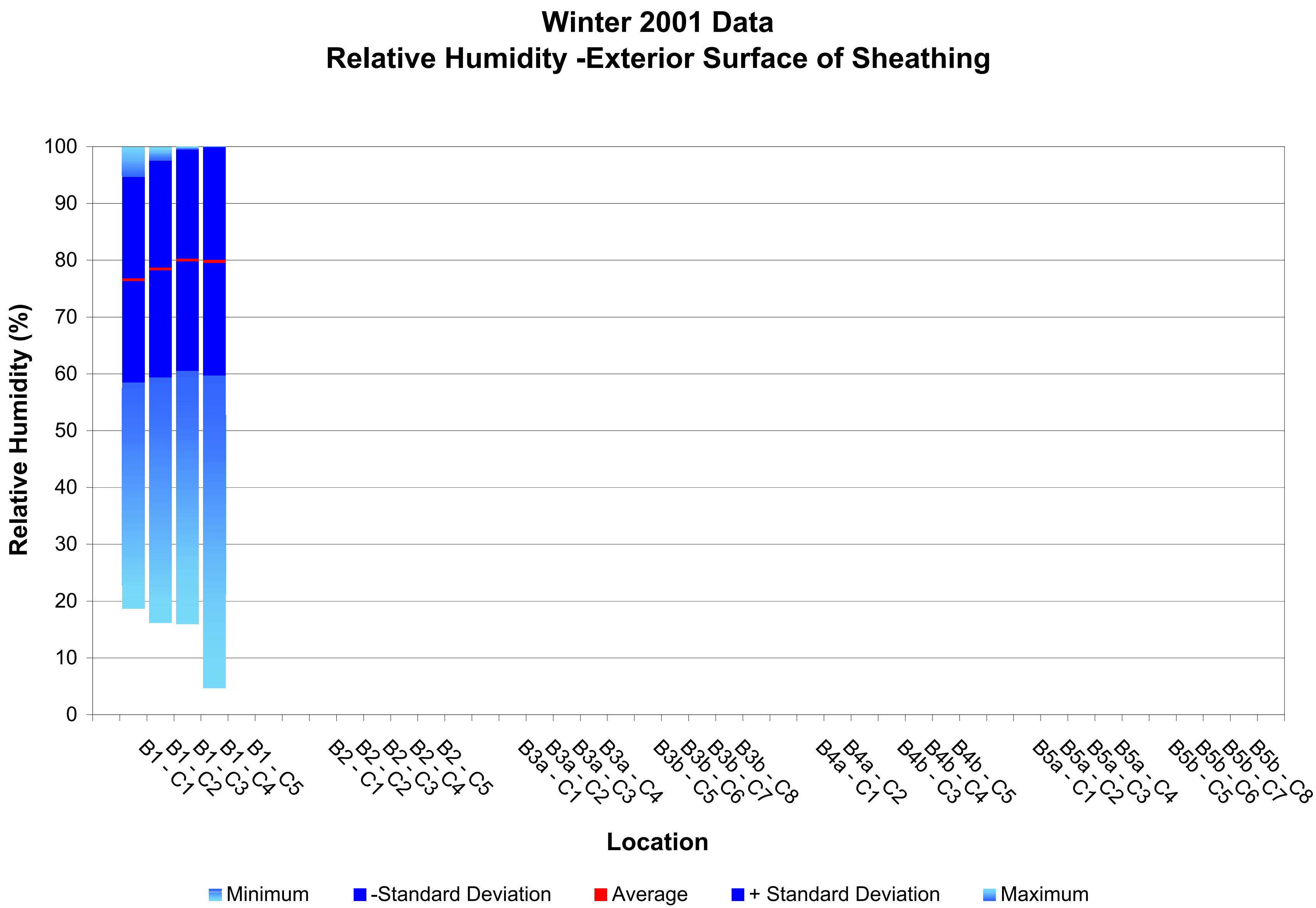
Wind Speed and Direction Chart
Building 5 - 2003

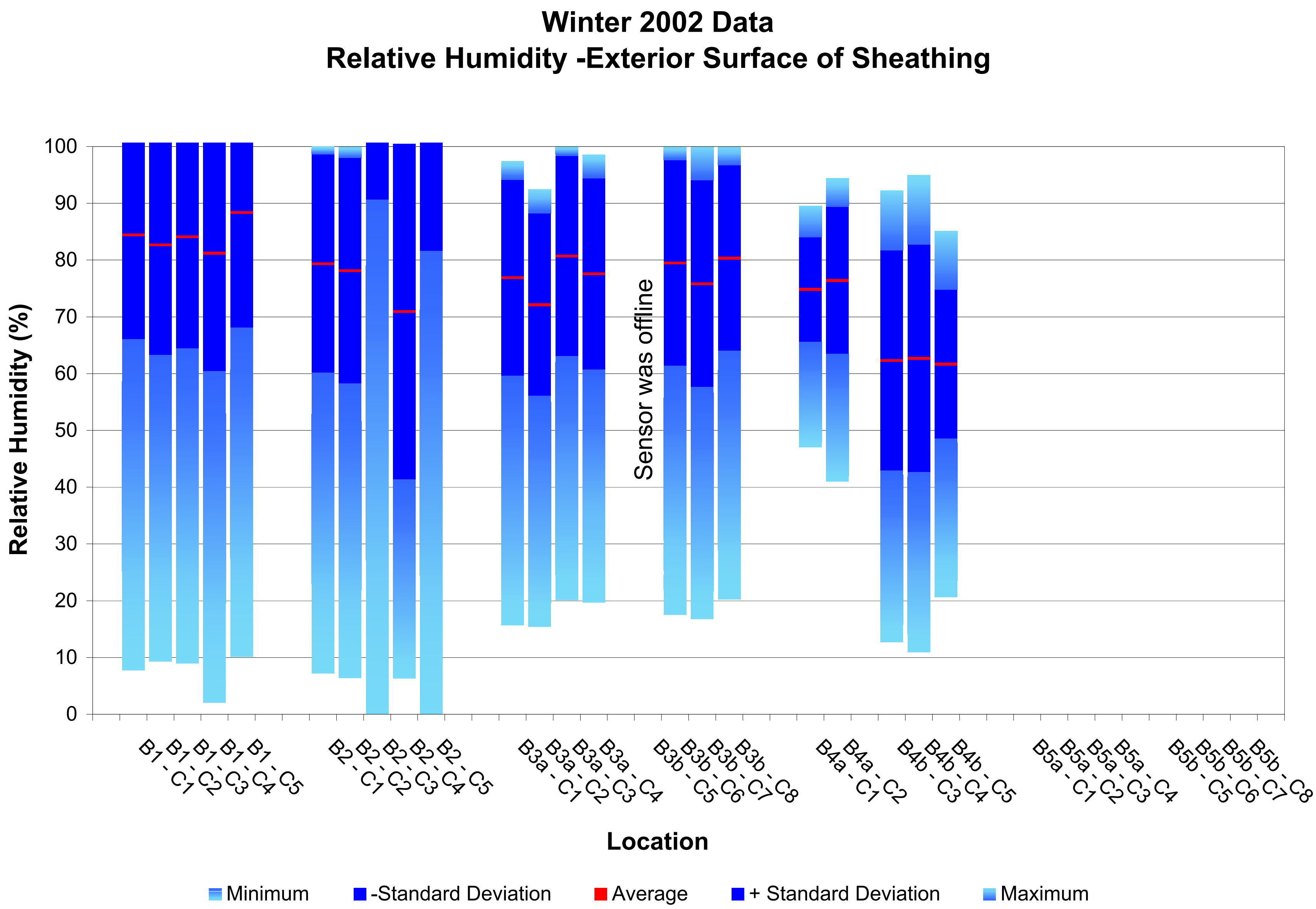



Wind Speed and Direction Chart
Building 5 - 2004
Wind Speed
km / hr
<=10
>10 - 20
>20 - 30
>30
0
45
90
135
180
225
270
315
0%
4%
8%
12%
16%
20%

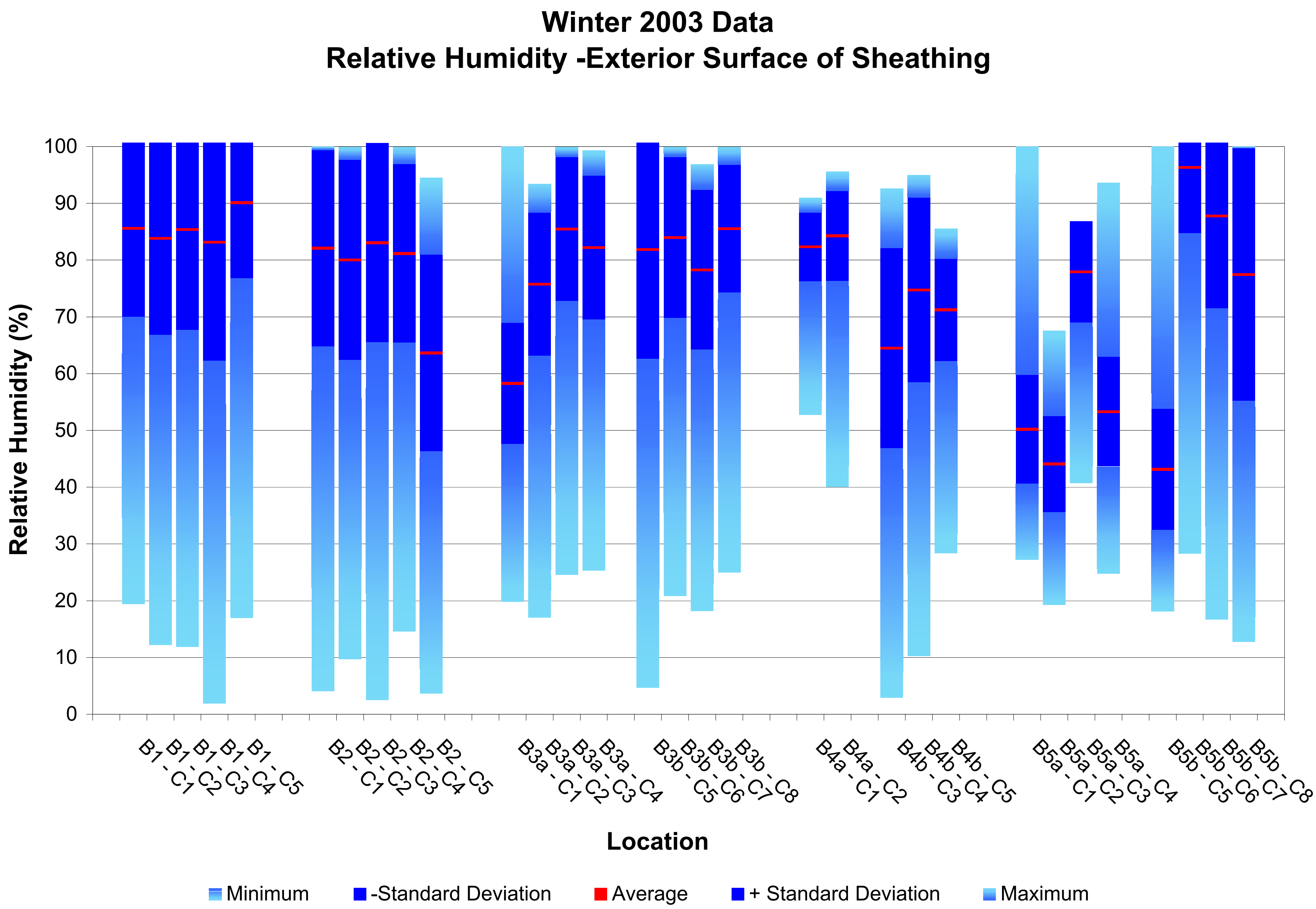
APPENDIX F

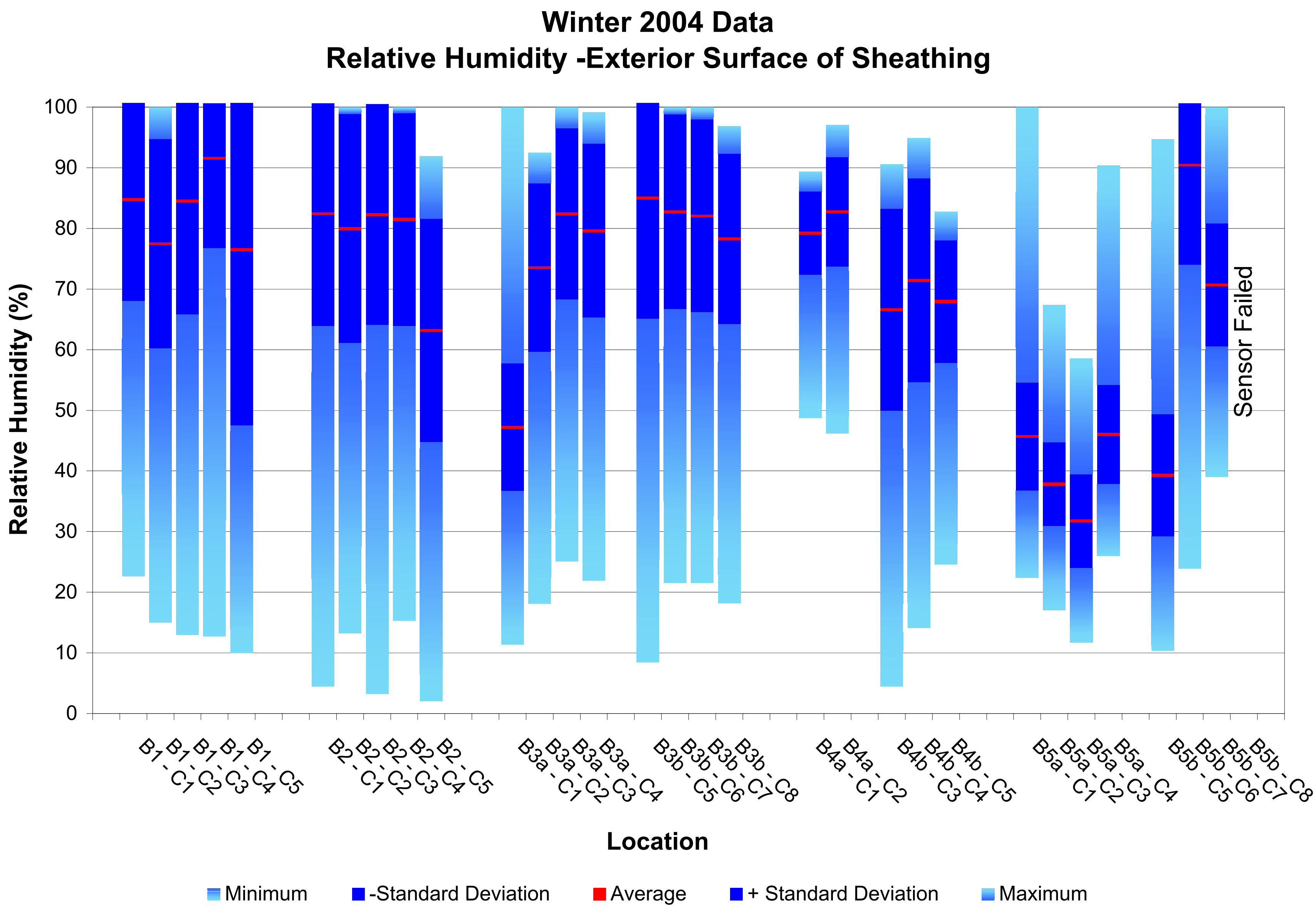
Relative Humidity


Winter 2001 Data
Relative Humidity -Exterior Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

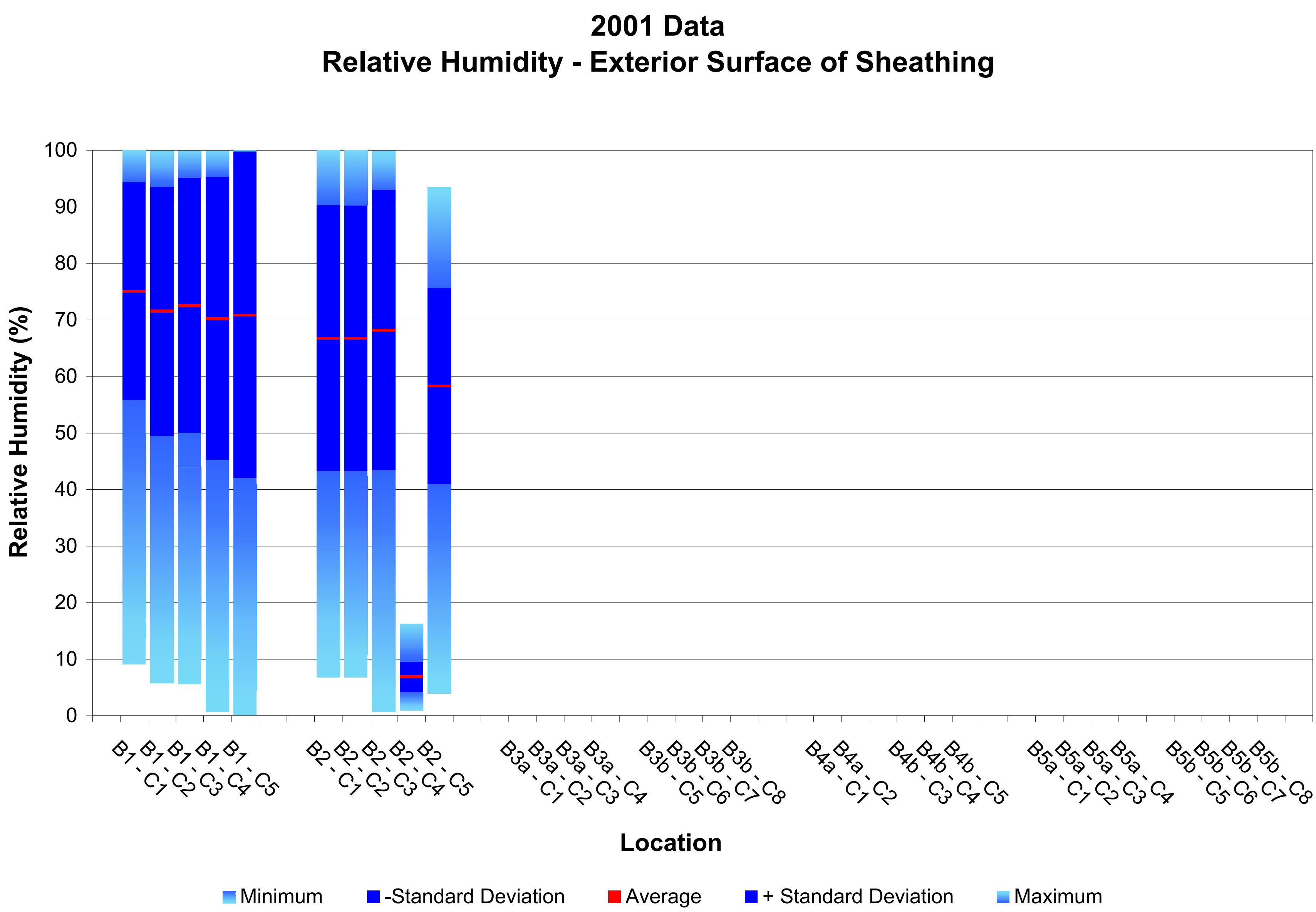


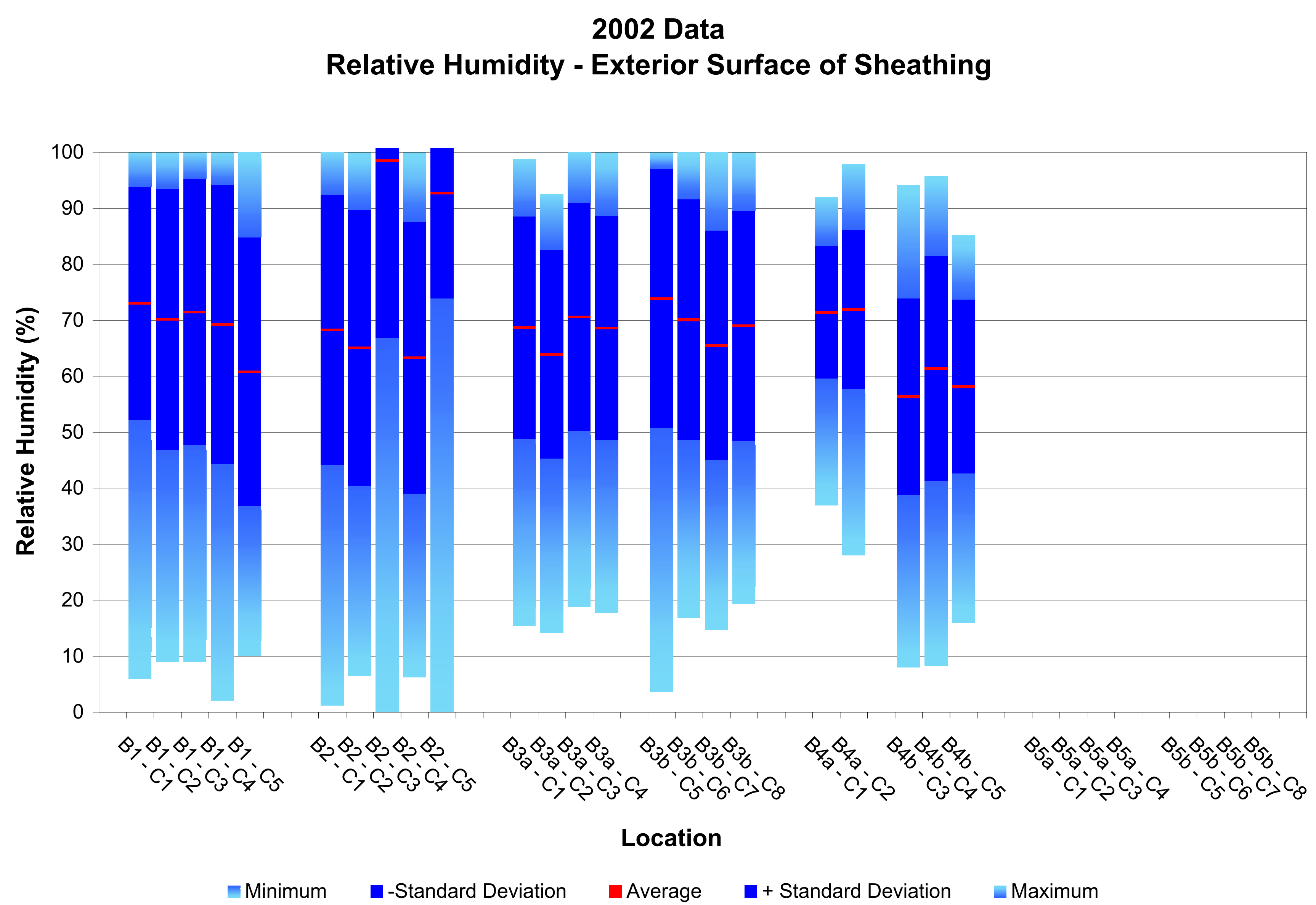
Winter 2002 Data
Relative Humidity -Exterior Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Sensor was offline
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

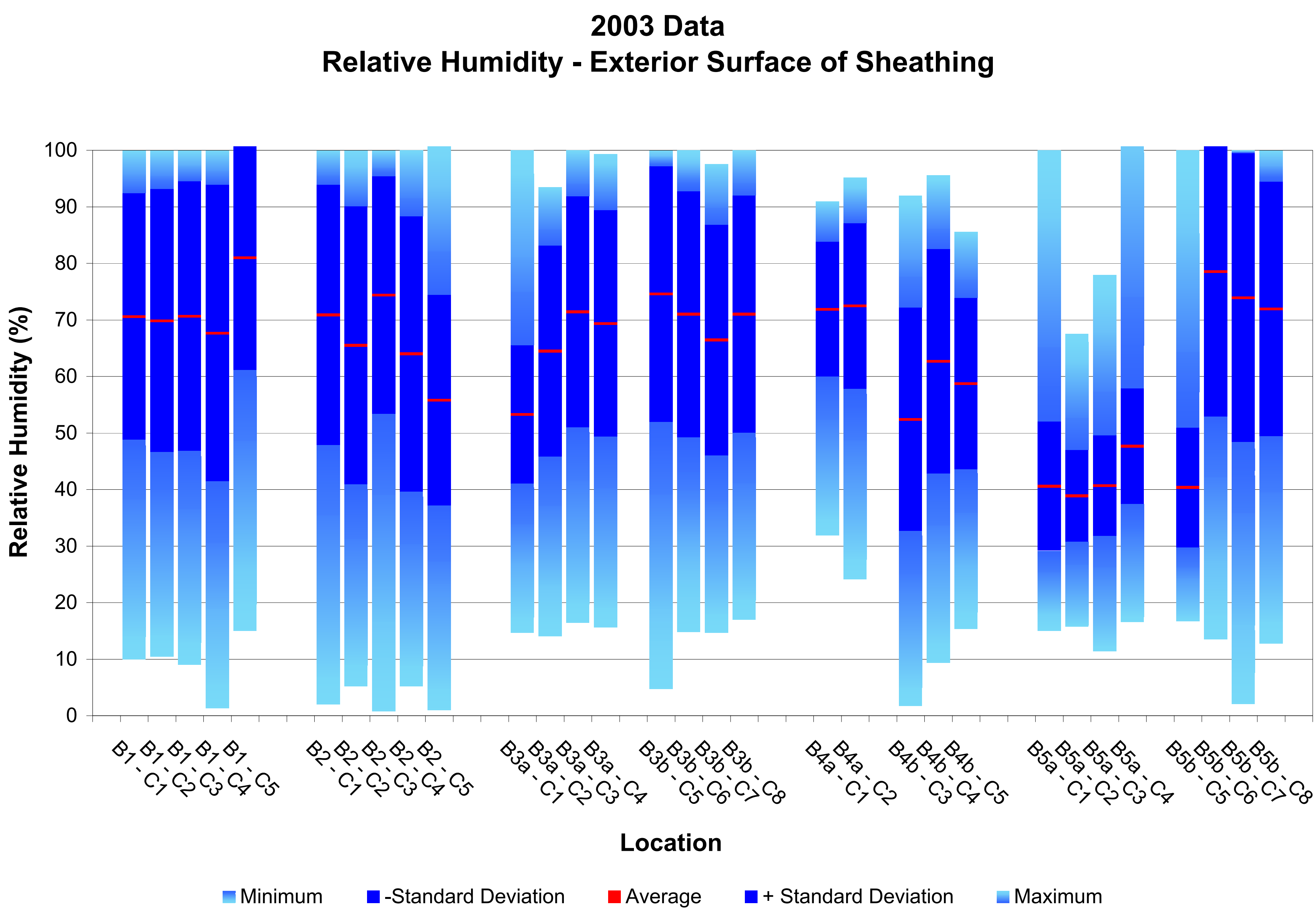

Winter 2003 Data
Relative Humidity -Exterior Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

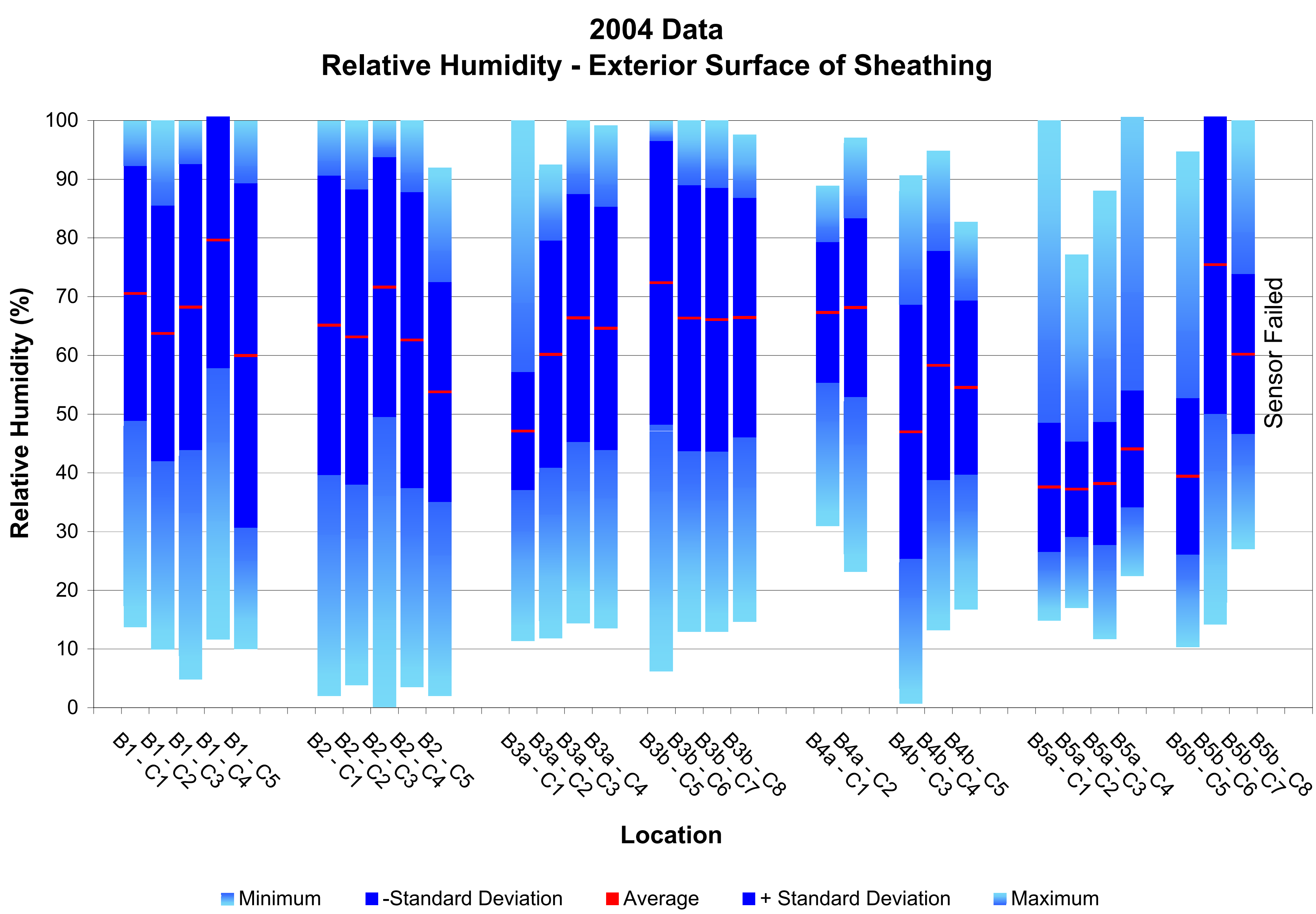


Winter 2004 Data
Relative Humidity -Exterior Surface of Sheathing
Relative Humidity (%)
0
10
20
30
40
50
60
70
80
90
100
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


2001 Data
Relative Humidity - Exterior Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

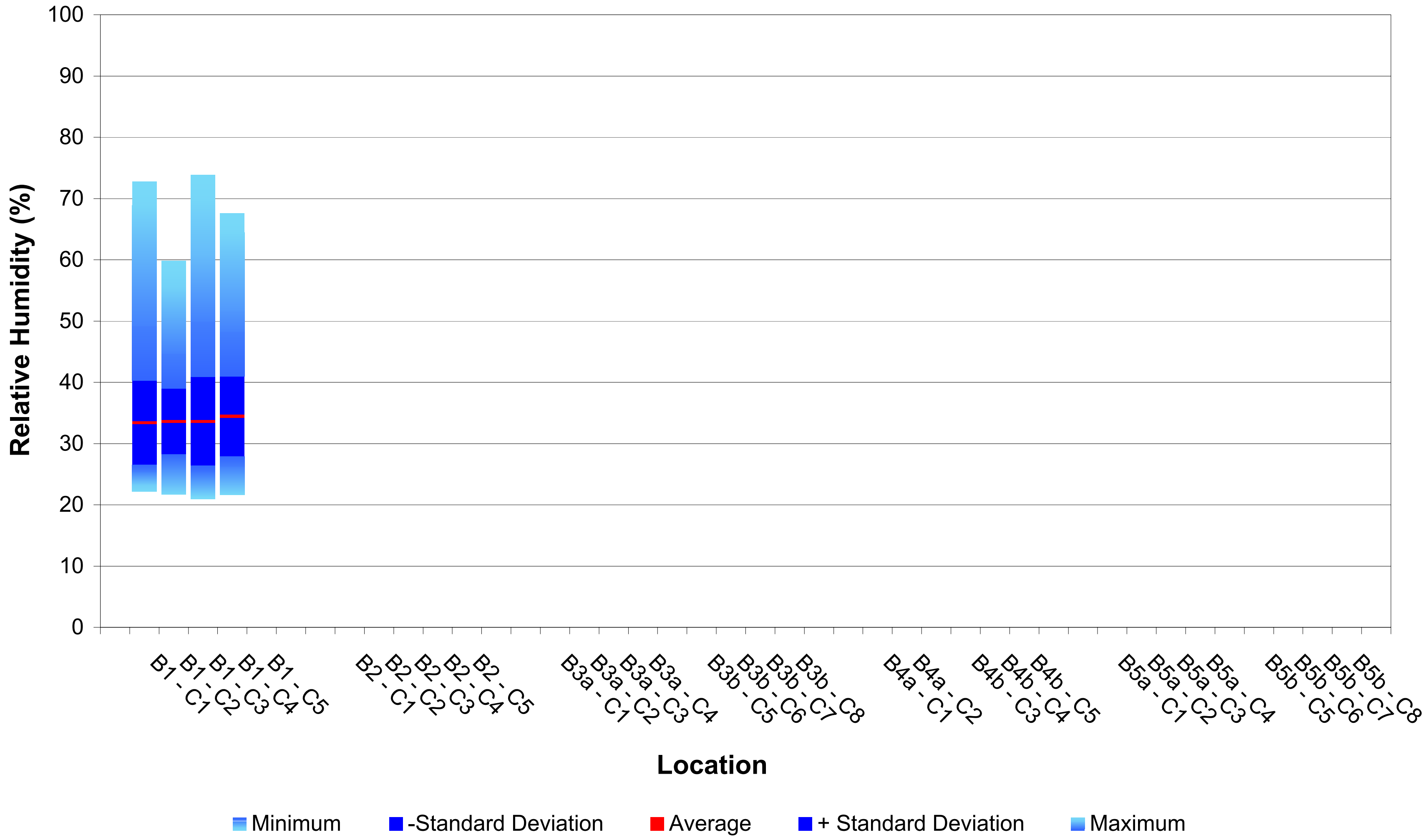

2002 Data
Relative Humidity - Exterior Surface of Sheathing
Relative Humidity (%)
0
10
20
30
40
50
60
70
80
90
100
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

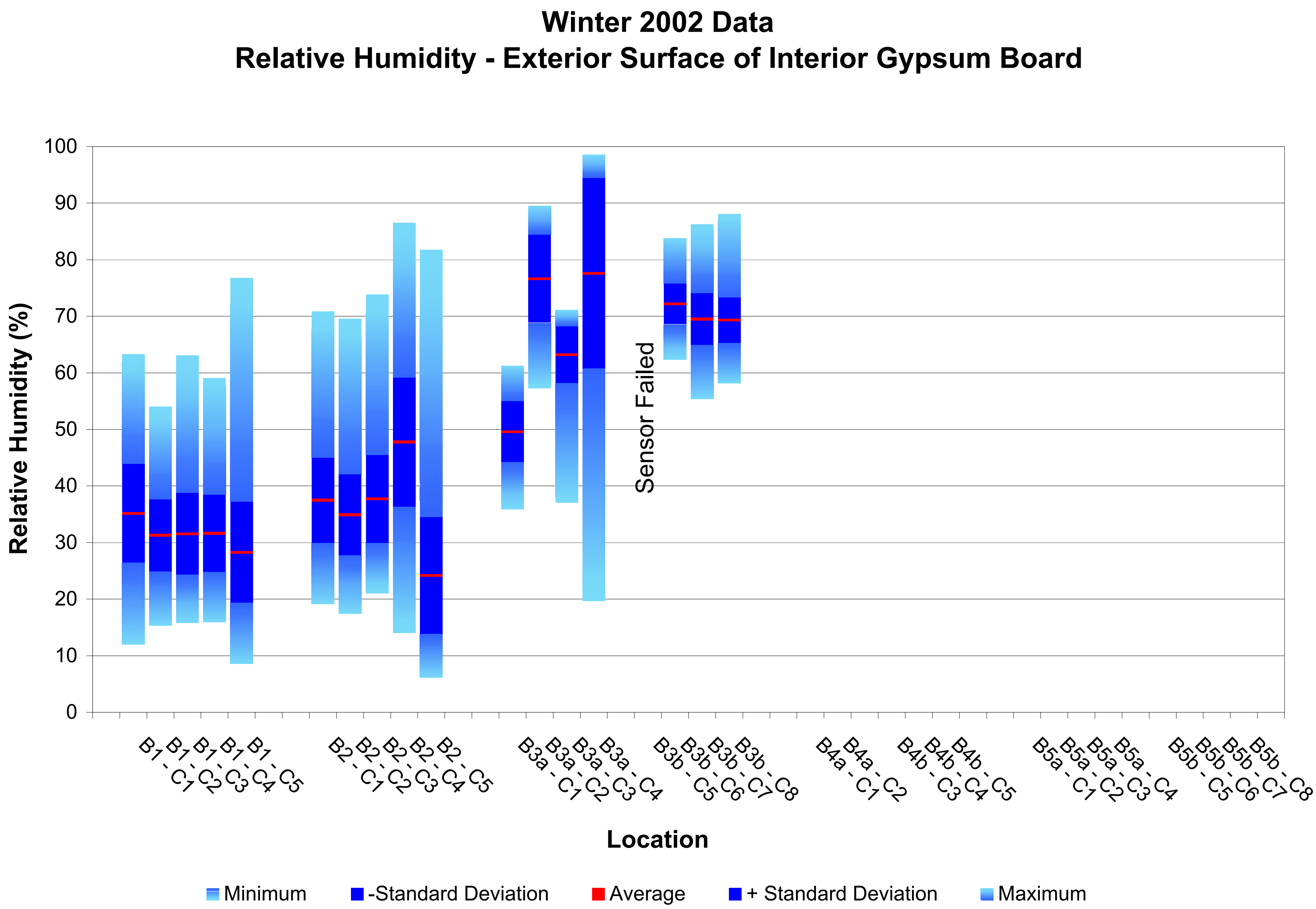

2003 Data
Relative Humidity - Exterior Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

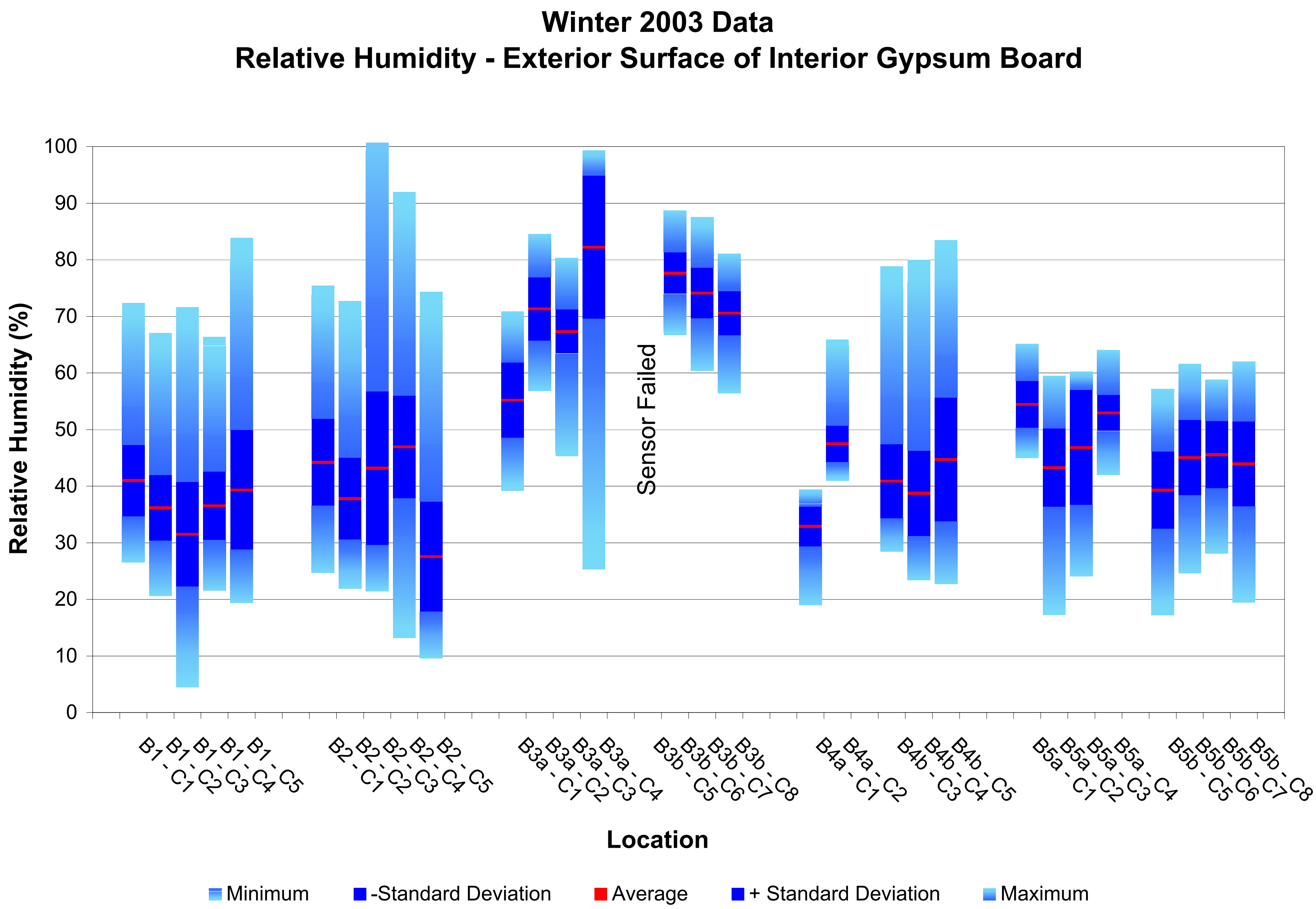


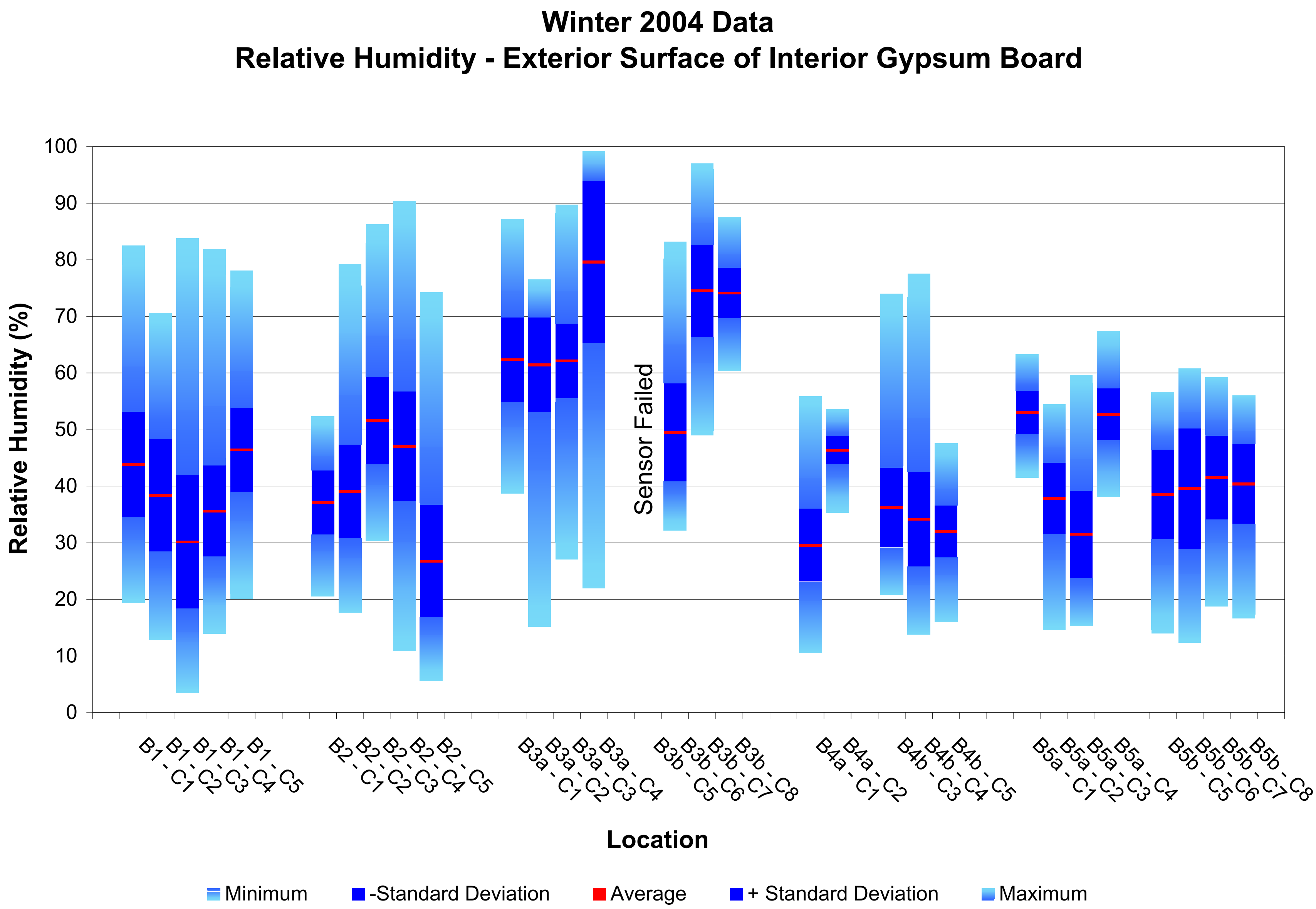
2004 Data
Relative Humidity - Exterior Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

Winter 2001 Data
Relative Humidity - Exterior Surface of Interior Gypsum Board

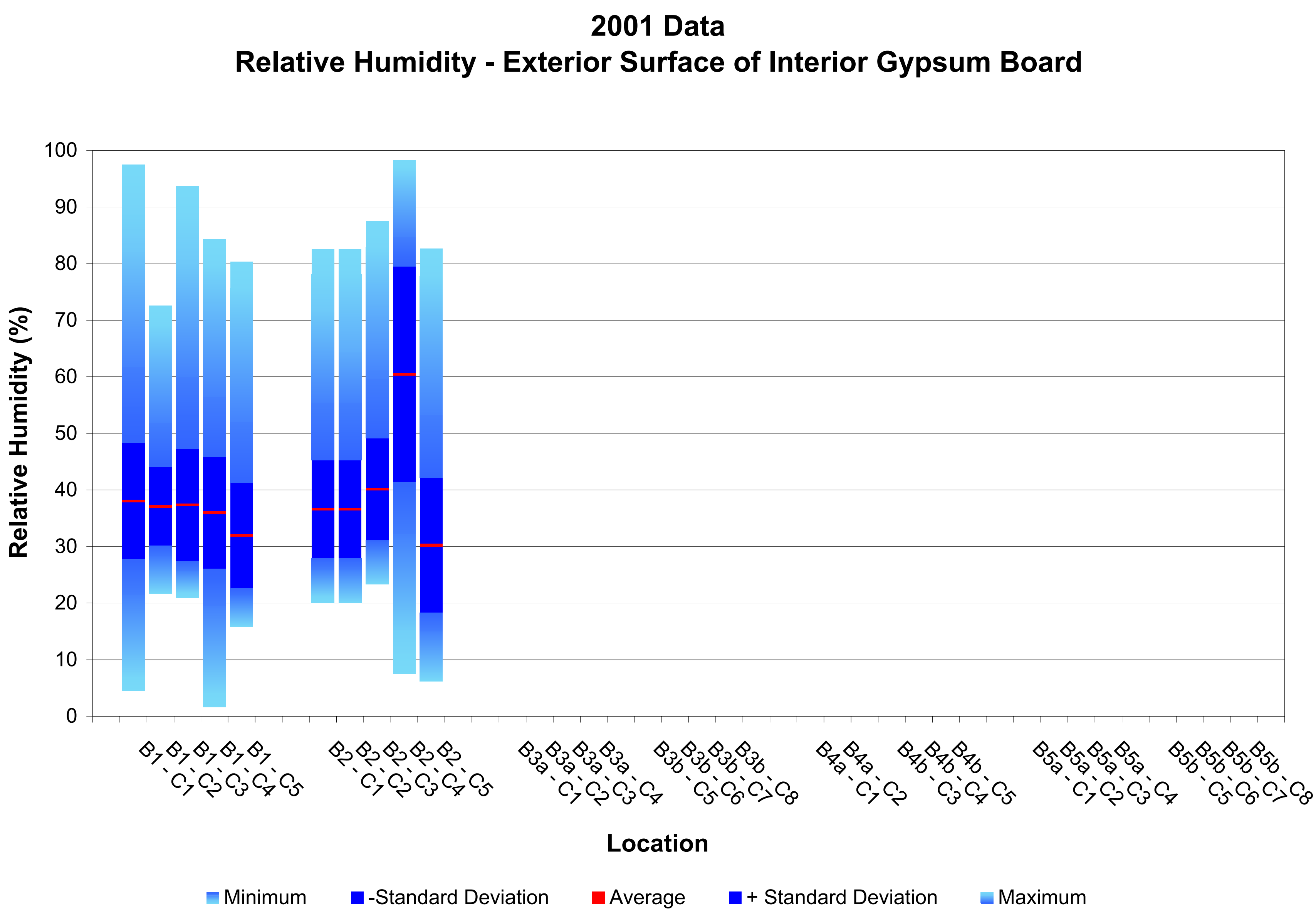



Winter 2002 Data
Relative Humidity - Exterior Surface of Interior Gypsum Board
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

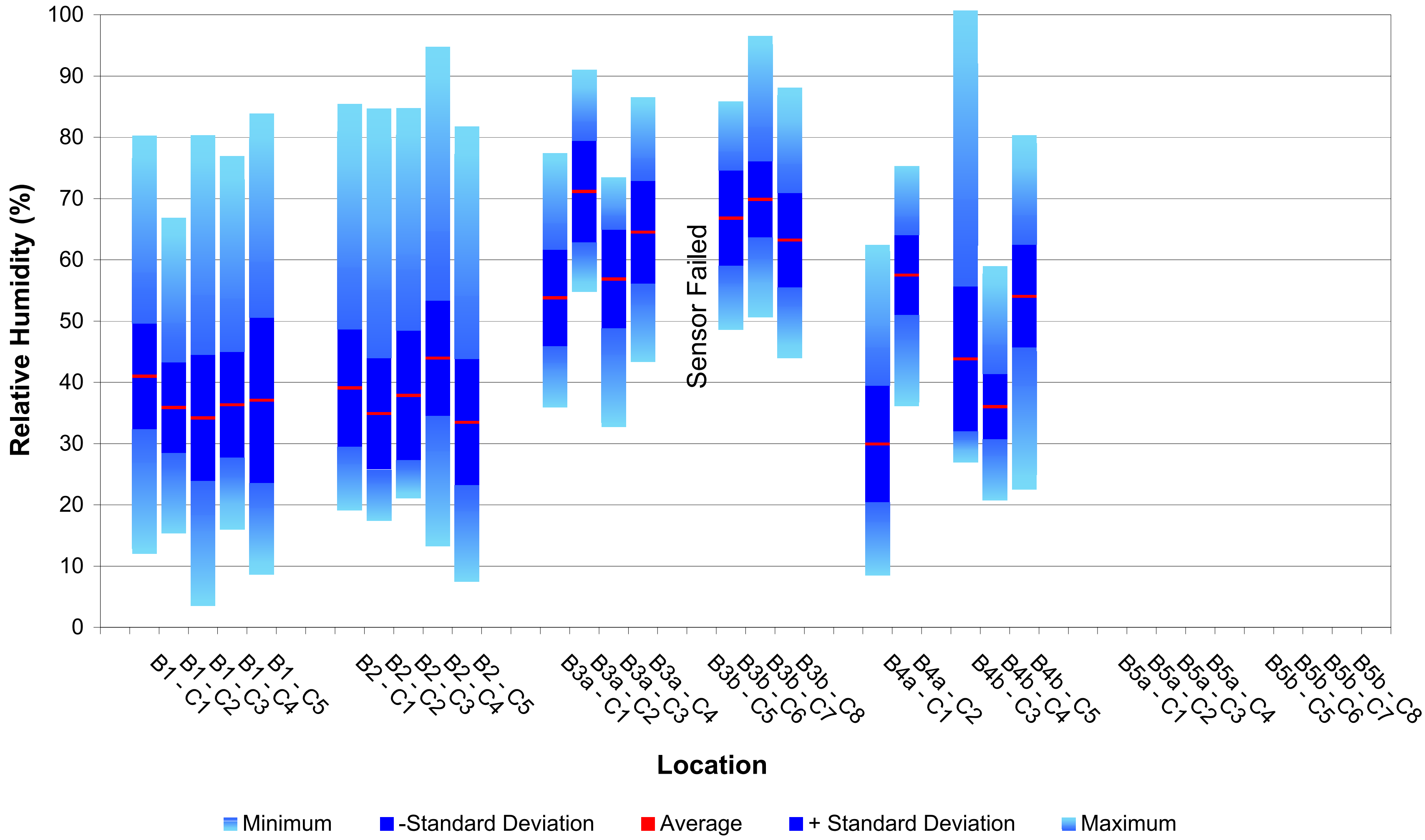

Winter 2003 Data
Relative Humidity - Exterior Surface of Interior Gypsum Board
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



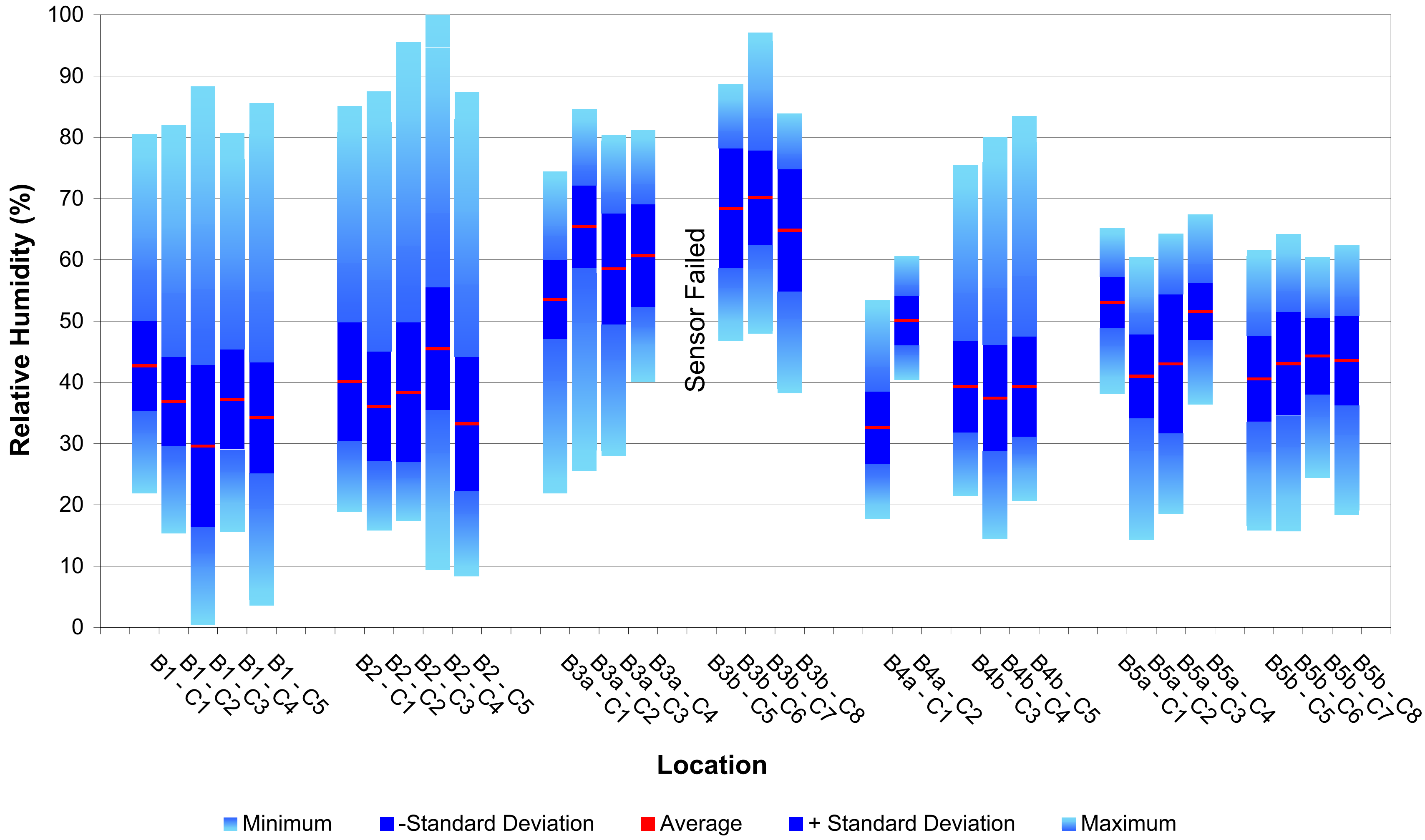
Winter 2004 Data
Relative Humidity - Exterior Surface of Interior Gypsum Board
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


2001 Data
Relative Humidity - Exterior Surface of Interior Gypsum Board
Relative Humidity (%)
0
10
20
30
40
50
60
70
80
90
100
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

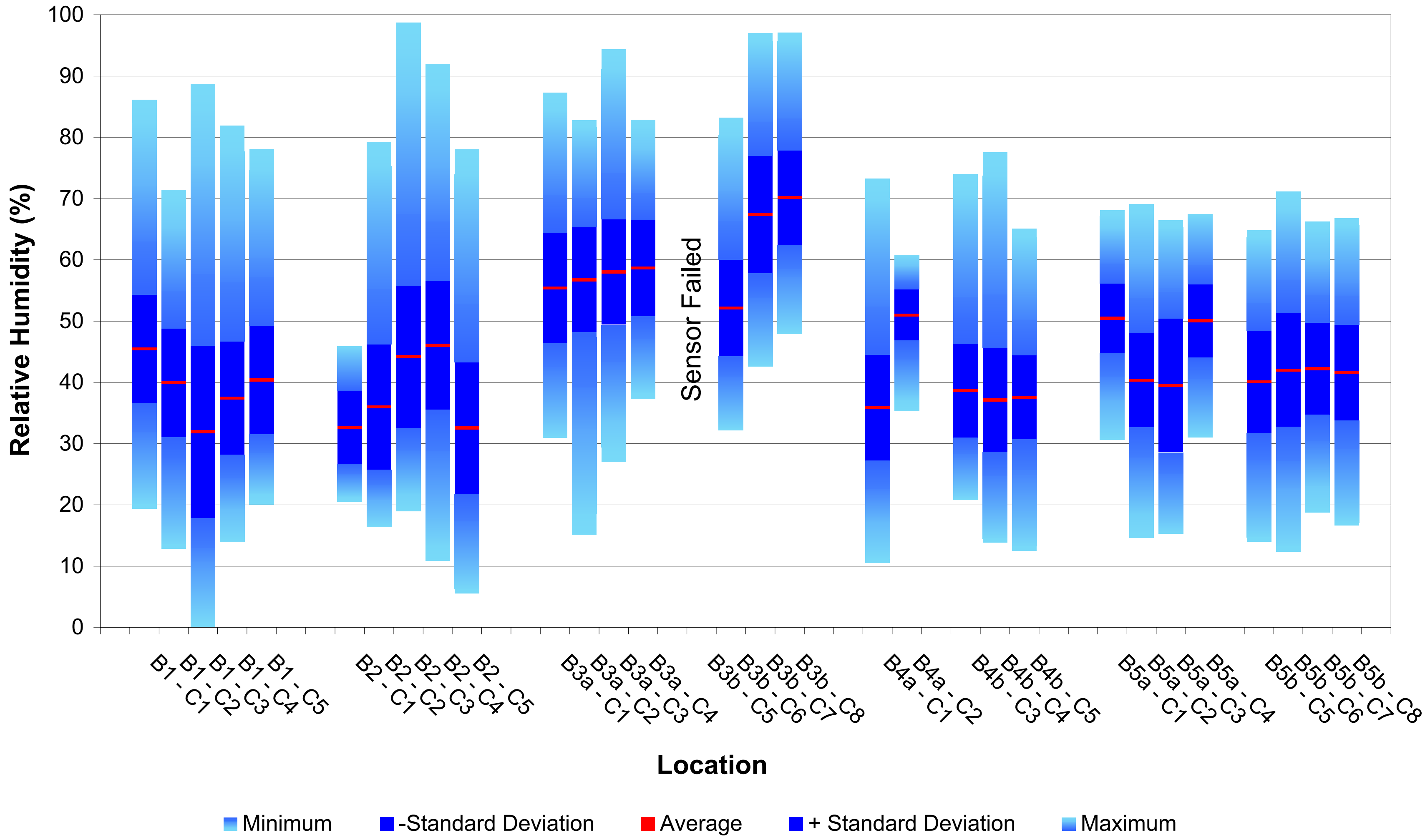
2002 Data
Relative Humidity - Exterior Surface of Interior Gypsum Board

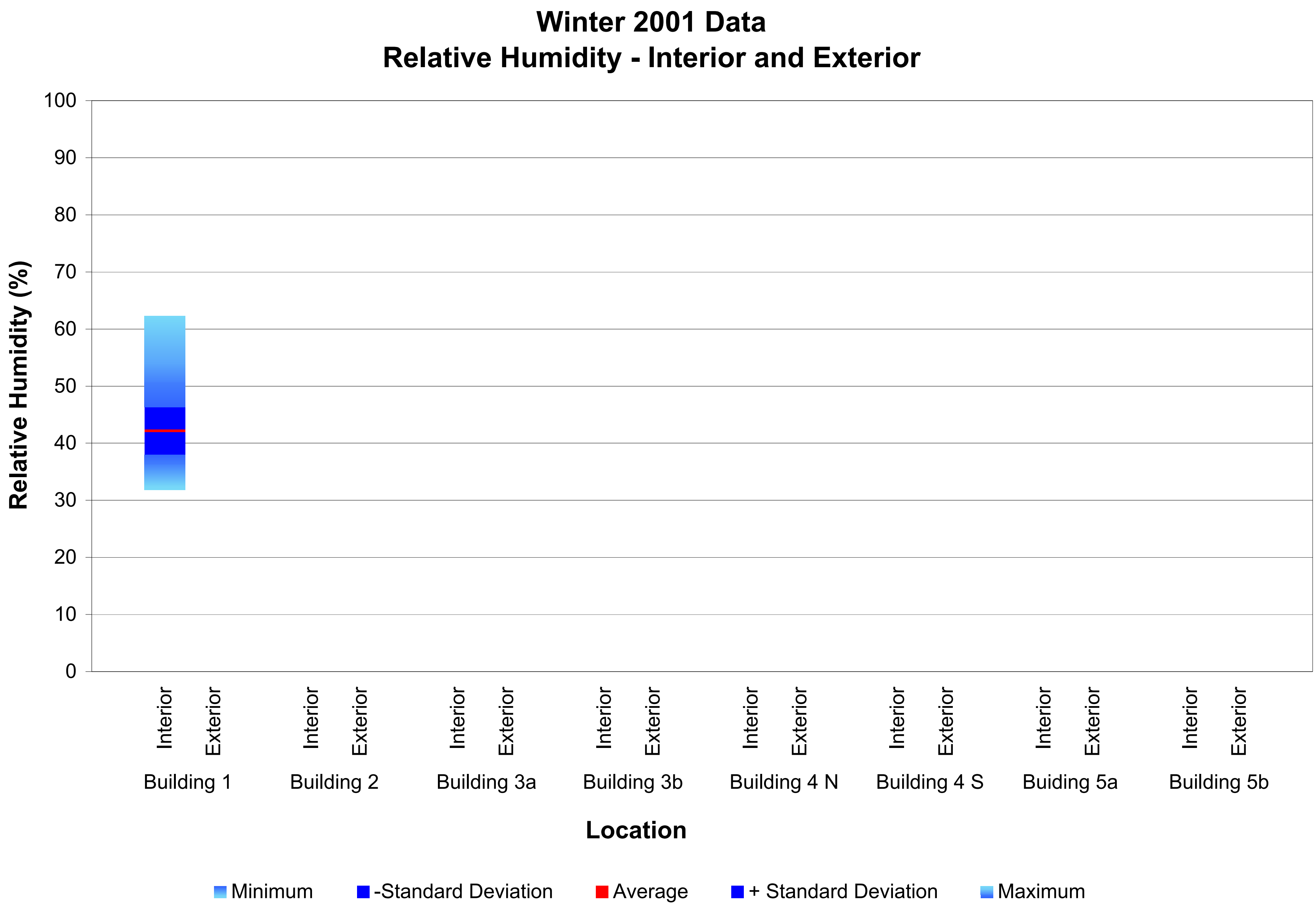


2003 Data
Relative Humidity - Exterior Surface of Interior Gypsum Board

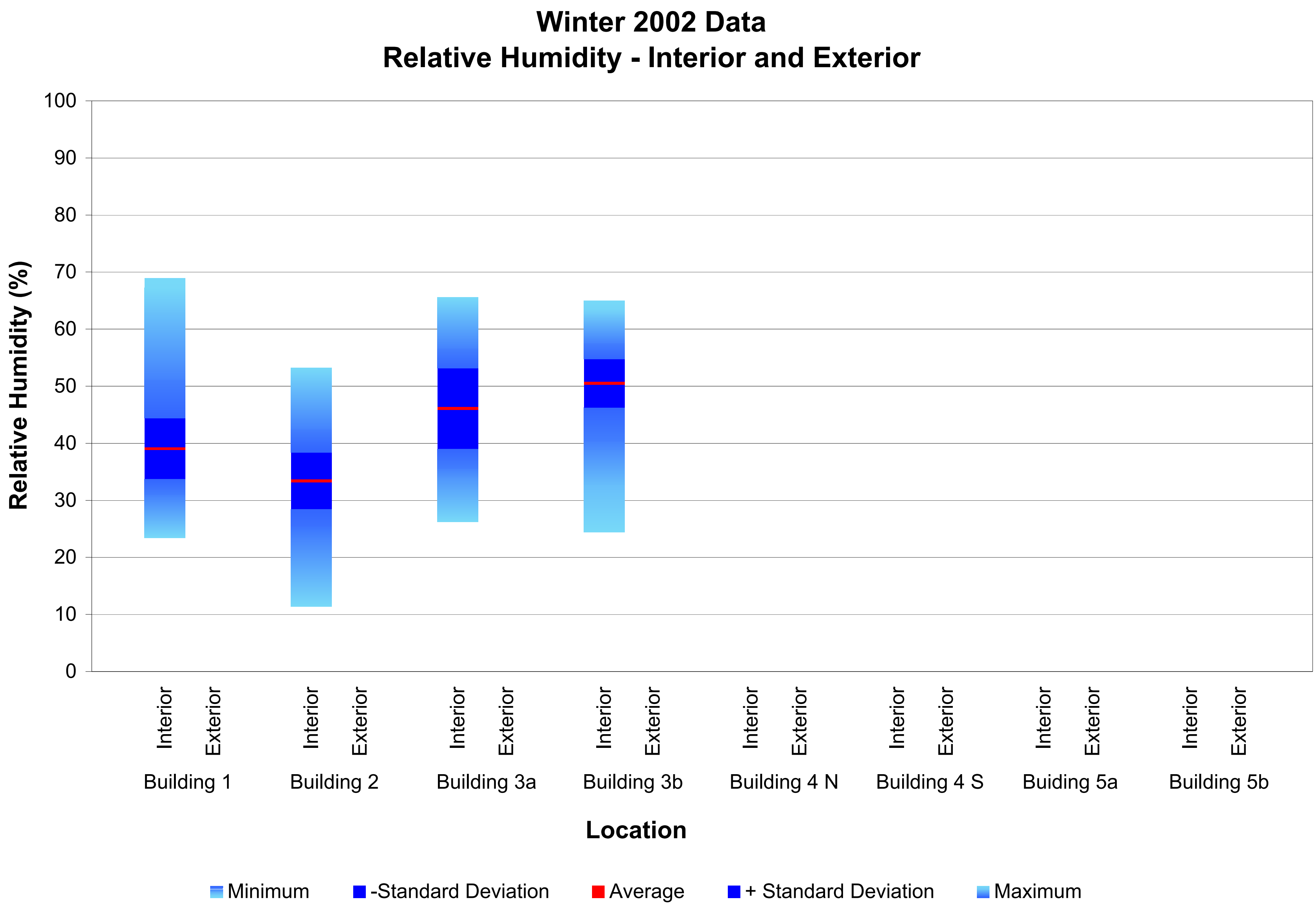


2004 Data
Relative Humidity - Exterior Surface of Interior Gypsum Board

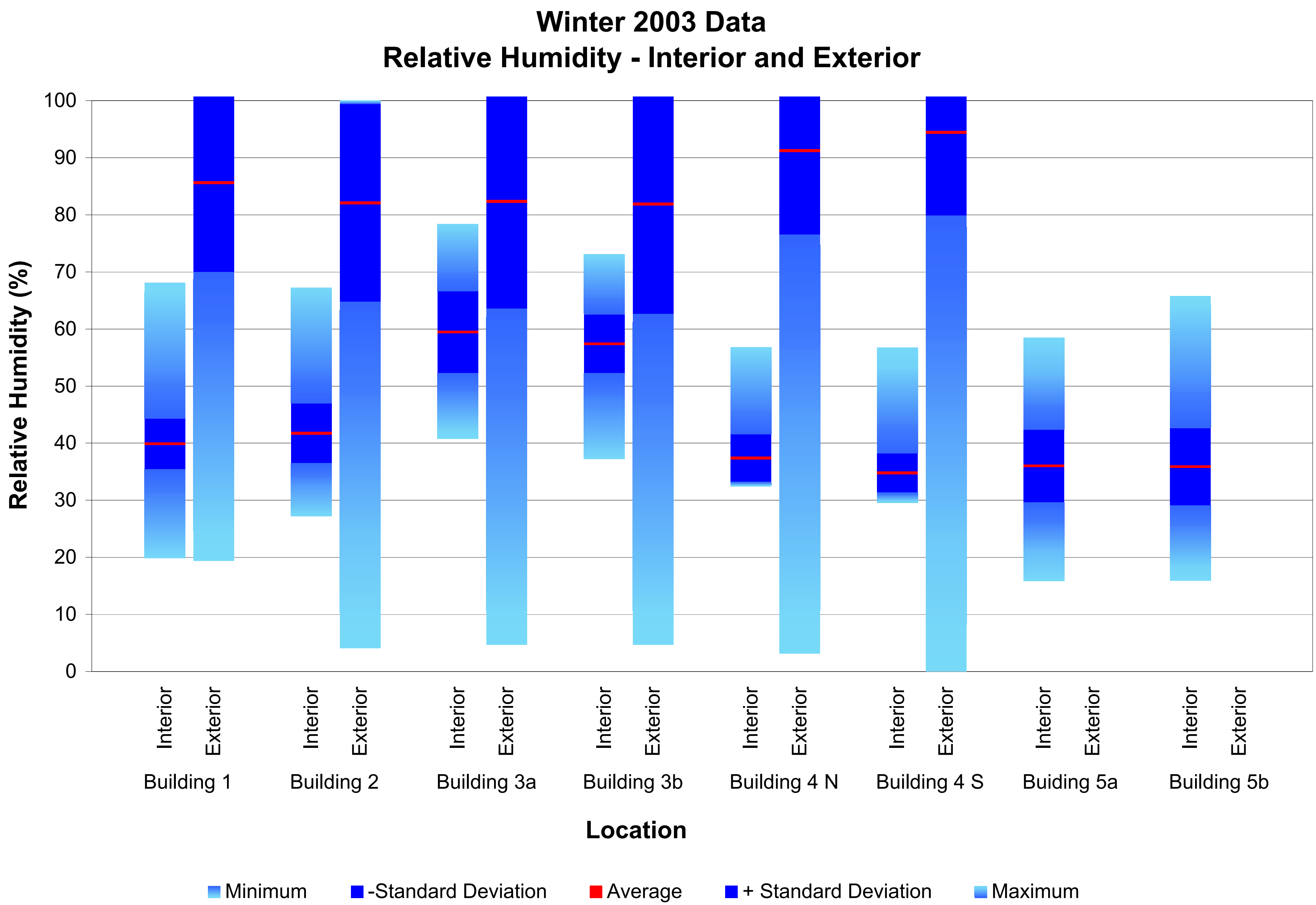


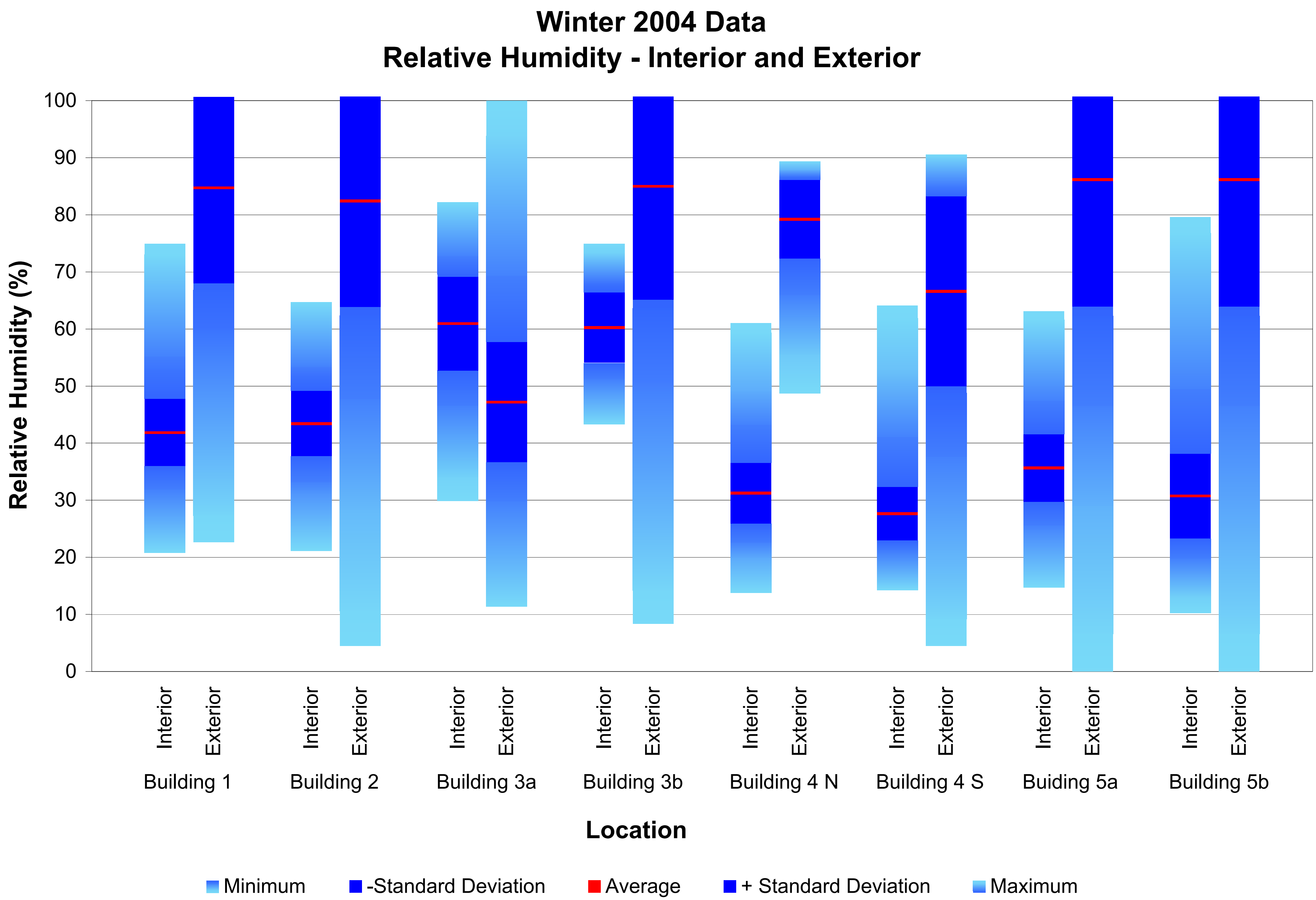


Winter 2001 Data
Relative Humidity - Interior and Exterior
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Interior
Exterior
Building 1
Building 2
Building 3a
Building 3b
Building 4 N
Building 4 S
Buiding 5a
Building 5b
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

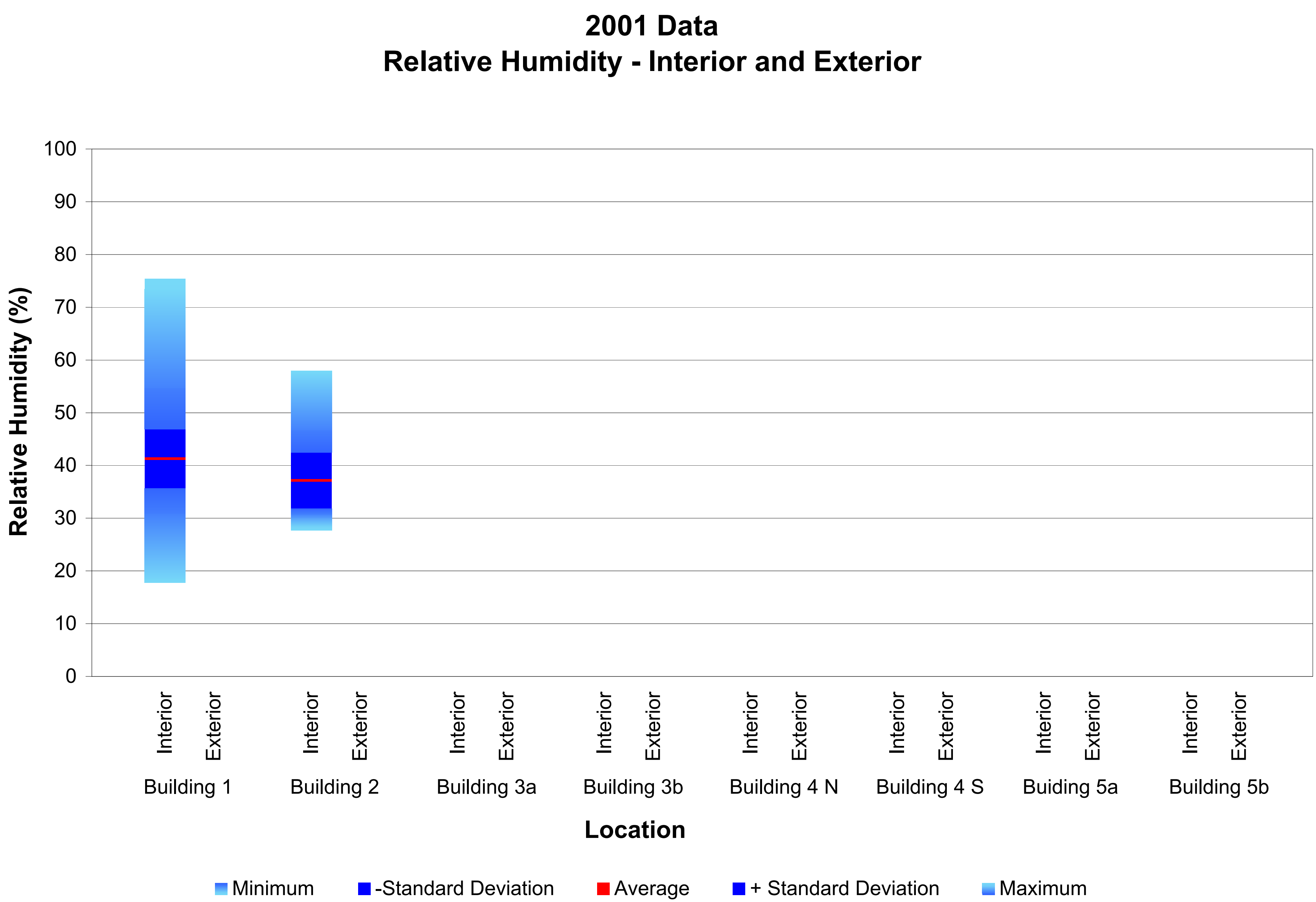


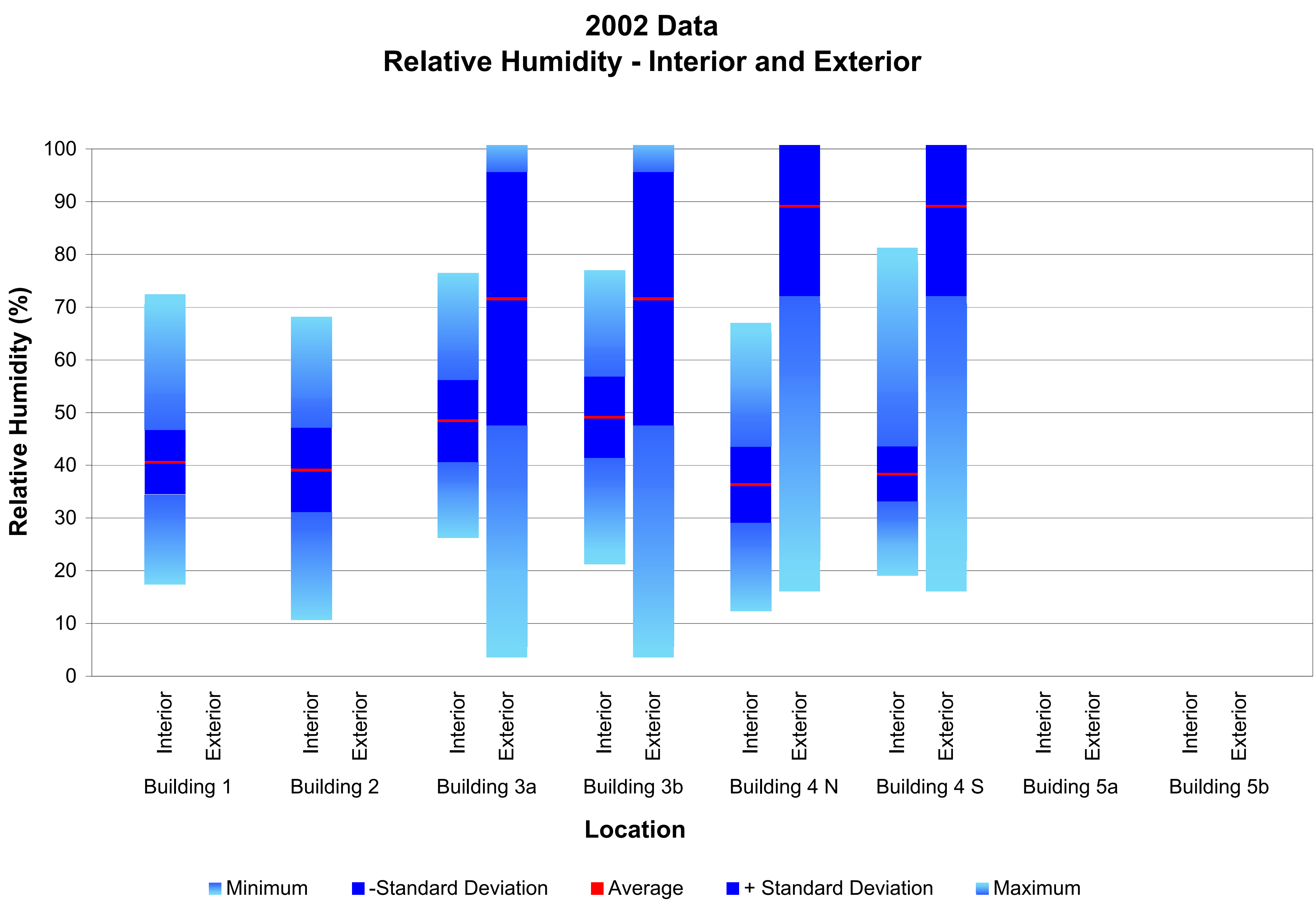
Winter 2002 Data
Relative Humidity - Interior and Exterior
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Interior
Exterior
Building 1
Building 2
Building 3a
Building 3b
Building 4 N
Building 4 S
Buiding 5a
Building 5b
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

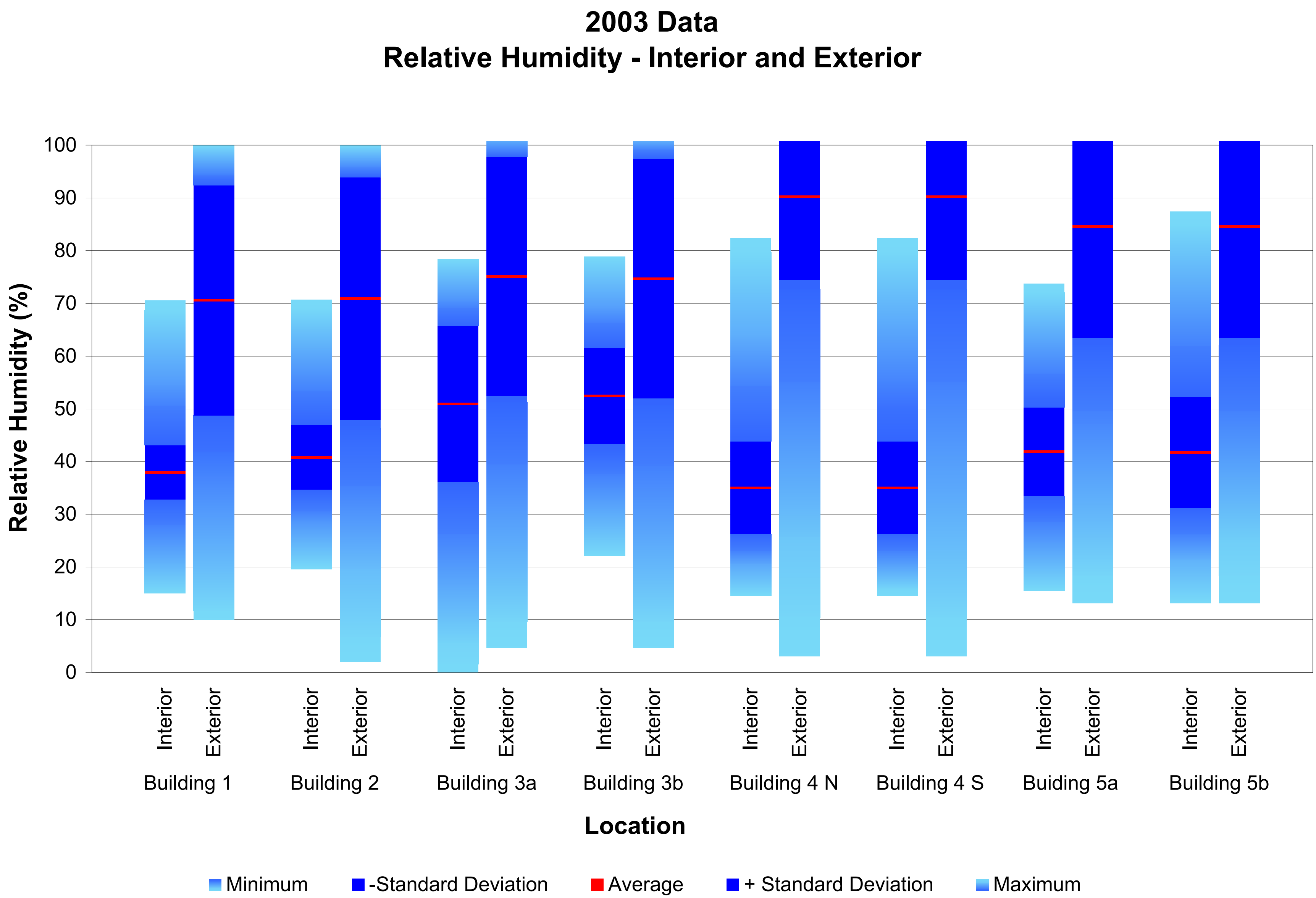

Winter 2003 Data
Relative Humidity - Interior and Exterior
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Interior
Exterior
Building 1
Building 2
Building 3a
Building 3b
Building 4 N
Building 4 S
Buiding 5a
Building 5b
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



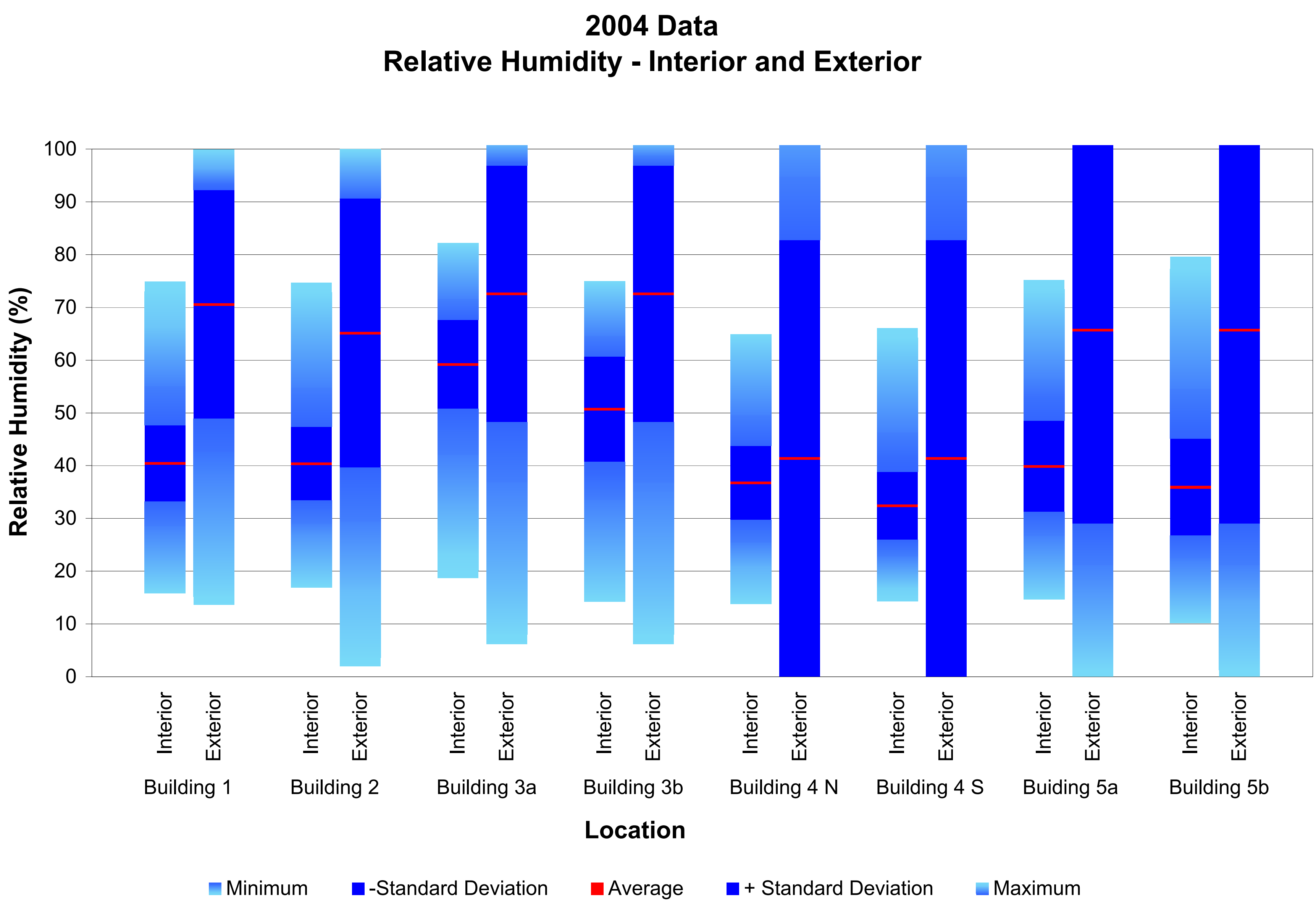
Winter 2004 Data
Relative Humidity - Interior and Exterior
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Interior
Exterior
Building 1
Building 2
Building 3a
Building 3b
Building 4 N
Building 4 S
Buiding 5a
Building 5b
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

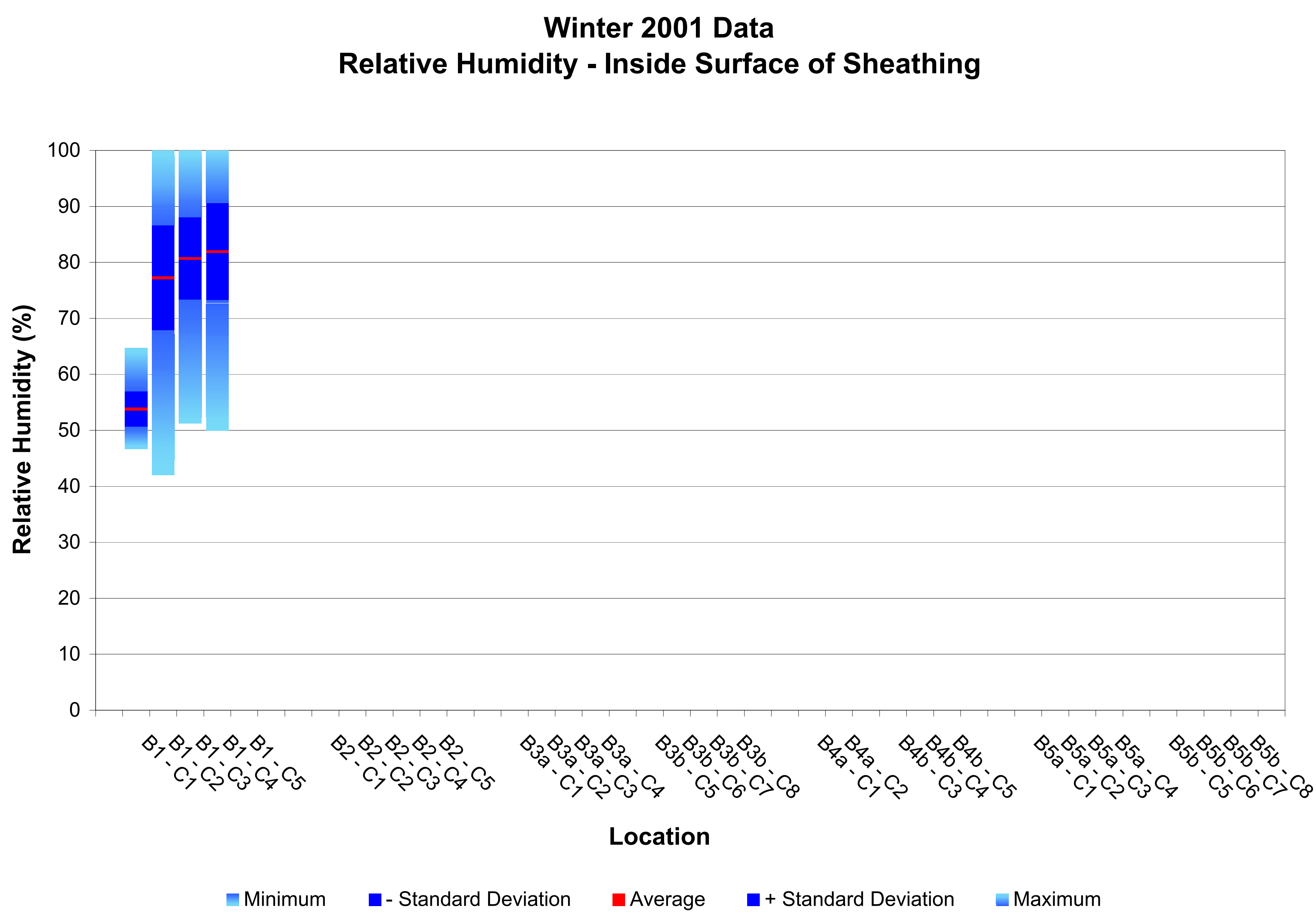

2001 Data
Relative Humidity - Interior and Exterior
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Interior
Exterior
Building 1
Building 2
Building 3a
Building 3b
Building 4 N
Building 4 S
Buiding 5a
Building 5b
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


2002 Data
Relative Humidity - Interior and Exterior
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Interior
Exterior
Building 1
Building 2
Building 3a
Building 3b
Building 4 N
Building 4 S
Buiding 5a
Building 5b
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

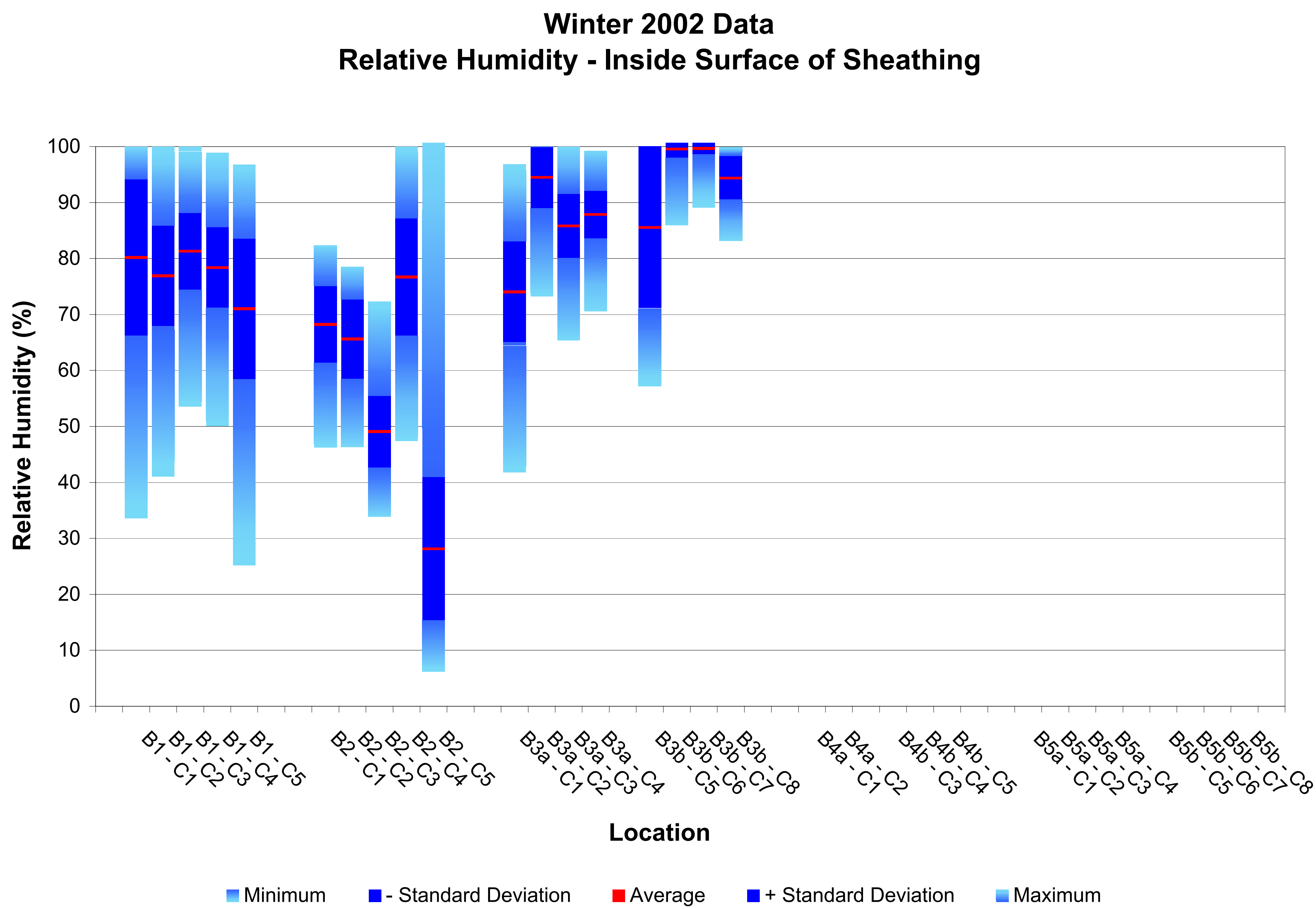


2003 Data
Relative Humidity - Interior and Exterior
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Interior
Exterior
Building 1
Building 2
Building 3a
Building 3b
Building 4 N
Building 4 S
Buiding 5a
Building 5b
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

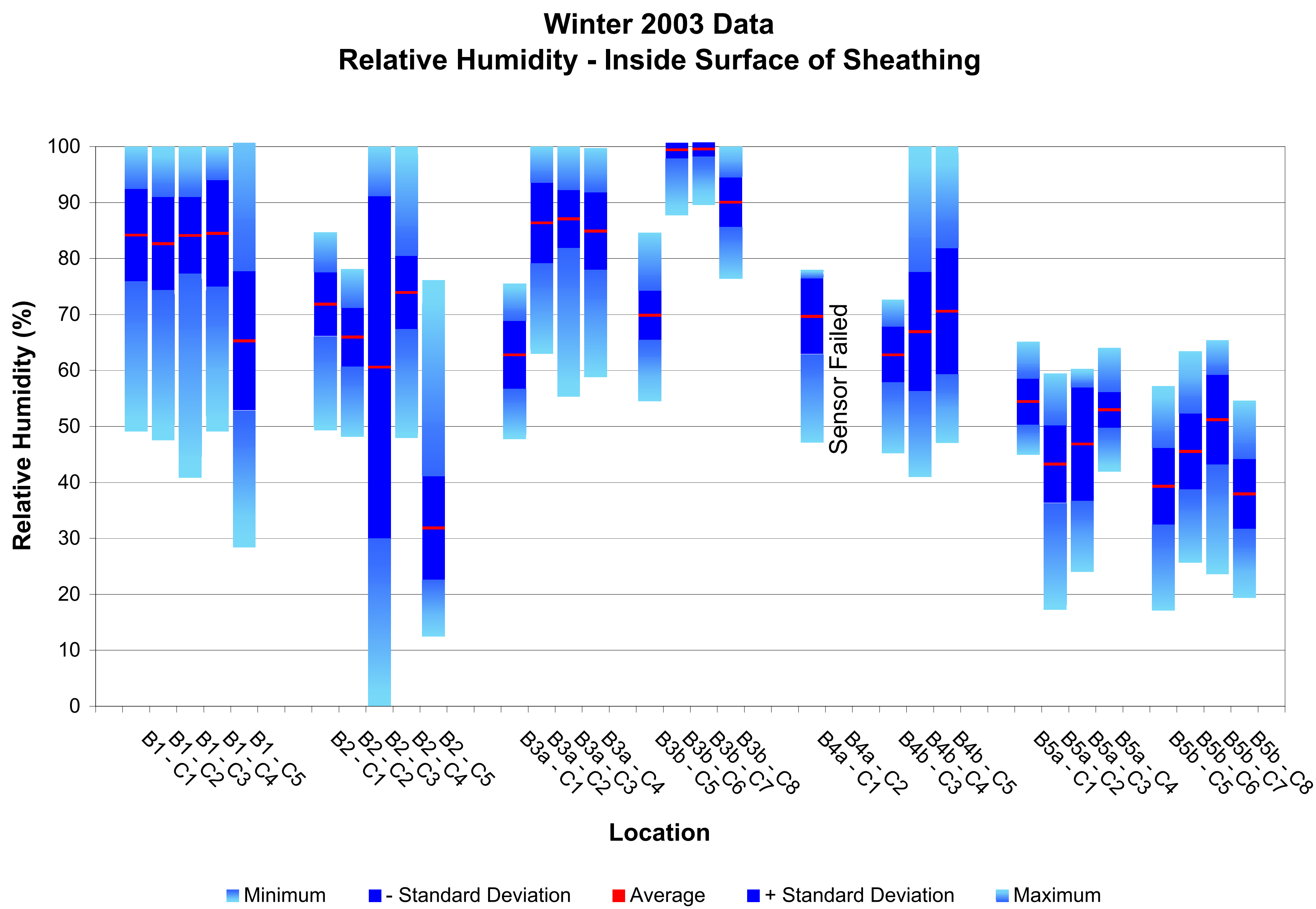

2004 Data
Relative Humidity - Interior and Exterior
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Interior
Exterior
Building 1
Building 2
Building 3a
Building 3b
Building 4 N
Building 4 S
Buiding 5a
Building 5b
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum



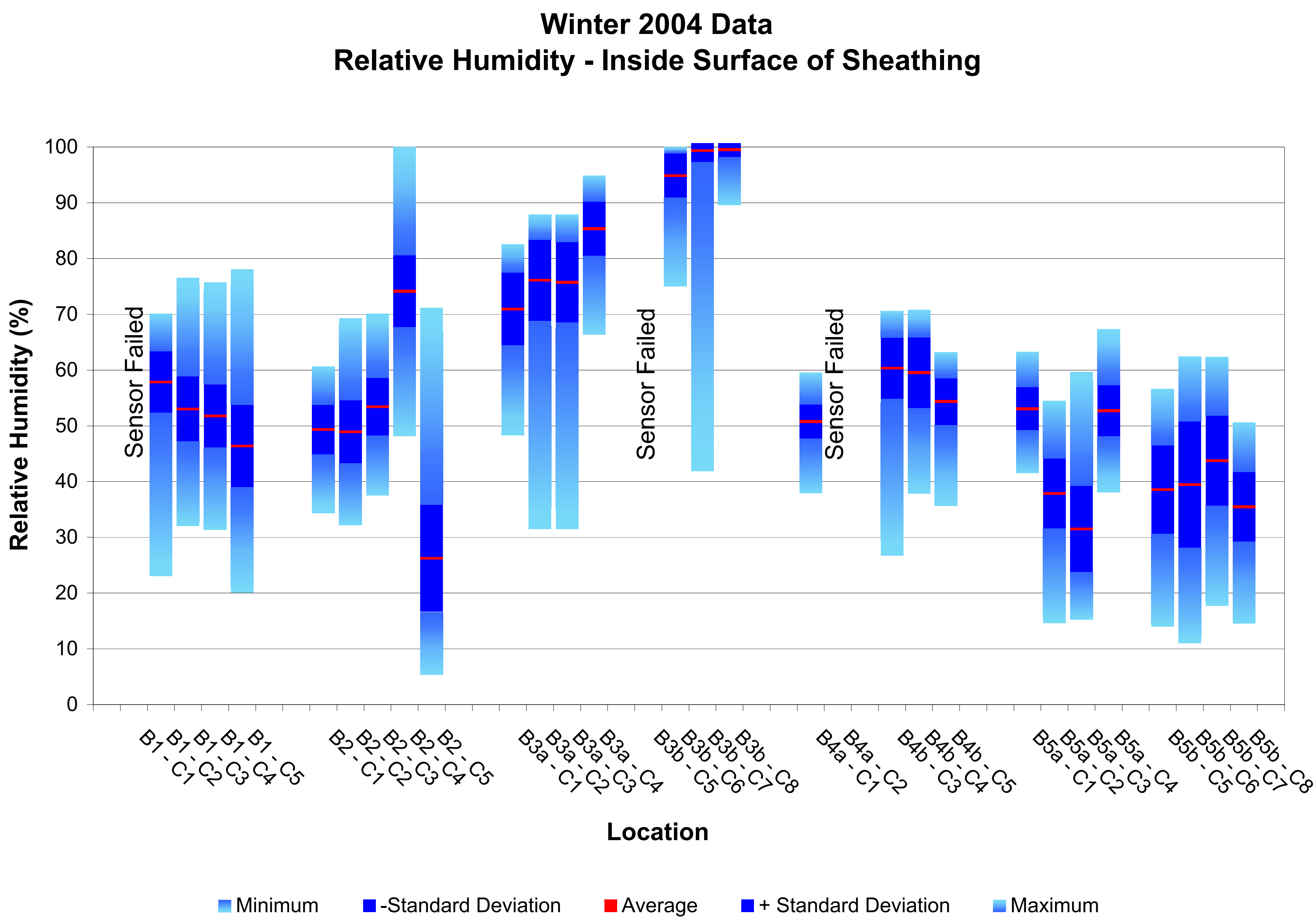
Winter 2001 Data
Relative Humidity - Inside Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

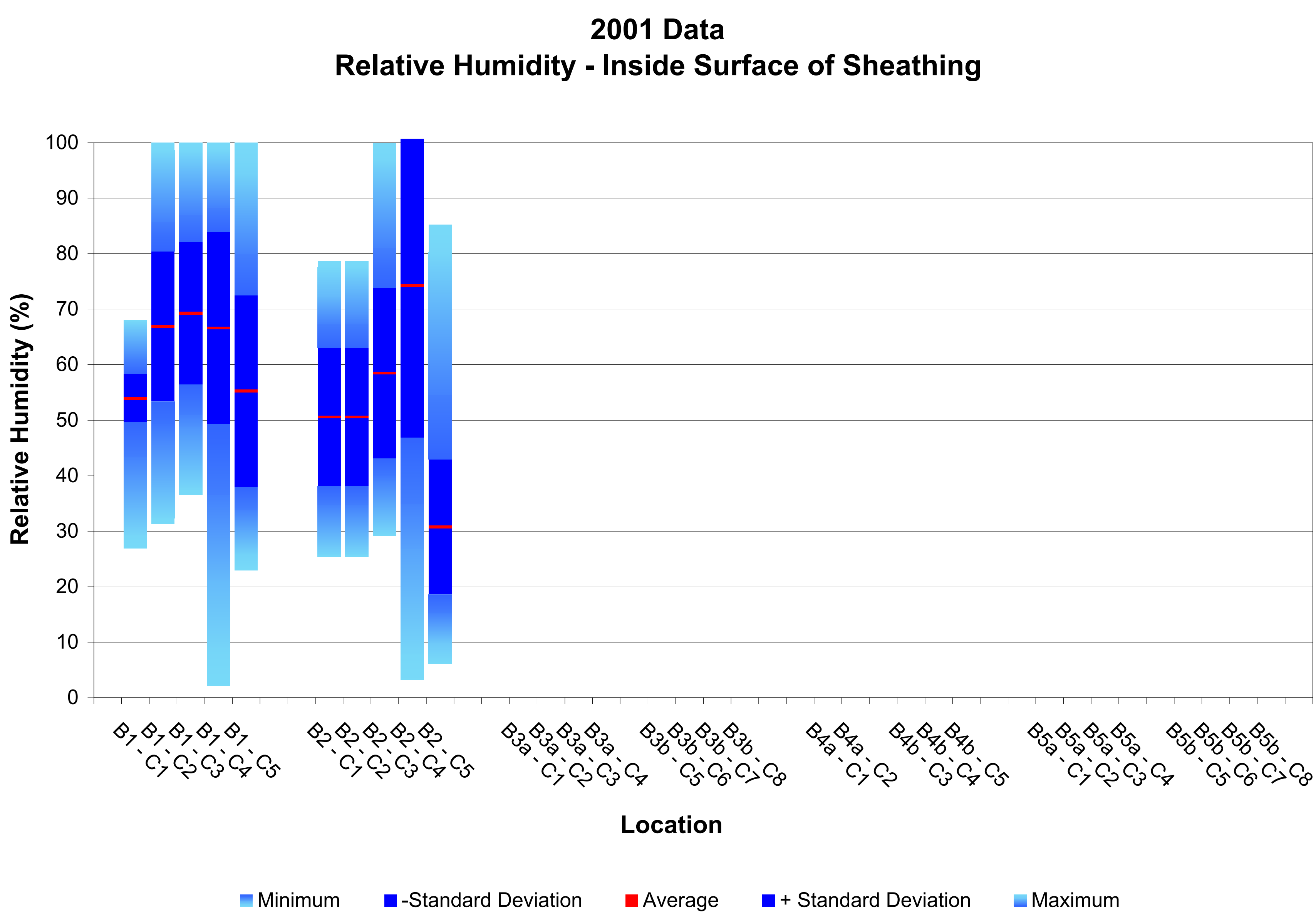


Winter 2002 Data
Relative Humidity - Inside Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

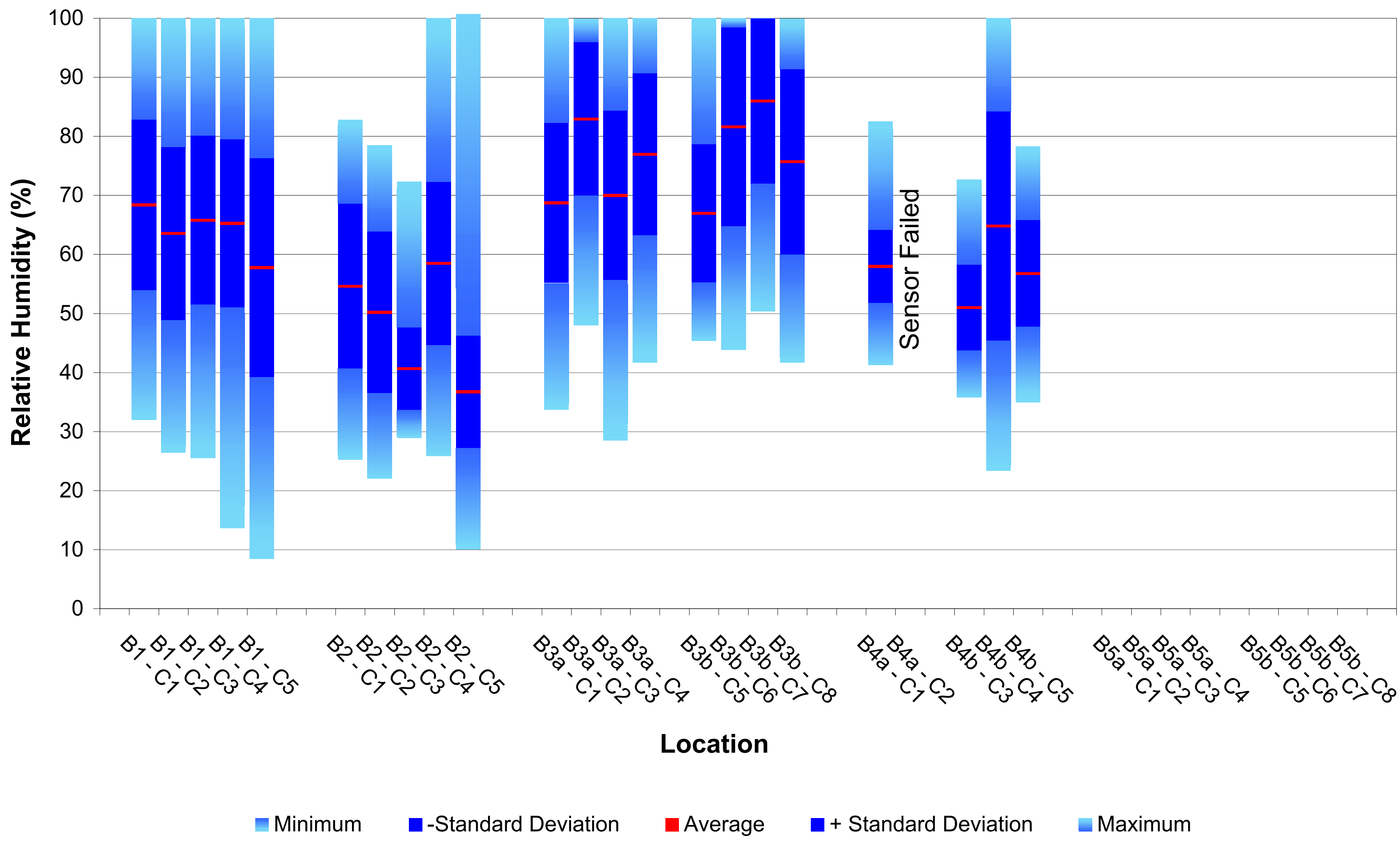


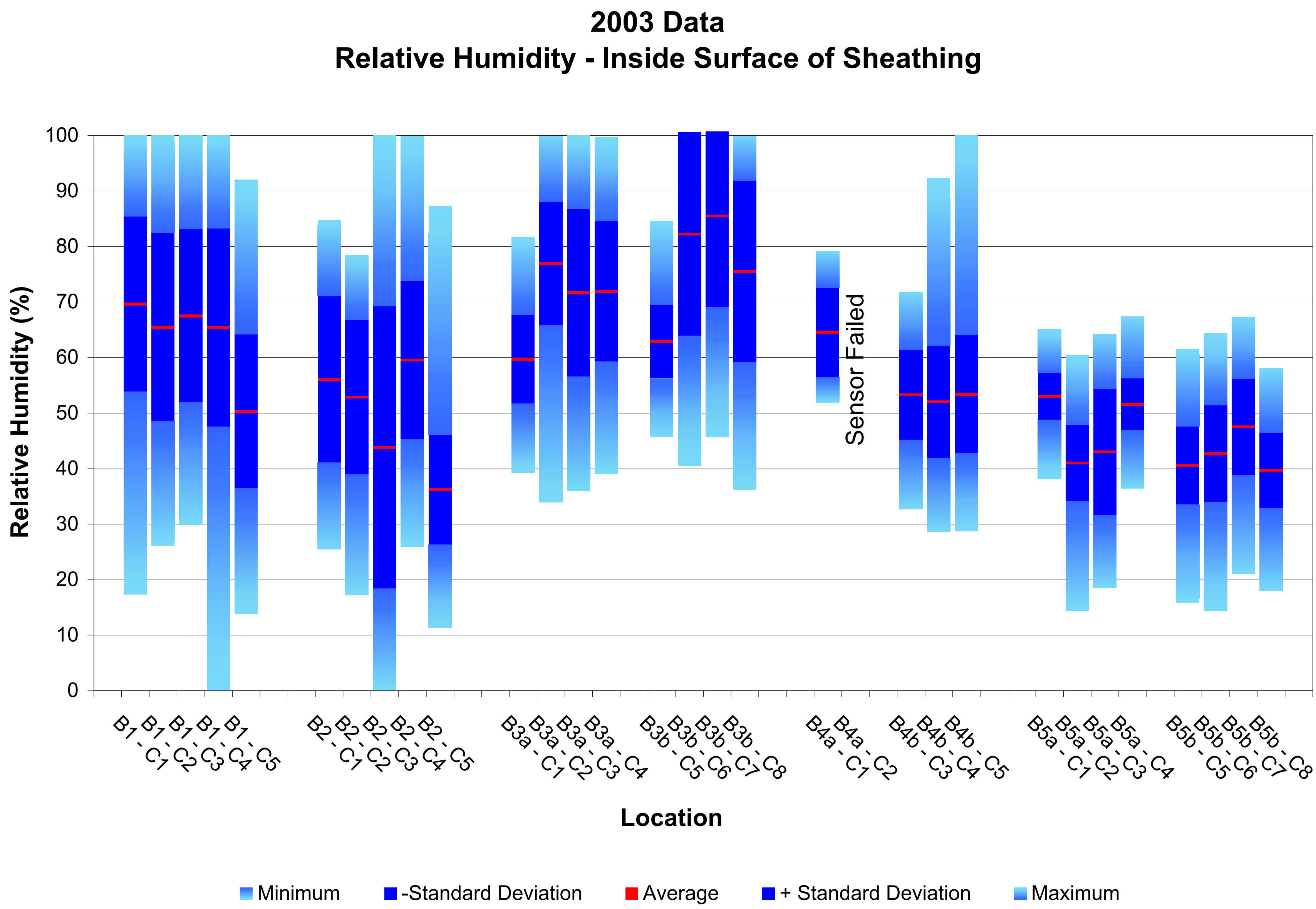
Winter 2003 Data
Relative Humidity - Inside Surface of Sheathing
Relative Humidity (%)
0
10
20
30
40
50
60
70
80
90
100
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
- Standard Deviation
Average
+ Standard Deviation
Maximum

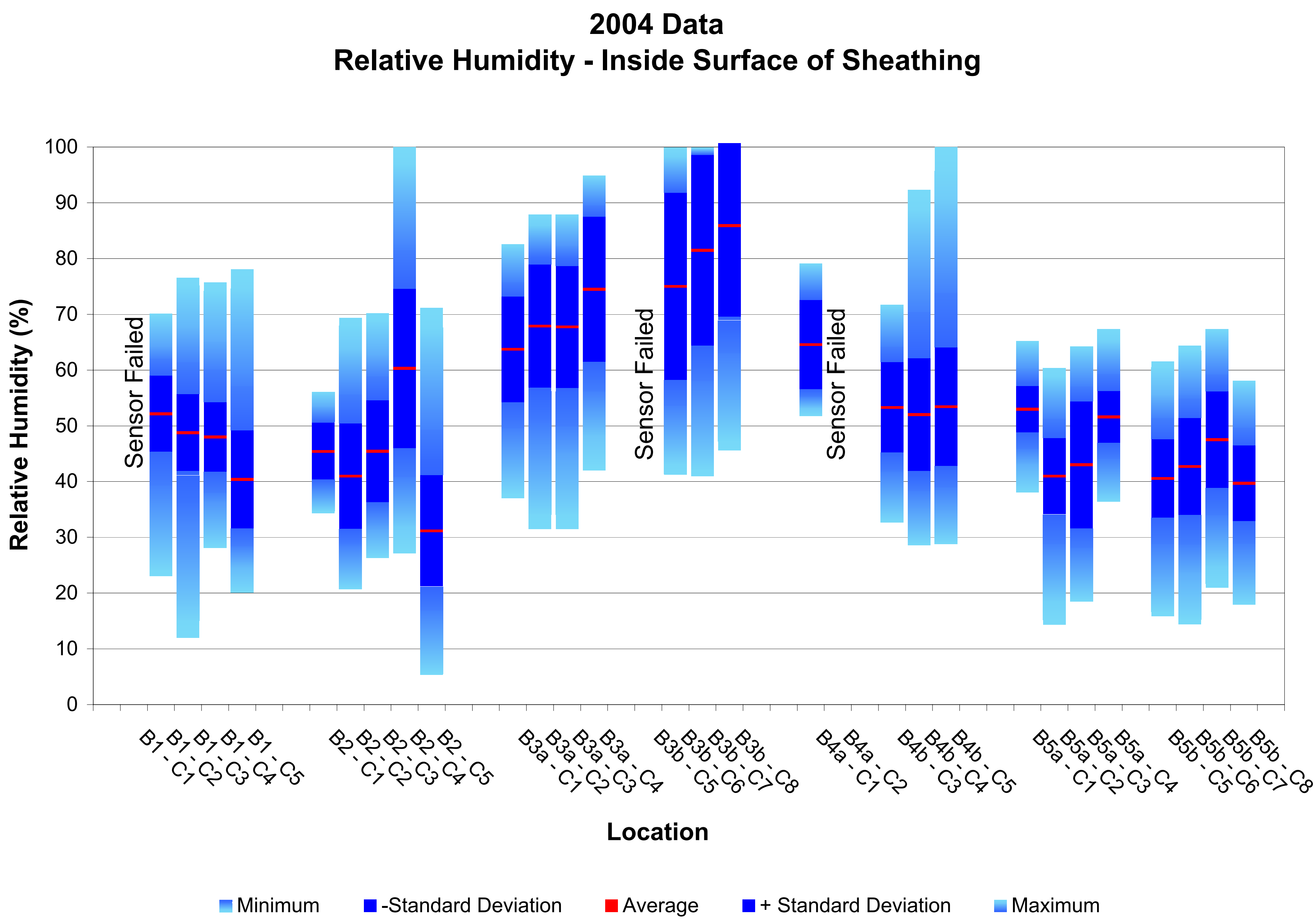

Winter 2004 Data
Relative Humidity - Inside Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Sensor Failed
Sensor Failed
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


2001 Data
Relative Humidity - Inside Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

2002 Data
Relative Humidity - Inside Surface of Sheathing




2003 Data
Relative Humidity - Inside Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum


2004 Data
Relative Humidity - Inside Surface of Sheathing
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Sensor Failed
Sensor Failed
Sensor Failed
B1 - C1
B1 - C2
B1 - C3
B1 - C4
B1 - C5
B2 - C1
B2 - C2
B2 - C3
B2 - C4
B2 - C5
B3a - C1
B3a - C2
B3a - C3
B3a - C4
B3b - C5
B3b - C6
B3b - C7
B3b - C8
B4a - C1
B4a - C2
B4b - C3
B4b - C4
B4b - C5
B5a - C1
B5a - C2
B5a - C3
B5a - C4
B5b - C5
B5b - C6
B5b - C7
B5b - C8
Location
Minimum
-Standard Deviation
Average
+ Standard Deviation
Maximum

APPENDIX G

Programs

```
;{CR10X}
;
; Station ID:
; Written:  September 12, 2001
; Programmer:  Peter Laffin
; Contact Info:  dataloggers@campbellsci.ca     (780) 454-2505
; Revision Number: N/A
; Revision Date:
; Description of Revision:
; Revised By:
; Description of Past Revisions:
;
; Station Description: RDH Building Engineering Ltd.
; Site Location:       #321 Princess Street, Vancouver, British Columbia
;
; Sensors Included: 16 RDH Wood Moisture Pin Sensors
;                   1 RMY 05103-10 Wind Speed and Wind Direction Sensor
;                   17 Honeywell Relative Humidity Sensors
;                   33 Fenwal (44033) Thermistors
;                   16 Davis Leaf Wetness Sensors
;                   4 Setra Pressure Transducers
;                   3 Tipping Bucket Rain Gauges (1 horizontal, 2 vertical)
;
; Output Description: 15 minute averages, samples and totals
;                     24 hour diagnostic info.
;
; Communication Method: Direct Connection or Telephone (COM200)
; Telephone Number: (604) ___-____
;
;
; Security Enabled: No
;
; FLAG USAGE
;
; Flag 00 - Output Flag
; Flag 01 - Unused
; Flag 02 - Unused
; Flag 03 - Unused
; Flag 04 - Program Signature
; Flag 05 - Unused
; Flag 06 - Unused
; Flag 07 - Unused
; Flag 08 - Unused
; Flag 09 - Disables Intermediate Storage
;
;

*Table 1 Program
  01: 20        Execution Interval (seconds)

; Record Program Signature on Startup and Daily at Midnight (Diagnostic)
```

321PRIN5.CSI, Table 1

```
1:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 24       Set Flag 4 Low

2:  If Flag/Port (P91)
 1: 24       Do if Flag 4 is Low
 2: 30       Then Do

     3:  Signature (P19)
      1: 1        Loc [ ProgSig   ]

     4:  Do (P86)
      1: 14       Set Flag 4 High

5:  End (P95)

; Measure Battery Voltage (Diagnostic)

6:  Batt Voltage (P10)
 1: 2        Loc [ BattVolt  ]

; Measure RMY 05103-10 Wind Speed (kmph) and Direction Sensor (degrees)

7:  Pulse (P3)
 1: 1        Reps
 2: 2        Pulse Channel 2
 3: 21       Low Level AC, Output Hz
 4: 3        Loc [ WSpdkmph  ]
 5: 0.3528   Mult
 6: 0        Offset

8:  Excite-Delay (SE) (P4)
 1: 1        Reps
 2: 5        2500 mV Slow Range
 3: 9        SE Channel
 4: 3        Excite all reps w/Exchan 3
 5: 2        Delay (units 0.01 sec)
 6: 2500     mV Excitation
 7: 4        Loc [ WDirDeg   ]
 8: 0.142    Mult
 9: 0        Offset

; Measure Horizontal Tipping Bucket Rain Gauge (mm)

9:  Pulse (P3)
 1: 1        Reps
 2: 6        Control Port 6 (switch closure only)
 3: 2        Switch Closure, All Counts
 4: 5        Loc [ RainH1mm  ]
 5: 0.2      Mult
 6: 0        Offset

; Measure (2) Vertical Tipping Bucket Rain Gauges (kg/m^2)
```

```
10:  Pulse (P3)
 1: 2        Reps
 2: 7        Control Port 7 (switch closure only)
 3: 2        Switch Closure, All Counts
 4: 6        Loc [ RainV1kgm ]
 5: 0.05     Mult
 6: 0.0      Offset

; Measure (4) Setra Pressure Transducers (inches of Water Column) on Multiplexer 1

11:  Do (P86)
 1: 43       Set Port 3 High

12:  Beginning of Loop (P87)
 1: 0        Delay
 2: 12       Loop Count

     13:  Do (P86)
      1: 74       Pulse Port 4

     14:  Excitation with Delay (P22)
      1: 1        Ex Channel
      2: 0        Delay W/Ex (units = 0.01 sec)
      3: 1        Delay After Ex (units = 0.01 sec)
      4: 0        mV Excitation

15:  End (P95)

16:  Beginning of Loop (P87)
 1: 0        Delay
 2: 4        Loop Count

     17:  Do (P86)
      1: 74       Pulse Port 4

     18:  Excitation with Delay (P22)
      1: 1        Ex Channel
      2: 0        Delay W/Ex (units = 0.01 sec)
      3: 1        Delay After Ex (units = 0.01 sec)
      4: 0        mV Excitation

     19:  Volt (Diff) (P2)
      1: 1        Reps
      2: 5        2500 mV Slow Range
      3: 3        DIFF Channel
      4: 8     -- Loc [ Pres1inWC ]
      5: .0996    Mult
      6: -124.5   Offset

20:  End (P95)
```

```
21:  Do (P86)
 1: 53       Set Port 3 Low

; Set condition for 15 minute measurement

22:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 15       Interval (same units as above)
 3: 30       Then Do

; Measure (17) Honeywell RH Sensors (%RH)
; & (16) DavisLeaf Wetness Sensors (?) on Multiplexer 1

     23:  Do (P86)
      1: 43       Set Port 3 High

     24:  Beginning of Loop (P87)
      1: 0        Delay
      2: 6        Loop Count

          25:  Step Loop Index (P90)
           1: 3        Step

          26:  Do (P86)
           1: 74       Pulse Port 4

          27:  Excitation with Delay (P22)
           1: 1        Ex Channel
           2: 0        Delay W/Ex (units = 0.01 sec)
           3: 1        Delay After Ex (units = 0.01 sec)
           4: 0        mV Excitation

          28:  Settling Time (P132)
           1: 50       Time (units = msec.):

          29:  Volt (SE) (P1)
           1: 3        Reps
           2: 5        2500 mV Slow Range
           3: 3        SE Channel
           4: 12    -- Loc [ HWPcntR_1 ]
           5: .058479  Mult
           6: -24.265  Offset

          30:  Settling Time (P132)
           1: 0.450    Time (units = msec.)

     31:  End (P95)

     32:  Beginning of Loop (P87)
      1: 0        Delay
      2: 6        Loop Count

          33:  Step Loop Index (P90)
           1: 3        Step
```

```
          34:  Do (P86)
           1: 74       Pulse Port 4

          35:  Excitation with Delay (P22)
           1: 1        Ex Channel
           2: 0        Delay W/Ex (units = 0.01 sec)
           3: 1        Delay After Ex (units = 0.01 sec)
           4: 0        mV Excitation

          36:  Volt (SE) (P1)
           1: 3        Reps
           2: 5        2500 mV Slow Range
           3: 3        SE Channel
           4: 30    -- Loc [ DvLeaf_1  ]
           5: 2.5      Mult
           6: 100      Offset

     37:  End (P95)

     38:  Do (P86)
      1: 53       Set Port 3 Low

; Measure Fenwal Thermistors (32) & RDH Moisture Pin Sensors (16) on Multiplexer 2

     39:  Do (P86)
      1: 41       Set Port 1 High

     40:  Beginning of Loop (P87)
      1: 0        Delay
      2: 16       Loop Count

          41:  Do (P86)
           1: 72       Pulse Port 2

          42:  Excitation with Delay (P22)
           1: 1        Ex Channel
           2: 0        Delay W/Ex (units = 0.01 sec)
           3: 1        Delay After Ex (units = 0.01 sec)
           4: 0        mV Excitation

; Measure Thermistors 1 through 16 (all L1 Thermistors)

          43:  AC Half Bridge (P5)
           1: 1        Reps
           2: 4        250 mV Slow Range
           3: 1        SE Channel
           4: 1        Excite all reps w/Exchan 1
           5: 690      mV Excitation
           6: 48    -- Loc [ FThermC_1 ]
           7: 10       Mult
           8: 0        Offset

; Measure Thermistors 17 through 32 (all H2 Thermistors)
```

```
          44:  AC Half Bridge (P5)
           1: 1        Reps
           2: 4        250 mV Slow Range
           3: 2        SE Channel
           4: 1        Excite all reps w/Exchan 1
           5: 690      mV Excitation
           6: 64    -- Loc [ FTherm_17 ]
           7: 10       Mult
           8: 0        Offset

; Measure 16 Moisture Pins

; Increase the Measurement Settling Time

          45:  Settling Time (P132)
           1: 50       Time (units = msec.)

; Take the measurement to get the value of X (Measured Voltage):

          46:  AC Half Bridge (P5)
           1: 1        Reps
           2: 20       Auto 60 Hz Rejection Range (OS>1.9)
           3: 8        SE Channel
           4: 2        Excite all reps w/Exchan 2
           5: 2500     mV Excitation
           6: 114   -- Loc [ RDHRxmV_1 ]
           7: 1        Mult
           8: 0        Offset

; Reset the Measurement Settling Time

          47:  Settling Time (P132)
           1: 0.450    Time (units = msec.)

; Calculation: RVariable = RPickoff * ((1 / Measured Voltage) -1)

; RPickoff = 10kohm

          48:  Z=F (P30)
           1: 10       F
           2: 0        Exponent of 10
           3: 162      Z Loc [ RpKohm    ]

          49:  Z=1/X (P42)
           1: 114   -- X Loc [ RDHRxmV_1 ]
           2: 163      Z Loc [ Rvkohm    ]

          50:  Z=X+F (P34)
           1: 163      X Loc [ Rvkohm    ]
           2: -1       F
           3: 163      Z Loc [ Rvkohm    ]
```

```
          51:  Z=X*Y (P36)
           1: 162      X Loc [ RpKohm    ]
           2: 163      Y Loc [ Rvkohm    ]
           3: 163      Z Loc [ Rvkohm    ]

; Transform RVariable from kohm to Mohm

          52:  Z=X*F (P37)
           1: 163      X Loc [ Rvkohm    ]
           2: .001     F
           3: 146   -- Z Loc [ RVMohm_1  ]

     53:  End (P95)

     54:  Do (P86)
      1: 51       Set Port 1 Low

; Measure 33rd Thermistor

     55:  AC Half Bridge (P5)
      1: 1        Reps
      2: 4        250 mV Slow Range
      3: 7        SE Channel
      4: 1        Excite all reps w/Exchan 1
      5: 690      mV Excitation
      6: 113      Loc [ FTCLin_33 ]
      7: 10       Mult
      8: 0        Offset

; Calculate Linearization for 33 Thermistors

     56:  Beginning of Loop (P87)
      1: 0        Delay
      2: 33       Loop Count


          57:  If (X<=>F) (P89)
           1: 48    -- X Loc [ FThermC_1 ]
           2: 4        <
           3: 0.46775  F
           4: 30       Then Do

               58:  Polynomial (P55)
                1: 1        Reps
                2: 48    -- X Loc [ FThermC_1 ]
                3: 81    -- F(X) Loc [ FTCLine_1 ]
                4: -49.446  C0
                5: 451.44   C1
                6: -2165.5  C2
                7: 6566.4   C3
                8: -10380   C4
                9: 6540.5   C5

          59:  Else (P94)
```

```
                60:  Polynomial (P55)
                 1: 1        Reps
                 2: 48    -- X Loc [ FThermC_1 ]
                 3: 81    -- F(X) Loc [ FTCLine_1 ]
                 4: -16.825  C0
                 5: 73.176   C1
                 6: -42.233  C2
                 7: 16.397   C3
                 8: -3.3270  C4
                 9: 0.27144  C5

           61:  End (P95)

      62:  End (P95)

; RDH Moisture Pin Threshold Calculation (1000 Meg-ohms)

      63:  Beginning of Loop (P87)
       1: 0        Delay
       2: 16       Loop Count

           64:  Z=F (P30)
            1: 1.0001   F
            2: 5     -- Exponent of 10
            3: 164      Z Loc [ RDHThresh ]


           65:  If (X<=>Y) (P88)
            1: 114   -- X Loc [ RDHRxmV_1 ]
            2: 4        <
            3: 164      Y Loc [ RDHThresh ]
            4: 30       Then Do


                66:  Z=F (P30)
                 1: 1000     F
                 2: 0        Exponent of 10
                 3: 146   -- Z Loc [ RVMohm_1  ]

           67:  End (P95)

      68:  End (P95)

69:  End (P95)

; Output (15 Minute Data and Daily Diagnostic)

70:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 15       Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)
```

```
71:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 15       Array ID

72:  Real Time (P77)
 1: 1220     Year,Day,Hour/Minute (midnight = 2400)

73:  Wind Vector (P69)
 1: 1        Reps
 2: 0        Samples per Sub-Interval
 3: 0        S, é1, & å(é1) Polar
 4: 3        Wind Speed/East Loc [ WSpdkmph  ]
 5: 4        Wind Direction/North Loc [ WDirDeg   ]

74:  Totalize (P72)
 1: 3        Reps
 2: 5        Loc [ RainH1mm  ]

75:  Average (P71)
 1: 4        Reps
 2: 8        Loc [ Pres1inWC ]

76:  Sample (P70)
 1: 17       Reps
 2: 12       Loc [ HWPcntR_1 ]

77:  Sample (P70)
 1: 16       Reps
 2: 30       Loc [ DvLeaf_1  ]

78:  Sample (P70)
 1: 33       Reps
 2: 81       Loc [ FTCLine_1 ]

79:  Sample (P70)
 1: 16       Reps
 2: 146      Loc [ RVMohm_1  ]

80:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

81:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 411      Array ID

82:  Real Time (P77)
 1: 1200     Year,Day (midnight = 2400)

83:  Sample (P70)
 1: 1        Reps
 2: 1        Loc [ ProgSig   ]
```

```
84:  Maximum (P73)
 1: 1        Reps
 2: 0        Value Only
 3: 2        Loc [ BattVolt  ]

85:  Minimum (P74)
 1: 1        Reps
 2: 0        Value Only
 3: 2        Loc [ BattVolt  ]

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

321PRIN5.CSI, Input Locations

Addr	Name	Flags	# Reads	# Writes	Blocks		
1	[ProgSig]	RW--	1	1	-----	------	---
2	[BattVolt]	RW--	2	1	-----	------	---
3	[WSpdkmph]	RW--	1	1	-----	------	---
4	[WDirDeg]	RW--	1	1	-----	------	---
5	[RainH1mm]	RW--	1	1	Start	------	---
6	[RainV1kgm]	RW--	1	1	Start	------	---
7	[RainV2kgm]	RW--	1	1	-----	------	End
8	[Pres1inWC]	RW--	1	1	-----	------	---
9	[Pres2inWC]	R---	1	0	-----	------	---
10	[Pres3inWC]	R---	1	0	-----	------	---
11	[Pres4inWC]	R---	1	0	-----	------	---
12	[HWPcntR_1]	RWM-	1	4	Start	------	---
13	[HWPcntR_2]	RWM-	1	1	-----	Member	---
14	[HWPcntR_3]	RWM-	1	1	-----	------	End
15	[HWPcntR_4]	R-M-	1	0	-----	------	---
16	[HWPcntR_5]	R-M-	1	0	-----	------	---
17	[HWPcntR_6]	R-M-	1	0	-----	------	---
18	[HWPcntR_7]	R-M-	1	0	-----	------	---
19	[HWPcntR_8]	R-M-	1	0	-----	------	---
20	[HWPcntR_9]	R-M-	1	0	-----	------	---
21	[HWPcnt_10]	R-M-	1	0	-----	------	---
22	[HWPcnt_11]	R-M-	1	0	-----	------	---
23	[HWPcnt_12]	R-M-	1	0	-----	------	---
24	[HWPcnt_13]	R-M-	1	0	-----	------	---
25	[HWPcnt_14]	R-M-	1	0	-----	------	---
26	[HWPcnt_15]	R-M-	1	0	-----	------	---
27	[HWPcnt_16]	R-M-	1	0	-----	------	---
28	[HWPcnt_17]	R-M-	1	0	-----	------	---
29	[HWPcnt_18]	--M-	0	0	-----	------	---
30	[DvLeaf_1]	RWM-	1	1	Start	------	---
31	[DvLeaf_2]	RWM-	1	1	-----	Member	---
32	[DvLeaf_3]	RWM-	1	1	-----	------	End
33	[DvLeaf_4]	R-M-	1	0	-----	------	---
34	[DvLeaf_5]	R-M-	1	0	-----	------	---
35	[DvLeaf_6]	R-M-	1	0	-----	------	---
36	[DvLeaf_7]	R-M-	1	0	-----	------	---
37	[DvLeaf_8]	R-M-	1	0	-----	------	---
38	[DvLeaf_9]	R-M-	1	0	-----	------	---
39	[DvLeaf_10]	R-M-	1	0	-----	------	---
40	[DvLeaf_11]	R-M-	1	0	-----	------	---
41	[DvLeaf_12]	R-M-	1	0	-----	------	---
42	[DvLeaf_13]	R-M-	1	0	-----	------	---
43	[DvLeaf_14]	R-M-	1	0	-----	------	---
44	[DvLeaf_15]	R-M-	1	0	-----	------	---
45	[DvLeaf_16]	R-M-	1	0	-----	------	---
46	[DvLeaf_17]	--M-	0	0	-----	------	---
47	[DvLeaf_18]	--M-	0	0	-----	------	---
48	[FThermC_1]	RWM-	3	1	-----	------	---
49	[FThermC_2]	--M-	0	0	-----	------	---
50	[FThermC_3]	--M-	0	0	-----	------	---
51	[FThermC_4]	--M-	0	0	-----	------	---
52	[FThermC_5]	--M-	0	0	-----	------	---

53	[FThermC_6]	--M-	0	0	-----	------	---
54	[FThermC_7]	--M-	0	0	-----	------	---
55	[FThermC_8]	--M-	0	0	-----	------	---
56	[FThermC_9]	--M-	0	0	-----	------	---
57	[FTherm_10]	--M-	0	0	-----	------	---
58	[FTherm_11]	--M-	0	0	-----	------	---
59	[FTherm_12]	--M-	0	0	-----	------	---
60	[FTherm_13]	--M-	0	0	-----	------	---
61	[FTherm_14]	--M-	0	0	-----	------	---
62	[FTherm_15]	--M-	0	0	-----	------	---
63	[FTherm_16]	--M-	0	0	-----	------	---
64	[FTherm_17]	-WM-	0	1	-----	------	---
65	[FTherm_18]	--M-	0	0	-----	------	---
66	[FTherm_19]	--M-	0	0	-----	------	---
67	[FTherm_20]	--M-	0	0	-----	------	---
68	[FTherm_21]	--M-	0	0	-----	------	---
69	[FTherm_22]	--M-	0	0	-----	------	---
70	[FTherm_23]	--M-	0	0	-----	------	---
71	[FTherm_24]	--M-	0	0	-----	------	---
72	[FTherm_25]	--M-	0	0	-----	------	---
73	[FTherm_26]	--M-	0	0	-----	------	---
74	[FTherm_27]	--M-	0	0	-----	------	---
75	[FTherm_28]	--M-	0	0	-----	------	---
76	[FTherm_29]	--M-	0	0	-----	------	---
77	[FTherm_30]	--M-	0	0	-----	------	---
78	[FTherm_31]	--M-	0	0	-----	------	---
79	[FTherm_32]	--M-	0	0	-----	------	---
80	[FTherm_33]	--M-	0	0	-----	------	---
81	[FTCLine_1]	RWM-	1	2	-----	------	---
82	[FTCLine_2]	R-M-	1	0	-----	------	---
83	[FTCLine_3]	R-M-	1	0	-----	------	---
84	[FTCLine_4]	R-M-	1	0	-----	------	---
85	[FTCLine_5]	R-M-	1	0	-----	------	---
86	[FTCLine_6]	R-M-	1	0	-----	------	---
87	[FTCLine_7]	R-M-	1	0	-----	------	---
88	[FTCLine_8]	R-M-	1	0	-----	------	---
89	[FTCLine_9]	R-M-	1	0	-----	------	---
90	[FTCLin_10]	R-M-	1	0	-----	------	---
91	[FTCLin_11]	R-M-	1	0	-----	------	---
92	[FTCLin_12]	R-M-	1	0	-----	------	---
93	[FTCLin_13]	R-M-	1	0	-----	------	---
94	[FTCLin_14]	R-M-	1	0	-----	------	---
95	[FTCLin_15]	R-M-	1	0	-----	------	---
96	[FTCLin_16]	R-M-	1	0	-----	------	---
97	[FTCLin_17]	R-M-	1	0	-----	------	---
98	[FTCLin_18]	R-M-	1	0	-----	------	---
99	[FTCLin_19]	R-M-	1	0	-----	------	---
100	[FTCLin_20]	R-M-	1	0	-----	------	---
101	[FTCLin_21]	R-M-	1	0	-----	------	---
102	[FTCLin_22]	R-M-	1	0	-----	------	---
103	[FTCLin_23]	R-M-	1	0	-----	------	---
104	[FTCLin_24]	R-M-	1	0	-----	------	---
105	[FTCLin_25]	R-M-	1	0	-----	------	---
106	[FTCLin_26]	R-M-	1	0	-----	------	---

```
107    [ FTCLin_27 ]  R-M-   1       0       ----- ------ ---
108    [ FTCLin_28 ]  R-M-   1       0       ----- ------ ---
109    [ FTCLin_29 ]  R-M-   1       0       ----- ------ ---
110    [ FTCLin_30 ]  R-M-   1       0       ----- ------ ---
111    [ FTCLin_31 ]  R-M-   1       0       ----- ------ ---
112    [ FTCLin_32 ]  R-M-   1       0       ----- ------ ---
113    [ FTCLin_33 ]  RWM-   1       1       ----- ------ ---
114    [ RDHRxmV_1 ]  RWM-   2       1       ----- ------ ---
115    [ RDHRxmV_2 ]  --M-   0       0       ----- ------ ---
116    [ RDHRxmV_3 ]  --M-   0       0       ----- ------ ---
117    [ RDHRxmV_4 ]  --M-   0       0       ----- ------ ---
118    [ RDHRxmV_5 ]  --M-   0       0       ----- ------ ---
119    [ RDHRxmV_6 ]  --M-   0       0       ----- ------ ---
120    [ RDHRxmV_7 ]  --M-   0       0       ----- ------ ---
121    [ RDHRxmV_8 ]  --M-   0       0       ----- ------ ---
122    [ RDHRxmV_9 ]  --M-   0       0       ----- ------ ---
123    [ RDHRxm_10 ]  --M-   0       0       ----- ------ ---
124    [ RDHRxm_11 ]  --M-   0       0       ----- ------ ---
125    [ RDHRxm_12 ]  --M-   0       0       ----- ------ ---
126    [ RDHRxm_13 ]  --M-   0       0       ----- ------ ---
127    [ RDHRxm_14 ]  --M-   0       0       ----- ------ ---
128    [ RDHRxm_15 ]  --M-   0       0       ----- ------ ---
129    [ RDHRxm_16 ]  --M-   0       0       ----- ------ ---
146    [ RVMohm_1  ]  RWM-   1       2       ----- ------ ---
147    [ RVMohm_2  ]  R-M-   1       0       ----- ------ ---
148    [ RVMohm_3  ]  R-M-   1       0       ----- ------ ---
149    [ RVMohm_4  ]  R-M-   1       0       ----- ------ ---
150    [ RVMohm_5  ]  R-M-   1       0       ----- ------ ---
151    [ RVMohm_6  ]  R-M-   1       0       ----- ------ ---
152    [ RVMohm_7  ]  R-M-   1       0       ----- ------ ---
153    [ RVMohm_8  ]  R-M-   1       0       ----- ------ ---
154    [ RVMohm_9  ]  R-M-   1       0       ----- ------ ---
155    [ RVMohm_10 ]  R-M-   1       0       ----- ------ ---
156    [ RVMohm_11 ]  R-M-   1       0       ----- ------ ---
157    [ RVMohm_12 ]  R-M-   1       0       ----- ------ ---
158    [ RVMohm_13 ]  R-M-   1       0       ----- ------ ---
159    [ RVMohm_14 ]  R-M-   1       0       ----- ------ ---
160    [ RVMohm_15 ]  R-M-   1       0       ----- ------ ---
161    [ RVMohm_16 ]  R-M-   1       0       ----- ------ ---
162    [ RpKohm    ]  RW--   1       1       ----- ------ ---
163    [ Rvkohm    ]  RW--   3       3       ----- ------ ---
164    [ RDHThresh ]  RW--   1       1       ----- ------ ---
165    [ RainV1m_1 ]  ----   0       0       ----- ------ ---
166    [ RainV1m_2 ]  ----   0       0       ----- ------ ---
```

```
;{CR10X}
;
; Station ID:
; Written:  January 22, 2002
; Programmer:  Matthew Hircock
; Contact Info:  MHircock@RDHBE.com
; Revision Number: N/A
; Revision Date:
; Description of Revision:
; Revised By:
; Description of Past Revisions:
;
; Station Description: RDH Building Engineering Ltd.
; Site Location:       #2626 Watson Street, Vancouver, British Columbia
;
; Sensors Included:
;    20 RDH Wood Moisture Pin Sensors
;           Multiplexor 1 (2x32) Odd  H Reading   CR10X Channel 8
;           Multiplexor 1 (2x32) Even H Reading   CR10X Channel 8
;     1  RMY 05103-10 Wind Speed and Wind Direction Sensor
;           CR10X Channel 9
;    11 Honeywell Relative Humidity Sensors
;           Multiplexor 2 (4x16) Even L Reading   CR10X Channel 3
;    21 Fenwal (44033) Thermistors
;           Multiplexor 2 (4x16) Odd  H Excitation   CR10X E1
;           Multiplexor 2 (4x16) Odd  L Reading   CR10X Channel 1
;           Multiplexor 2 (4x16) Even H Reading   CR10X Channel 2
;     3 Davis Leaf Wetness Sensors
;           Multiplexor 2 (4x16) Even L Reading   CR10X Channel 3
;     2 Setra Pressure Transducers
;           Multiplexor 2 (4x16) Even L Reading   CR10X Channel 3
;     3 Tipping Bucket Rain Gauges (1 horizontal, 2 vertical)
;           CR10X
;           CR10X
;           CR10X
;
; Output Description: 15 minute averages, samples and totals
;                     24 hour diagnostic info.
;
; Communication Method: Direct Connection or Telephone (COM200)
; Telephone Number: (604) ___-____
;
;
; Security Enabled: No
;
; FLAG USAGE
;
; Flag 00 - Output Flag
; Flag 01 - Unused
; Flag 02 - Unused
; Flag 03 - Unused
; Flag 04 - Program Signature
; Flag 05 - Unused
; Flag 06 - Unused
```

```
; Flag 07 - Unused
; Flag 08 - Unused
; Flag 09 - Disables Intermediate Storage
;
;

*Table 1 Program
  01: 20        Execution Interval (seconds)

; Record Program Signature on Startup and Daily at Midnight (Diagnostic)

1:  If time is (P92)
 1: 0         Minutes (Seconds --) into a
 2: 1440      Interval (same units as above)
 3: 24        Set Flag 4 Low

2:  If Flag/Port (P91)
 1: 24        Do if Flag 4 is Low
 2: 30        Then Do

     3:  Signature (P19)
      1: 1         Loc [ ProgSig   ]

     4:  Do (P86)
      1: 14        Set Flag 4 High

5:  End (P95)

; Measure Battery Voltage (Diagnostic)

6:  Batt Voltage (P10)
 1: 2         Loc [ BattVolt  ]

; Measure RMY 05103-10 Wind Speed (kmph) and Direction Sensor (degrees)

7:  Pulse (P3)
 1: 1         Reps
 2: 2         Pulse Channel 2
 3: 21        Low Level AC, Output Hz
 4: 3         Loc [ WSpdkmph  ]
 5: 0.3528    Mult
 6: 0         Offset

8:  Excite-Delay (SE) (P4)
 1: 1         Reps
 2: 5         2500 mV Slow Range
 3: 9         SE Channel
 4: 3         Excite all reps w/Exchan 3
 5: 2         Delay (units 0.01 sec)
 6: 2500      mV Excitation
 7: 4         Loc [ WDirDeg   ]
 8: 0.142     Mult
 9: 0         Offset
```

```
; Measure Horizontal Tipping Bucket Rain Gauge (mm)

9:  Pulse (P3)
 1: 1        Reps
 2: 6        Control Port 6 (switch closure only)
 3: 2        Switch Closure, All Counts
 4: 5        Loc [ RainH1mm  ]
 5: 0.2      Mult
 6: 0        Offset

; Measure (2) Vertical Tipping Bucket Rain Gauges (kg/m^2)


10:  Pulse (P3)
 1: 2        Reps
 2: 7        Control Port 7 (switch closure only)
 3: 2        Switch Closure, All Counts
 4: 6        Loc [ RainV1kgm ]
 5: 0.05     Mult
 6: 0.0      Offset

; Measure (2) Setra Pressure Transducers (inches of Water Column) on Multiplexer 1

11:  Do (P86)
 1: 43       Set Port 3 High

12:  Beginning of Loop (P87)
 1: 0        Delay
 2: 14       Loop Count

     13:  Do (P86)
      1: 74       Pulse Port 4

     14:  Excitation with Delay (P22)
      1: 1        Ex Channel
      2: 0        Delay W/Ex (units = 0.01 sec)
      3: 1        Delay After Ex (units = 0.01 sec)
      4: 0        mV Excitation

15:  End (P95)

16:  Do (P86)
 1: 74       Pulse Port 4

17:  Excitation with Delay (P22)
 1: 1        Ex Channel
 2: 0        Delay W/Ex (units = 0.01 sec)
 3: 1        Delay After Ex (units = 0.01 sec)
 4: 0        mV Excitation
```

```
18:  Volt (SE) (P1)
 1: 1        Reps
 2: 5        2500 mV Slow Range
 3: 3        SE Channel
 4: 8        Loc [ Pres1inWC ]
 5: .0996    Mult
 6: -124.538 Offset

19:  Do (P86)
 1: 74       Pulse Port 4

20:  Excitation with Delay (P22)
 1: 1        Ex Channel
 2: 0        Delay W/Ex (units = 0.01 sec)
 3: 1        Delay After Ex (units = 0.01 sec)
 4: 0        mV Excitation

21:  Volt (SE) (P1)
 1: 1        Reps
 2: 5        2500 mV Slow Range
 3: 3        SE Channel
 4: 9        Loc [ Pres2inWC ]
 5: .0996    Mult
 6: -124.538 Offset


22:  Do (P86)
 1: 53       Set Port 3 Low

; Set condition for 15 minute measurement

23:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 15       Interval (same units as above)
 3: 30       Then Do

; Measure (11) Honeywell RH Sensors (%RH)
; Measure <21> Fenwal Thermisters
; Measure ( 3) DavisLeaf Wetness Sensors (?)

     24:  Do (P86)
      1: 43       Set Port 3 High

     25:  Beginning of Loop (P87)
      1: 0        Delay
      2: 11       Loop Count

          26:  Do (P86)
           1: 74       Pulse Port 4
```

```
        27:  Excitation with Delay (P22)
         1: 1        Ex Channel
         2: 0        Delay W/Ex (units = 0.01 sec)
         3: 1        Delay After Ex (units = 0.01 sec)
         4: 0        mV Excitation


        28:  AC Half Bridge (P5)
         1: 1        Reps
         2: 4        250 mV Slow Range
         3: 1        SE Channel
         4: 1        Excite all reps w/Exchan 1
         5: 690      mV Excitation
         6: 48    -- Loc [ FThermC_1 ]
         7: 10       Mult
         8: 0        Offset

        29:  AC Half Bridge (P5)
         1: 1        Reps
         2: 4        250 mV Slow Range
         3: 2        SE Channel
         4: 1        Excite all reps w/Exchan 1
         5: 690      mV Excitation
         6: 59    -- Loc [ FTherm_12 ]
         7: 10       Mult
         8: 0        Offset

        30:  Settling Time (P132)
         1: 50       Time (units = msec.):

        31:  Volt (SE) (P1)
         1: 1        Reps
         2: 5        2500 mV Slow Range
         3: 3        SE Channel
         4: 12    -- Loc [ HWPcntR_1 ]
         5: .058479  Mult
         6: -24.265  Offset

        32:  Settling Time (P132)
         1: 0.450    Time (units = msec.)

    33:  End (P95)

    34:  Beginning of Loop (P87)
     1: 0        Delay
     2: 3        Loop Count

        35:  Do (P86)
         1: 74       Pulse Port 4
```

```
          36:  Excitation with Delay (P22)
           1: 1        Ex Channel
           2: 0        Delay W/Ex (units = 0.01 sec)
           3: 1        Delay After Ex (units = 0.01 sec)
           4: 0        mV Excitation

37:  AC Half Bridge (P5)
 1: 1        Reps
 2: 4        250 mV Slow Range
 3: 3        SE Channel
 4: 1        Excite all reps w/Exchan 1
 5: 690      mV Excitation
 6: 30       Loc [ DvLeaf_1  ]
 7: 1        Mult
 8: 0        Offset

     38:  End (P95)

     39:  Do (P86)
      1: 53       Set Port 3 Low

; RDH Moisture Pin Sensors (20) on Multiplexer 1

     40:  Do (P86)
      1: 41       Set Port 1 High

     41:  Beginning of Loop (P87)
      1: 0        Delay
      2: 20       Loop Count

          42:  Do (P86)
           1: 72       Pulse Port 2

          43:  Excitation with Delay (P22)
           1: 1        Ex Channel
           2: 0        Delay W/Ex (units = 0.01 sec)
           3: 1        Delay After Ex (units = 0.01 sec)
           4: 0        mV Excitation

; Measure 20 Moisture Pins

; Increase the Measurement Settling Time

          44:  Settling Time (P132)
           1: 50       Time (units = msec.)

; Take the measurement to get the value of X (Measured Voltage):
```

```
          45:  AC Half Bridge (P5)
           1: 1          Reps
           2: 20         Auto 60 Hz Rejection Range (OS>1.9)
           3: 8          SE Channel
           4: 2          Excite all reps w/Exchan 2
           5: 2500       mV Excitation
           6: 114     -- Loc [ RDHRxmV_1 ]
           7: 1          Mult
           8: 0          Offset

; Reset the Measurement Settling Time

          46:  Settling Time (P132)
           1: 0.450      Time (units = msec.)

; Calculation: RVariable = RPickoff * ((1 / Measured Voltage) -1)

; RPickoff = 10kohm

          47:  Z=F (P30)
           1: 10         F
           2: 0          Exponent of 10
           3: 166        Z Loc [ RpKohm    ]

          48:  Z=1/X (P42)
           1: 114     -- X Loc [ RDHRxmV_1 ]
           2: 167        Z Loc [ Rvkohm    ]

          49:  Z=X+F (P34)
           1: 167        X Loc [ Rvkohm    ]
           2: -1         F
           3: 167        Z Loc [ Rvkohm    ]

          50:  Z=X*Y (P36)
           1: 166        X Loc [ RpKohm    ]
           2: 167        Y Loc [ Rvkohm    ]
           3: 167        Z Loc [ Rvkohm    ]

; Transform RVariable from kohm to Mohm

          51:  Z=X*F (P37)
           1: 167        X Loc [ Rvkohm    ]
           2: .001       F
           3: 146     -- Z Loc [ RVMohm_1  ]

     52:  End (P95)

     53:  Do (P86)
      1: 51         Set Port 1 Low

; Calculate Linearization for 33 Thermistors
```

```
     54:  Beginning of Loop (P87)
      1: 0        Delay
      2: 21       Loop Count


          55:  If (X<=>F) (P89)
           1: 48    -- X Loc [ FThermC_1 ]
           2: 4        <
           3: 0.46775  F
           4: 30       Then Do

               56:  Polynomial (P55)
                1: 1        Reps
                2: 48    -- X Loc [ FThermC_1 ]
                3: 81    -- F(X) Loc [ FTCLine_1 ]
                4: -49.446  C0
                5: 451.44   C1
                6: -2165.5  C2
                7: 6566.4   C3
                8: -10380   C4
                9: 6540.5   C5

          57:  Else (P94)

               58:  Polynomial (P55)
                1: 1        Reps
                2: 48    -- X Loc [ FThermC_1 ]
                3: 81    -- F(X) Loc [ FTCLine_1 ]
                4: -16.825  C0
                5: 73.176   C1
                6: -42.233  C2
                7: 16.397   C3
                8: -3.3270  C4
                9: 0.27144  C5

          59:  End (P95)

     60:  End (P95)

; RDH Moisture Pin Threshold Calculation (1000 Meg-ohms)

     61:  Beginning of Loop (P87)
      1: 0        Delay
      2: 20       Loop Count

          62:  Z=F (P30)
           1: 1.0001   F
           2: 5     -- Exponent of 10
           3: 168      Z Loc [ RDHThresh ]
```

```
          63:  If (X<=>Y) (P88)
           1: 114    -- X Loc [ RDHRxmV_1 ]
           2: 4         <
           3: 168       Y Loc [ RDHThresh ]
           4: 30        Then Do


               64:  Z=F (P30)
                1: 1000     F
                2: 0        Exponent of 10
                3: 146   -- Z Loc [ RVMohm_1  ]

          65:  End (P95)

     66:  End (P95)

67:  End (P95)

; Output (15 Minute Data and Daily Diagnostic)

68:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 15       Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

69:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 15       Array ID

70:  Real Time (P77)
 1: 1220     Year,Day,Hour/Minute (midnight = 2400)

71:  Wind Vector (P69)
 1: 1        Reps
 2: 0        Samples per Sub-Interval
 3: 0        S, é1, & å(é1) Polar
 4: 3        Wind Speed/East Loc [ WSpdkmph  ]
 5: 4        Wind Direction/North Loc [ WDirDeg   ]

72:  Totalize (P72)
 1: 3        Reps
 2: 5        Loc [ RainH1mm  ]

73:  Average (P71)
 1: 2        Reps
 2: 8        Loc [ Pres1inWC ]

74:  Sample (P70)
 1: 11       Reps
 2: 12       Loc [ HWPcntR_1 ]

75:  Sample (P70)
 1: 3        Reps
 2: 30       Loc [ DvLeaf_1  ]
```

```
76:  Sample (P70)
 1: 21       Reps
 2: 81       Loc [ FTCLine_1 ]

77:  Sample (P70)
 1: 20       Reps
 2: 146      Loc [ RVMohm_1  ]

78:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

79:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 411      Array ID

80:  Real Time (P77)
 1: 1200     Year,Day (midnight = 2400)

81:  Sample (P70)
 1: 1        Reps
 2: 1        Loc [ ProgSig   ]

82:  Maximum (P73)
 1: 1        Reps
 2: 0        Value Only
 3: 2        Loc [ BattVolt  ]

83:  Minimum (P74)
 1: 1        Reps
 2: 0        Value Only
 3: 2        Loc [ BattVolt  ]

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

Addr	Name	Flags	# Reads	# Writes	Blocks
1	[ProgSig]	RW--	1	1	----- ------ ---
2	[BattVolt]	RW--	2	1	----- ------ ---
3	[WSpdkmph]	RW--	1	1	----- ------ ---
4	[WDirDeg]	RW--	1	1	----- ------ ---
5	[RainH1mm]	RW--	1	1	Start ------ ---
6	[RainV1kgm]	RW--	1	1	Start ------ ---
7	[RainV2kgm]	RW--	1	1	----- ------ End
8	[Pres1inWC]	RW--	1	1	Start ------ ---
9	[Pres2inWC]	RW--	1	1	----- ------ End
10	[Pres3inWC]	----	0	0	----- ------ ---
11	[Pres4inWC]	----	0	0	----- ------ ---
12	[HWPcntR_1]	RWM-	1	1	Start ------ ---
13	[HWPcntR_2]	R-M-	1	0	----- Member ---
14	[HWPcntR_3]	R-M-	1	0	----- Member ---
15	[HWPcntR_4]	R-M-	1	0	----- Member ---
16	[HWPcntR_5]	R-M-	1	0	----- Member ---
17	[HWPcntR_6]	R-M-	1	0	----- Member ---
18	[HWPcntR_7]	R-M-	1	0	----- Member ---
19	[HWPcntR_8]	R-M-	1	0	----- Member ---
20	[HWPcntR_9]	R-M-	1	0	----- Member ---
21	[HWPcnt_10]	R-M-	1	0	----- Member ---
22	[HWPcnt_11]	R-M-	1	0	----- ------ End
23	[HWPcnt_12]	--M-	0	0	----- ------ ---
24	[HWPcnt_13]	--M-	0	0	----- ------ ---
25	[HWPcnt_14]	--M-	0	0	----- ------ ---
26	[HWPcnt_15]	--M-	0	0	----- ------ ---
27	[HWPcnt_16]	--M-	0	0	----- ------ ---
28	[HWPcnt_17]	--M-	0	0	----- ------ ---
29	[HWPcnt_18]	--M-	0	0	----- ------ ---
30	[DvLeaf_1]	RWM-	1	1	Start ------ ---
31	[DvLeaf_2]	R-M-	1	0	----- Member ---
32	[DvLeaf_3]	R-M-	1	0	----- ------ End
33	[DvLeaf_4]	--M-	0	0	----- ------ ---
34	[DvLeaf_5]	--M-	0	0	----- ------ ---
35	[DvLeaf_6]	--M-	0	0	----- ------ ---
36	[DvLeaf_7]	--M-	0	0	----- ------ ---
37	[DvLeaf_8]	--M-	0	0	----- ------ ---
38	[DvLeaf_9]	--M-	0	0	----- ------ ---
39	[DvLeaf_10]	--M-	0	0	----- ------ ---
40	[DvLeaf_11]	--M-	0	0	----- ------ ---
41	[DvLeaf_12]	--M-	0	0	----- ------ ---
42	[DvLeaf_13]	--M-	0	0	----- ------ ---
43	[DvLeaf_14]	--M-	0	0	----- ------ ---
44	[DvLeaf_15]	--M-	0	0	----- ------ ---
45	[DvLeaf_16]	--M-	0	0	----- ------ ---
46	[DvLeaf_17]	--M-	0	0	----- ------ ---
47	[DvLeaf_18]	--M-	0	0	----- ------ ---
48	[FThermC_1]	RWM-	3	1	----- ------ ---
49	[FThermC_2]	--M-	0	0	----- ------ ---
50	[FThermC_3]	--M-	0	0	----- ------ ---
51	[FThermC_4]	--M-	0	0	----- ------ ---
52	[FThermC_5]	--M-	0	0	----- ------ ---

53	[FThermC_6]	--M-	0	0	-----	------	---
54	[FThermC_7]	--M-	0	0	-----	------	---
55	[FThermC_8]	--M-	0	0	-----	------	---
56	[FThermC_9]	--M-	0	0	-----	------	---
57	[FTherm_10]	--M-	0	0	-----	------	---
58	[FTherm_11]	--M-	0	0	-----	------	---
59	[FTherm_12]	-WM-	0	1	-----	------	---
60	[FTherm_13]	--M-	0	0	-----	------	---
61	[FTherm_14]	--M-	0	0	-----	------	---
62	[FTherm_15]	--M-	0	0	-----	------	---
63	[FTherm_16]	--M-	0	0	-----	------	---
64	[FTherm_17]	--M-	0	0	-----	------	---
65	[FTherm_18]	--M-	0	0	-----	------	---
66	[FTherm_19]	--M-	0	0	-----	------	---
67	[FTherm_20]	--M-	0	0	-----	------	---
68	[FTherm_21]	--M-	0	0	-----	------	---
69	[FTherm_22]	--M-	0	0	-----	------	---
70	[FTherm_23]	--M-	0	0	-----	------	---
71	[FTherm_24]	--M-	0	0	-----	------	---
72	[FTherm_25]	--M-	0	0	-----	------	---
73	[FTherm_26]	--M-	0	0	-----	------	---
74	[FTherm_27]	--M-	0	0	-----	------	---
75	[FTherm_28]	--M-	0	0	-----	------	---
76	[FTherm_29]	--M-	0	0	-----	------	---
77	[FTherm_30]	--M-	0	0	-----	------	---
78	[FTherm_31]	--M-	0	0	-----	------	---
79	[FTherm_32]	--M-	0	0	-----	------	---
80	[FTherm_33]	--M-	0	0	-----	------	---
81	[FTCLine_1]	RWM-	1	2	Start	------	---
82	[FTCLine_2]	R-M-	1	0	-----	Member	---
83	[FTCLine_3]	R-M-	1	0	-----	Member	---
84	[FTCLine_4]	R-M-	1	0	-----	Member	---
85	[FTCLine_5]	R-M-	1	0	-----	Member	---
86	[FTCLine_6]	R-M-	1	0	-----	Member	---
87	[FTCLine_7]	R-M-	1	0	-----	Member	---
88	[FTCLine_8]	R-M-	1	0	-----	Member	---
89	[FTCLine_9]	R-M-	1	0	-----	Member	---
90	[FTCLin_10]	R-M-	1	0	-----	Member	---
91	[FTCLin_11]	R-M-	1	0	-----	Member	---
92	[FTCLin_12]	R-M-	1	0	-----	Member	---
93	[FTCLin_13]	R-M-	1	0	-----	Member	---
94	[FTCLin_14]	R-M-	1	0	-----	Member	---
95	[FTCLin_15]	R-M-	1	0	-----	Member	---
96	[FTCLin_16]	R-M-	1	0	-----	Member	---
97	[FTCLin_17]	R-M-	1	0	-----	Member	---
98	[FTCLin_18]	R-M-	1	0	-----	Member	---
99	[FTCLin_19]	R-M-	1	0	-----	Member	---
100	[FTCLin_20]	R-M-	1	0	-----	Member	---
101	[FTCLin_21]	R-M-	1	0	-----	------	End
102	[FTCLin_22]	--M-	0	0	-----	------	---
103	[FTCLin_23]	--M-	0	0	-----	------	---
104	[FTCLin_24]	--M-	0	0	-----	------	---
105	[FTCLin_25]	--M-	0	0	-----	------	---
106	[FTCLin_26]	--M-	0	0	-----	------	---

107	[FTCLin_27]	--M-	0	0	-----	------	---
108	[FTCLin_28]	--M-	0	0	-----	------	---
109	[FTCLin_29]	--M-	0	0	-----	------	---
110	[FTCLin_30]	--M-	0	0	-----	------	---
111	[FTCLin_31]	--M-	0	0	-----	------	---
112	[FTCLin_32]	--M-	0	0	-----	------	---
113	[FTCLin_33]	--M-	0	0	-----	------	---
114	[RDHRxmV_1]	RWM-	2	1	-----	------	---
115	[RDHRxmV_2]	--M-	0	0	-----	------	---
116	[RDHRxmV_3]	--M-	0	0	-----	------	---
117	[RDHRxmV_4]	--M-	0	0	-----	------	---
118	[RDHRxmV_5]	--M-	0	0	-----	------	---
119	[RDHRxmV_6]	--M-	0	0	-----	------	---
120	[RDHRxmV_7]	--M-	0	0	-----	------	---
121	[RDHRxmV_8]	--M-	0	0	-----	------	---
122	[RDHRxmV_9]	--M-	0	0	-----	------	---
123	[RDHRxm_10]	--M-	0	0	-----	------	---
124	[RDHRxm_11]	--M-	0	0	-----	------	---
125	[RDHRxm_12]	--M-	0	0	-----	------	---
126	[RDHRxm_13]	--M-	0	0	-----	------	---
127	[RDHRxm_14]	--M-	0	0	-----	------	---
128	[RDHRxm_15]	--M-	0	0	-----	------	---
129	[RDHRxm_16]	--M-	0	0	-----	------	---
130	[RDHRxm_17]	--M-	0	0	-----	------	---
131	[RDHRxm_18]	--M-	0	0	-----	------	---
132	[RDHRxm_19]	--M-	0	0	-----	------	---
133	[RDHRxm_20]	--M-	0	0	-----	------	---
146	[RVMohm_1]	RWM-	1	2	-----	------	---
147	[RVMohm_2]	R-M-	1	0	-----	------	---
148	[RVMohm_3]	R-M-	1	0	-----	------	---
149	[RVMohm_4]	R-M-	1	0	-----	------	---
150	[RVMohm_5]	R-M-	1	0	-----	------	---
151	[RVMohm_6]	R-M-	1	0	-----	------	---
152	[RVMohm_7]	R-M-	1	0	-----	------	---
153	[RVMohm_8]	R-M-	1	0	-----	------	---
154	[RVMohm_9]	R-M-	1	0	-----	------	---
155	[RVMohm_10]	R-M-	1	0	-----	------	---
156	[RVMohm_11]	R-M-	1	0	-----	------	---
157	[RVMohm_12]	R-M-	1	0	-----	------	---
158	[RVMohm_13]	R-M-	1	0	-----	------	---
159	[RVMohm_14]	R-M-	1	0	-----	------	---
160	[RVMohm_15]	R-M-	1	0	-----	------	---
161	[RVMohm_16]	R-M-	1	0	-----	------	---
162	[RVMohm_17]	--M-	0	0	-----	------	---
163	[RVMohm_18]	--M-	0	0	-----	------	---
164	[RVMohm_19]	--M-	0	0	-----	------	---
165	[RVMohm_20]	--M-	0	0	-----	------	---
166	[RpKohm]	RW--	1	1	-----	------	---
167	[Rvkohm]	RW--	3	3	-----	------	---
168	[RDHThresh]	RW--	1	1	-----	------	---
169	[RainV1m_1]	----	0	0	-----	------	---
170	[RainV1m_2]	----	0	0	-----	------	---

```
;{CR10X}
;
; Station ID:  Building 5 - 1356 Monitoring Project - Lot J
; Written:  November 27, 2002
; Programmer:  Matthew Hircock
; Contact Info:  MHircock@RDHBE.com     (604) 873-1181
; Revision Number:
; Revision Date:
; Description of Revision:
; Revised By:
; Description of Past Revisions:
;
; Station Description: Wall Monitoring Station, Building 5
; Site Location:       1299 W. Hastings St., Vancouver, British Columbia
;
; Sensors Included: 10 RDH Wood Moisture Pin Sensors
;                   1 RMY 05103-10 Wind Speed and Wind Direction Sensor
;                   21 Honeywell Relative Humidity Sensors
;                   38 Fenwal (44033) Thermistors
;                   20 Davis Leaf Wetness Sensors
;                   4 Setra Pressure Transducers
;                   5 Tipping Bucket Rain Gauges (1 horizontal, 2 vertical)
;
; Output Description: 15 minute averages, samples and totals
;                     24 hour diagnostic info.
;
; Communication Method: Direct Connection or Telephone (COM200)
; Telephone Number: (604) ___-____
;
;
; Security Enabled: No
;
; FLAG USAGE
;
; Flag 00 - Output Flag
; Flag 01 - Unused
; Flag 02 - Unused
; Flag 03 - Unused
; Flag 04 - Program Signature
; Flag 05 - Unused
; Flag 06 - Unused
; Flag 07 - Unused
; Flag 08 - Unused
; Flag 09 - Disables Intermediate Storage
;
;

*Table 1 Program
  01: 20        Execution Interval (seconds)

; Record Program Signature on Startup and Daily at Midnight (Diagnostic)
```

```
1:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 24       Set Flag 4 Low

2:  If Flag/Port (P91)
 1: 24       Do if Flag 4 is Low
 2: 30       Then Do

     3:  Signature (P19)
      1: 1        Loc [ ProgSig   ]

     4:  Do (P86)
      1: 14       Set Flag 4 High

5:  End (P95)

; Measure Battery Voltage (Diagnostic)

6:  Batt Voltage (P10)
 1: 2        Loc [ BattVolt  ]

; Measure RMY 05103-10 Wind Speed (kmph) and Direction Sensor (degrees)

7:  Pulse (P3)
 1: 1        Reps
 2: 2        Pulse Channel 2
 3: 21       Low Level AC, Output Hz
 4: 3        Loc [ WSpdkmph  ]
 5: 0.3528   Mult
 6: 0        Offset

8:  Excite-Delay (SE) (P4)
 1: 1        Reps
 2: 5        2500 mV Slow Range
 3: 9        SE Channel
 4: 3        Excite all reps w/Exchan 3
 5: 2        Delay (units 0.01 sec)
 6: 2500     mV Excitation
 7: 4        Loc [ WDirDeg   ]
 8: 0.142    Mult
 9: 0        Offset

; Measure Horizontal Tipping Bucket Rain Gauge (mm)

9:  Pulse (P3)
 1: 1        Reps
 2: 6        Control Port 6 (switch closure only)
 3: 2        Switch Closure, All Counts
 4: 5        Loc [ Rainroof  ]
 5: 0.2      Mult
 6: 0        Offset

; Measure (2) Vertical Tipping Bucket Rain Gauges (kg/m^2)
```

```
10:  Pulse (P3)
 1: 2        Reps
 2: 7        Control Port 7 (switch closure only)
 3: 2        Switch Closure, All Counts
 4: 8        Loc [ Rain_30E  ]
 5: 0.05     Mult
 6: 0.0      Offset


11:  Pulse (P3)
 1: 1        Reps
 2: 1        Pulse Channel 1
 3: 2        Switch Closure, All Counts
 4: 6        Loc [ Rain_05E  ]
 5: 0.05     Mult
 6: 0.0      Offset

; Measure (4) Setra Pressure Transducers (inches of Water Column) on Multiplexer 1
; Located on East and South elevation of 5th and 30th Floor

12:  Do (P86)
 1: 41       Set Port 1 High

13:  Beginning of Loop (P87)
 1: 0        Delay
 2: 28       Loop Count

     14:  Do (P86)
      1: 72       Pulse Port 2

     15:  Excitation with Delay (P22)
      1: 1        Ex Channel
      2: 0        Delay W/Ex (units = 0.01 sec)
      3: 1        Delay After Ex (units = 0.01 sec)
      4: 0        mV Excitation

16:  End (P95)

17:  Beginning of Loop (P87)
 1: 0        Delay
 2: 4        Loop Count

     18:  Do (P86)
      1: 72       Pulse Port 2

     19:  Excitation with Delay (P22)
      1: 1        Ex Channel
      2: 0        Delay W/Ex (units = 0.01 sec)
      3: 1        Delay After Ex (units = 0.01 sec)
      4: 0        mV Excitation
```

```
     20:  Volt (SE) (P1)
      1: 1        Reps
      2: 5        2500 mV Slow Range
      3: 5        SE Channel
      4: 10    -- Loc [ Pres1inWC ]
      5: .0996    Mult
      6: -124.5   Offset

21:  End (P95)

22:  Do (P86)
 1: 51       Set Port 1 Low

; Set condition for 15 minute measurement

23:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 15       Interval (same units as above)
 3: 30       Then Do

; Measure (22) Honeywell RH Sensors (%RH)
; & (20) DavisLeaf Wetness Sensors (?) on Multiplexer 1

     24:  Do (P86)
      1: 41       Set Port 1 High

     25:  Beginning of Loop (P87)
      1: 0        Delay
      2: 22       Loop Count

          26:  Do (P86)
           1: 72       Pulse Port 2

          27:  Excitation with Delay (P22)
           1: 1        Ex Channel
           2: 0        Delay W/Ex (units = 0.01 sec)
           3: 1        Delay After Ex (units = 0.01 sec)
           4: 0        mV Excitation

          28:  Settling Time (P132)
           1: 50       Time (units = msec.):
; Measurments of Honeywells RH sensors

          29:  Volt (SE) (P1)
           1: 1        Reps
           2: 5        2500 mV Slow Range
           3: 5        SE Channel
           4: 14    -- Loc [ HWPcntR_1 ]
           5: .058479  Mult
           6: -24.265  Offset

; Measurment of Davis Leaf Wetness (22)
```

```
          30:  AC Half Bridge (P5)
           1: 1         Reps
           2: 20        Auto 60 Hz Rejection Range (OS>1.9)
           3: 8         SE Channel
           4: 2         Excite all reps w/Exchan 2
           5: 2500      mV Excitation
           6: 138    -- Loc [ Davis_1   ]
           7: 1         Mult
           8: 0         Offset

; Reset the Measurement Settling Time

          31:  Settling Time (P132)
           1: 0.450     Time (units = msec.)

; Calculation: RVariable = RPickoff * ((1 / Measured Voltage) -1)

; RPickoff = 10kohm

          32:  Z=F (P30)
           1: 10        F
           2: 0         Exponent of 10
           3: 192       Z Loc [ RpKohm    ]

          33:  Z=1/X (P42)
           1: 138    -- X Loc [ Davis_1   ]
           2: 193       Z Loc [ Rvkohm    ]

          34:  Z=X+F (P34)
           1: 193       X Loc [ Rvkohm    ]
           2: -1        F
           3: 193       Z Loc [ Rvkohm    ]

          35:  Z=X*Y (P36)
           1: 192       X Loc [ RpKohm    ]
           2: 193       Y Loc [ Rvkohm    ]
           3: 193       Z Loc [ Rvkohm    ]

; Transform RVariable from kohm to Mohm

          36:  Z=X*F (P37)
           1: 193       X Loc [ Rvkohm    ]
           2: .001      F
           3: 170    -- Z Loc [ DMohm_1   ]

     37:  End (P95)

     38:  Do (P86)
      1: 51        Set Port 1 Low


     39:  Beginning of Loop (P87)
      1: 0         Delay
      2: 10        Loop Count
```

```
          40:  Do (P86)
           1: 72       Pulse Port 2

          41:  Excitation with Delay (P22)
           1: 1        Ex Channel
           2: 0        Delay W/Ex (units = 0.01 sec)
           3: 1        Delay After Ex (units = 0.01 sec)
           4: 0        mV Excitation

          42:  Settling Time (P132)
           1: 50       Time (units = msec.):

; Measurment of (10) RDH Moisture sensors.

          43:  AC Half Bridge (P5)
           1: 1        Reps
           2: 20       Auto 60 Hz Rejection Range (OS>1.9)
           3: 8        SE Channel
           4: 2        Excite all reps w/Exchan 2
           5: 2500     mV Excitation
           6: 128   -- Loc [ RDHRxmV_1 ]
           7: 1        Mult
           8: 0        Offset

; Reset the Measurement Settling Time

          44:  Settling Time (P132)
           1: 0.450    Time (units = msec.)

; Calculation: RVariable = RPickoff * ((1 / Measured Voltage) -1)

; RPickoff = 10kohm

          45:  Z=F (P30)
           1: 10       F
           2: 0        Exponent of 10
           3: 192      Z Loc [ RpKohm    ]

          46:  Z=1/X (P42)
           1: 128   -- X Loc [ RDHRxmV_1 ]
           2: 193      Z Loc [ Rvkohm    ]

          47:  Z=X+F (P34)
           1: 193      X Loc [ Rvkohm    ]
           2: -1       F
           3: 193      Z Loc [ Rvkohm    ]

          48:  Z=X*Y (P36)
           1: 192      X Loc [ RpKohm    ]
           2: 193      Y Loc [ Rvkohm    ]
           3: 193      Z Loc [ Rvkohm    ]

; Transform RVariable from kohm to Mohm
```

```
          49:  Z=X*F (P37)
           1: 193       X Loc [ Rvkohm    ]
           2: .001      F
           3: 160    -- Z Loc [ RVMohm_1  ]

     50:  End (P95)


; Measure Fenwal Thermistors (39) on Multiplexer 2

     51:  Do (P86)
      1: 43        Set Port 3 High

     52:  Beginning of Loop (P87)
      1: 0         Delay
      2: 13        Loop Count

          53:  Do (P86)
           1: 74        Pulse Port 4

          54:  Excitation with Delay (P22)
           1: 1         Ex Channel
           2: 0         Delay W/Ex (units = 0.01 sec)
           3: 1         Delay After Ex (units = 0.01 sec)
           4: 0         mV Excitation

; Measure Thermistors 1 through 16 (all L1 Thermistors)

          55:  AC Half Bridge (P5)
           1: 1         Reps
           2: 4         250 mV Slow Range
           3: 1         SE Channel
           4: 1         Excite all reps w/Exchan 1
           5: 690       mV Excitation
           6: 50     -- Loc [ FThermC_1 ]
           7: 10        Mult
           8: 0         Offset

          56:  AC Half Bridge (P5)
           1: 1         Reps
           2: 4         250 mV Slow Range
           3: 2         SE Channel
           4: 1         Excite all reps w/Exchan 1
           5: 690       mV Excitation
           6: 63     -- Loc [ FTherm_14 ]
           7: 10        Mult
           8: 0         Offset
```

```
         57:  AC Half Bridge (P5)
          1: 1        Reps
          2: 4        250 mV Slow Range
          3: 3        SE Channel
          4: 1        Excite all reps w/Exchan 1
          5: 690      mV Excitation
          6: 76    -- Loc [ FTherm_27 ]
          7: 10       Mult
          8: 0        Offset

    58:  End (P95)

    59:  Do (P86)
     1: 53       Set Port 3 Low

; Calculate Linearization for 33 Thermistors

    60:  Beginning of Loop (P87)
     1: 0        Delay
     2: 39       Loop Count


         61:  If (X<=>F) (P89)
          1: 50    -- X Loc [ FThermC_1 ]
          2: 4        <
          3: 0.46775  F
          4: 30       Then Do

              62:  Polynomial (P55)
               1: 1        Reps
               2: 50    -- X Loc [ FThermC_1 ]
               3: 89    -- F(X) Loc [ FTCLine_1 ]
               4: -49.446  C0
               5: 451.44   C1
               6: -2165.5  C2
               7: 6566.4   C3
               8: -10380   C4
               9: 6540.5   C5

         63:  Else (P94)

              64:  Polynomial (P55)
               1: 1        Reps
               2: 50    -- X Loc [ FThermC_1 ]
               3: 89    -- F(X) Loc [ FTCLine_1 ]
               4: -16.825  C0
               5: 73.176   C1
               6: -42.233  C2
               7: 16.397   C3
               8: -3.3270  C4
               9: 0.27144  C5

         65:  End (P95)
```

```
     66:  End (P95)

; RDH Moisture Pin Threshold Calculation (1000 Meg-ohms)

     67:  Beginning of Loop (P87)
      1: 0        Delay
      2: 10       Loop Count

          68:  Z=F (P30)
           1: 1.0001   F
           2: 5     -- Exponent of 10
           3: 194      Z Loc [ RDHThresh ]


          69:  If (X<=>Y) (P88)
           1: 128   -- X Loc [ RDHRxmV_1 ]
           2: 4        <
           3: 194      Y Loc [ RDHThresh ]
           4: 30       Then Do


               70:  Z=F (P30)
                1: 1000     F
                2: 0        Exponent of 10
                3: 160   -- Z Loc [ RVMohm_1  ]

          71:  End (P95)

     72:  End (P95)

73:  End (P95)

; Output (15 Minute Data and Daily Diagnostic)

74:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 15       Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

75:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 15       Array ID

76:  Real Time (P77)
 1: 1220     Year,Day,Hour/Minute (midnight = 2400)

77:  Wind Vector (P69)
 1: 1        Reps
 2: 0        Samples per Sub-Interval
 3: 0        S, é1, & å(é1) Polar
 4: 3        Wind Speed/East Loc [ WSpdkmph  ]
 5: 4        Wind Direction/North Loc [ WDirDeg   ]
```

```
78:  Totalize (P72)
 1: 5        Reps
 2: 5        Loc [ Rainroof  ]

79:  Average (P71)
 1: 4        Reps
 2: 10       Loc [ Pres1inWC ]

80:  Sample (P70)
 1: 22       Reps
 2: 14       Loc [ HWPcntR_1 ]

81:  Sample (P70)
 1: 20       Reps
 2: 170      Loc [ DMohm_1   ]

82:  Sample (P70)
 1: 39       Reps
 2: 89       Loc [ FTCLine_1 ]

83:  Sample (P70)
 1: 10       Reps
 2: 160      Loc [ RVMohm_1  ]

84:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

85:  Set Active Storage Area (P80)
 1: 1        Final Storage Area 1
 2: 411      Array ID

86:  Real Time (P77)
 1: 1200     Year,Day (midnight = 2400)

87:  Sample (P70)
 1: 1        Reps
 2: 1        Loc [ ProgSig   ]

88:  Maximum (P73)
 1: 1        Reps
 2: 0        Value Only
 3: 2        Loc [ BattVolt  ]

89:  Minimum (P74)
 1: 1        Reps
 2: 0        Value Only
 3: 2        Loc [ BattVolt  ]

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines
```

LOT_J.CSI, Table 3

End Program

LOT_J.CSI, Input Locations

Addr	Name	Flags	# Reads	# Writes	Blocks		
1	[ProgSig]	RW--	1	1	-----	------	---
2	[BattVolt]	RW--	2	1	-----	------	---
3	[WSpdkmph]	RW--	1	1	-----	------	---
4	[WDirDeg]	RW--	1	1	-----	------	---
5	[Rainroof]	RW--	1	1	-----	------	---
6	[Rain_05E]	RW--	1	1	-----	------	---
7	[Rain_05S]	R---	1	0	-----	------	---
8	[Rain_30E]	RW--	1	1	Start	------	---
9	[Rain_30S]	RW--	1	1	-----	------	End
10	[Pres1inWC]	RW--	1	1	-----	------	---
11	[Pres2inWC]	R---	1	0	-----	------	---
12	[Pres3inWC]	R---	1	0	-----	------	---
13	[Pres4inWC]	R---	1	0	-----	------	---
14	[HWPcntR_1]	RWM-	1	1	-----	------	---
15	[HWPcntR_2]	R-M-	1	0	-----	------	---
16	[HWPcntR_3]	R-M-	1	0	-----	------	---
17	[HWPcntR_4]	R-M-	1	0	-----	------	---
18	[HWPcntR_5]	R-M-	1	0	-----	------	---
19	[HWPcntR_6]	R-M-	1	0	-----	------	---
20	[HWPcntR_7]	R-M-	1	0	-----	------	---
21	[HWPcntR_8]	R-M-	1	0	-----	------	---
22	[HWPcntR_9]	R-M-	1	0	-----	------	---
23	[HWPcnt_10]	R-M-	1	0	-----	------	---
24	[HWPcnt_11]	R-M-	1	0	-----	------	---
25	[HWPcnt_12]	R-M-	1	0	-----	------	---
26	[HWPcnt_13]	R-M-	1	0	-----	------	---
27	[HWPcnt_14]	R-M-	1	0	-----	------	---
28	[HWPcnt_15]	R-M-	1	0	-----	------	---
29	[HWPcnt_16]	R-M-	1	0	-----	------	---
30	[HWPcnt_17]	R-M-	1	0	-----	------	---
31	[HWPcnt_18]	R-M-	1	0	-----	------	---
32	[HWPcnt_19]	R---	1	0	-----	------	---
33	[HWPcnt_20]	R---	1	0	-----	------	---
34	[HWPcnt_21]	R---	1	0	-----	------	---
35	[HWPcnt_22]	R---	1	0	-----	------	---
50	[FThermC_1]	RWM-	3	1	-----	------	---
51	[FThermC_2]	--M-	0	0	-----	------	---
52	[FThermC_3]	--M-	0	0	-----	------	---
53	[FThermC_4]	--M-	0	0	-----	------	---
54	[FThermC_5]	--M-	0	0	-----	------	---
55	[FThermC_6]	--M-	0	0	-----	------	---
56	[FThermC_7]	--M-	0	0	-----	------	---
57	[FThermC_8]	--M-	0	0	-----	------	---
58	[FThermC_9]	--M-	0	0	-----	------	---
59	[FTherm_10]	--M-	0	0	-----	------	---
60	[FTherm_11]	--M-	0	0	-----	------	---
61	[FTherm_12]	--M-	0	0	-----	------	---
62	[FTherm_13]	--M-	0	0	-----	------	---
63	[FTherm_14]	-WM-	0	1	-----	------	---
64	[FTherm_15]	--M-	0	0	-----	------	---
65	[FTherm_16]	--M-	0	0	-----	------	---
66	[FTherm_17]	--M-	0	0	-----	------	---

67	[FTherm_18]	--M-	0	0	-----	------	---
68	[FTherm_19]	--M-	0	0	-----	------	---
69	[FTherm_20]	--M-	0	0	-----	------	---
70	[FTherm_21]	--M-	0	0	-----	------	---
71	[FTherm_22]	--M-	0	0	-----	------	---
72	[FTherm_23]	--M-	0	0	-----	------	---
73	[FTherm_24]	--M-	0	0	-----	------	---
74	[FTherm_25]	--M-	0	0	-----	------	---
75	[FTherm_26]	--M-	0	0	-----	------	---
76	[FTherm_27]	-WM-	0	1	-----	------	---
77	[FTherm_28]	--M-	0	0	-----	------	---
78	[FTherm_29]	--M-	0	0	-----	------	---
79	[FTherm_30]	--M-	0	0	-----	------	---
80	[FTherm_31]	--M-	0	0	-----	------	---
81	[FTherm_32]	--M-	0	0	-----	------	---
82	[FTherm_33]	--M-	0	0	-----	------	---
89	[FTCLine_1]	RWM-	1	2	-----	------	---
90	[FTCLine_2]	R-M-	1	0	-----	------	---
91	[FTCLine_3]	R-M-	1	0	-----	------	---
92	[FTCLine_4]	R-M-	1	0	-----	------	---
93	[FTCLine_5]	R-M-	1	0	-----	------	---
94	[FTCLine_6]	R-M-	1	0	-----	------	---
95	[FTCLine_7]	R-M-	1	0	-----	------	---
96	[FTCLine_8]	R-M-	1	0	-----	------	---
97	[FTCLine_9]	R-M-	1	0	-----	------	---
98	[FTCLin_10]	R-M-	1	0	-----	------	---
99	[FTCLin_11]	R-M-	1	0	-----	------	---
100	[FTCLin_12]	R-M-	1	0	-----	------	---
101	[FTCLin_13]	R-M-	1	0	-----	------	---
102	[FTCLin_14]	R-M-	1	0	-----	------	---
103	[FTCLin_15]	R-M-	1	0	-----	------	---
104	[FTCLin_16]	R-M-	1	0	-----	------	---
105	[FTCLin_17]	R-M-	1	0	-----	------	---
106	[FTCLin_18]	R-M-	1	0	-----	------	---
107	[FTCLin_19]	R-M-	1	0	-----	------	---
108	[FTCLin_20]	R-M-	1	0	-----	------	---
109	[FTCLin_21]	R-M-	1	0	-----	------	---
110	[FTCLin_22]	R-M-	1	0	-----	------	---
111	[FTCLin_23]	R-M-	1	0	-----	------	---
112	[FTCLin_24]	R-M-	1	0	-----	------	---
113	[FTCLin_25]	R-M-	1	0	-----	------	---
114	[FTCLin_26]	R-M-	1	0	-----	------	---
115	[FTCLin_27]	R-M-	1	0	-----	------	---
116	[FTCLin_28]	R-M-	1	0	-----	------	---
117	[FTCLin_29]	R-M-	1	0	-----	------	---
118	[FTCLin_30]	R-M-	1	0	-----	------	---
119	[FTCLin_31]	R-M-	1	0	-----	------	---
120	[FTCLin_32]	R-M-	1	0	-----	------	---
121	[FTCLin_33]	R-M-	1	0	-----	------	---
122	[FTCLin_34]	R---	1	0	-----	------	---
123	[FTCLin_35]	R---	1	0	-----	------	---
124	[FTCLin_36]	R---	1	0	-----	------	---
125	[FTCLin_37]	R---	1	0	-----	------	---
126	[FTCLin_38]	R---	1	0	-----	------	---

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127    [ FTCLin_39 ]  R---   1       0       ----- ------ ---
128    [ RDHRxmV_1 ]  RWM-   2       1       ----- ------ ---
129    [ RDHRxmV_2 ]  --M-   0       0       ----- ------ ---
130    [ RDHRxmV_3 ]  --M-   0       0       ----- ------ ---
131    [ RDHRxmV_4 ]  --M-   0       0       ----- ------ ---
132    [ RDHRxmV_5 ]  --M-   0       0       ----- ------ ---
133    [ RDHRxmV_6 ]  --M-   0       0       ----- ------ ---
134    [ RDHRxmV_7 ]  --M-   0       0       ----- ------ ---
135    [ RDHRxmV_8 ]  --M-   0       0       ----- ------ ---
136    [ RDHRxmV_9 ]  --M-   0       0       ----- ------ ---
137    [ RDHRxm_10 ]  --M-   0       0       ----- ------ ---
138    [ Davis_1   ]  RWM-   1       1       ----- ------ ---
139    [ Davis_2   ]  --M-   0       0       ----- ------ ---
140    [ Davis_3   ]  --M-   0       0       ----- ------ ---
141    [ Davis_4   ]  --M-   0       0       ----- ------ ---
142    [ Davis_5   ]  --M-   0       0       ----- ------ ---
143    [ Davis_6   ]  --M-   0       0       ----- ------ ---
144    [ Davis_7   ]  --M-   0       0       ----- ------ ---
145    [ Davis_8   ]  --M-   0       0       ----- ------ ---
146    [ Davis_9   ]  --M-   0       0       ----- ------ ---
147    [ Davis_10  ]  --M-   0       0       ----- ------ ---
148    [ Davis_11  ]  --M-   0       0       ----- ------ ---
149    [ Davis_12  ]  --M-   0       0       ----- ------ ---
150    [ Davis_13  ]  --M-   0       0       ----- ------ ---
151    [ Davis_14  ]  --M-   0       0       ----- ------ ---
152    [ Davis_15  ]  --M-   0       0       ----- ------ ---
153    [ Davis_16  ]  --M-   0       0       ----- ------ ---
154    [ Davis_17  ]  --M-   0       0       ----- ------ ---
155    [ Davis_18  ]  --M-   0       0       ----- ------ ---
156    [ Davis_19  ]  --M-   0       0       ----- ------ ---
157    [ Davis_20  ]  --M-   0       0       ----- ------ ---
158    [ Davis_21  ]  --M-   0       0       ----- ------ ---
159    [ Davis_22  ]  --M-   0       0       ----- ------ ---
160    [ RVMohm_1  ]  RWM-   1       2       ----- ------ ---
161    [ RVMohm_2  ]  R-M-   1       0       ----- ------ ---
162    [ RVMohm_3  ]  R-M-   1       0       ----- ------ ---
163    [ RVMohm_4  ]  R-M-   1       0       ----- ------ ---
164    [ RVMohm_5  ]  R-M-   1       0       ----- ------ ---
165    [ RVMohm_6  ]  R-M-   1       0       ----- ------ ---
166    [ RVMohm_7  ]  R-M-   1       0       ----- ------ ---
167    [ RVMohm_8  ]  R-M-   1       0       ----- ------ ---
168    [ RVMohm_9  ]  R-M-   1       0       ----- ------ ---
169    [ RVMohm_10 ]  R-M-   1       0       ----- ------ ---
170    [ DMohm_1   ]  RWM-   1       1       ----- ------ ---
171    [ DMohm_2   ]  R-M-   1       0       ----- ------ ---
172    [ DMohm_3   ]  R-M-   1       0       ----- ------ ---
173    [ DMohm_4   ]  R-M-   1       0       ----- ------ ---
174    [ DMohm_5   ]  R-M-   1       0       ----- ------ ---
175    [ DMohm_6   ]  R-M-   1       0       ----- ------ ---
176    [ DMohm_7   ]  R-M-   1       0       ----- ------ ---
177    [ DMohm_8   ]  R-M-   1       0       ----- ------ ---
178    [ DMohm_9   ]  R-M-   1       0       ----- ------ ---
179    [ DMohm_10  ]  R-M-   1       0       ----- ------ ---
180    [ DMohm_11  ]  R-M-   1       0       ----- ------ ---
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181	[DMohm_12]	R-M-	1	0	-----	------	---
182	[DMohm_13]	R-M-	1	0	-----	------	---
183	[DMohm_14]	R-M-	1	0	-----	------	---
184	[DMohm_15]	R-M-	1	0	-----	------	---
185	[DMohm_16]	R-M-	1	0	-----	------	---
186	[DMohm_17]	R-M-	1	0	-----	------	---
187	[DMohm_18]	R-M-	1	0	-----	------	---
188	[DMohm_19]	R-M-	1	0	-----	------	---
189	[DMohm_20]	R-M-	1	0	-----	------	---
190	[DMohm_21]	--M-	0	0	-----	------	---
191	[DMohm_22]	--M-	0	0	-----	------	---
192	[RpKohm]	RW--	2	2	-----	------	---
193	[Rvkohm]	RW--	6	6	-----	------	---
194	[RDHThresh]	RW--	1	1	-----	------	---