Instrumentation Overview

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1 Introduction

This document describes the instrumentation used for performance monitoring in the technical brief "Real-world Efficiency of a Monobloc Heat Pump for Multi-Unit Residential Buildings" published on sustainabletechnologies.ca.

2 Outdoor Intake and Exhaust Air Temperatures

The outdoor intake and exhaust air temperatures were measured with a grid of 5 Type K thermocouples connected to a Monnit Alta MNS2-9-W2-TS-TC-KP thermocouple reader. The grid was arranged with 1 thermcouple covering each quadrant of the round duct, and 1 thermocouple in the middle (Figure 1).

Figure 1. Thermocouple grid shown for exhaust duct of heat pump. A similar grid was used on the intake.

Prior to installation both grids were put in a Sika K32SK wet well temperature calibrator prior. The calibrator was set to different set-points from -10 ^oC to 55 ^oC in 5 ^oC increments. The readings from each grid (connected to the Monnit Alta thermocouple reader) were then recorded. The grids are well-matched, to within +/- 0.5 ^oC at the greatest, but typically within +/- 0.2 ^oC.

Table 1. Temperature calibrator set-points and supply/intake thermocouple grid readings.

Time	Set point	Supply Grid	Exhaust Grid	Difference
16:55	55	55.4	55.2	0.2
17:15	50	50.7	50.4	0.3
17:31	45	45.6	45.4	0.2
17:45	40	40.8	40.4	0.4
18:00	35	35.7	35.5	0.2
18:15	30	30.8	30.7	0.1
18:30	25	25.7	25.6	0.1
18:48	20	20.2	20.4	-0.2
19:01	15	15.5	15.5	0
19:15	10	10	10.5	-0.5
19:30	5	5.7	5.7	0
19:45	0	0.7	0.8	-0.1
20:00	-5	-4.1	-4.1	0
20:15	-10	-9.1	-9.2	0.1

3 Outdoor Airflow

Outdoor airflow was measured with a Nailor 6-inch 36FMI round airflow station (Figure 2). It has an accuracy of ± 5% if there is a straight inlet with a minimum length of two equivalent duct diameters. In this set-up there was greater than two duct diameters upstream and downstream of the flow station. The flow station uses 4 ports across the duct cross-section to produce a differential pressure reading that can be used to determine the volumetric airflow. The differential pressure was read by a Dwyer 677B-03 transducer which produced a 4 to 20 mA output. It has a manufacturer stated accuracy of ±0.4% FS at room temperature. The transducer was read by a Monnit Alta 0 to 20 mA (MNS2-9-W2-MA-020) analog input sensor. It has a typical accuracy of +/- 0.35 mA if purchased uncalibrated. Verification of the input sensor was done prior to the heating season and this is discussed below.

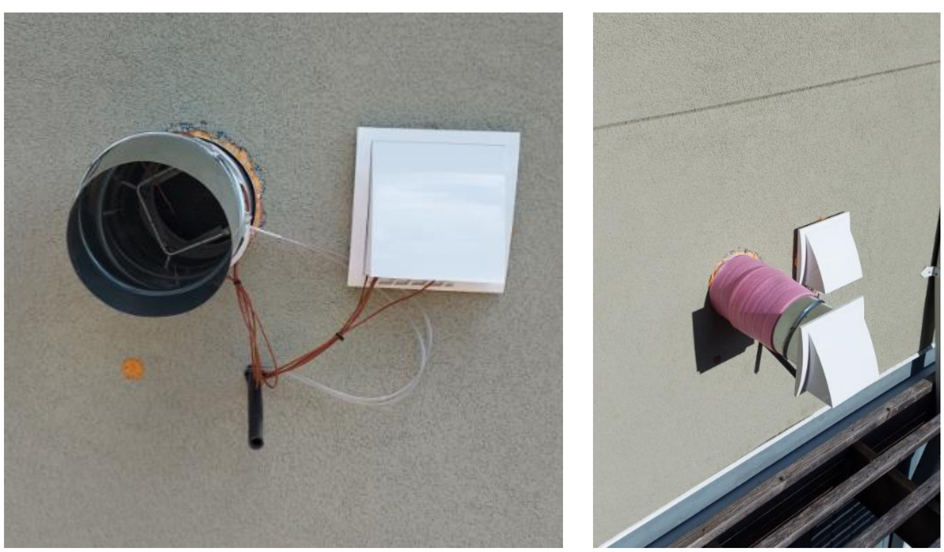
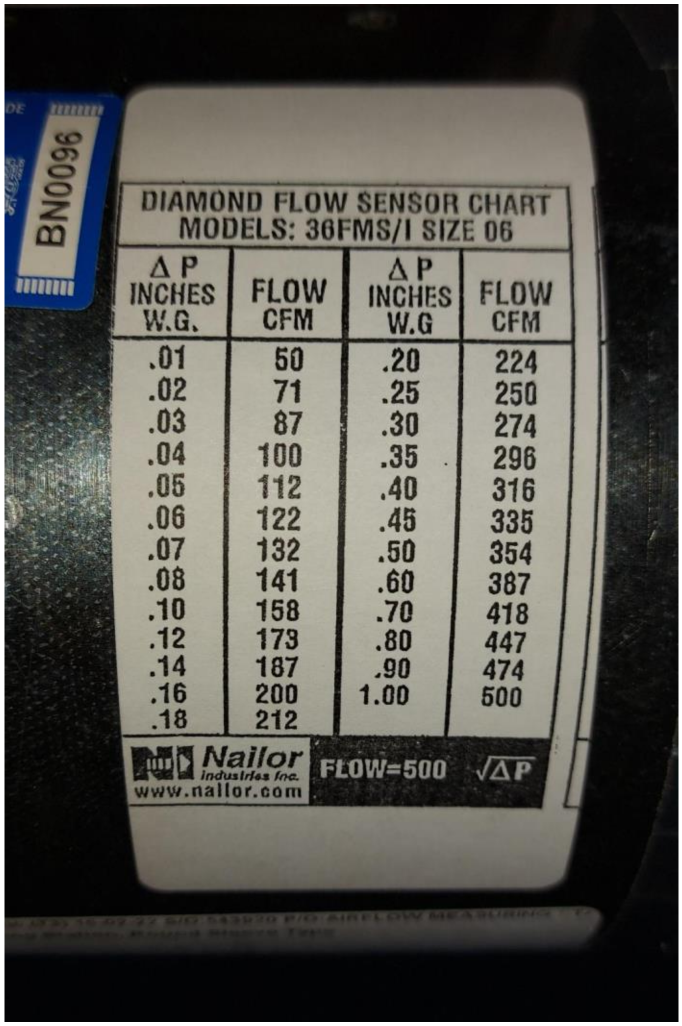


Figure 2. The exhaust duct was extended to allow for the installation of the airflow station.

The relationship between differential pressure (in units of inches W.G.) and airflow (in units cfm) is shown in Figure 3. The Dwyer 677B-03 transducer has a range of 0” W.G. (4 mA) to 0.5” W.G. (20 mA). The equation to determine cfm from the mA reading of the transducer is shown in Equation 1.



DIAMOND FLOW SENSOR CHART
MODELS: 36FMS/I SIZE 06

Δ P INCHES W.G.	FLOW CFM	Δ P INCHES W.G	FLOW CFM
.01	50	.20	224
.02	71	.25	250
.03	87	.30	274
.04	100	.35	296
.05	112	.40	316
.06	122	.45	335
.07	132	.50	354
.08	141	.60	387
.10	158	.70	418
.12	173	.80	447
.14	187	.90	474
.16	200	1.00	500
.18	212		

Figure 3. The differential airflow is related to the airflow according to this chart.

$$cfm = 500 \cdot (0.03125 \cdot mA - 0.125)^{0.5} \tag{1}$$

Measurements from the airflow set-up were verified prior to the heating season. A Fluke 289 meter was hooked up in series with the Monnit Alta analog input sensor to verify the current readings. The current readings from the Fluke 289 and Monnit Alta are shown in Table 2. The current readings agree to within +/- 0.20 mA.

Table 2. Monnit Alta analog input verification results.

Time	Fluke 289	Monnit Alta	Difference
Low speed	8.12	8.06	0.06
Medium speed	9.80	10.0	-0.20
High Speed	11.91	11.80	0.11

The readings from the full set-up were compared against airflow samples from a E Instruments VT 50 hotwire anemometer. For three fan speeds, 18 air speed measurements (3 measurement planes each 120^o apart and consisting of 6 measurements) were taken with the hotwire anemometer while simultaneously logging with the Monnit Alta meter. Results are shown in Table 3. There was reasonable agreement.

Table 2. Airflow set-up verification results.

	Low Speed [fpm]	Medium Speed [fpm]	High Speed [fpm]
	767	926	1062
	826	944	1141
	984	1082	1279
	984	1122	1299
	944	1062	1240
	905	1043	1141
	807	921	1046
	866	964	1052
	944	1082	1141
	984	1122	1181
	944	1043	1181
	885	1003	1141
	885	915	1043
	885	1003	1162
	885	1043	1182
	944	1062	1181
	925	1082	1181
	866	1062	1161
Hotwire ave:	*902*	*1027*	*1156*
Hotwire cfm:	*177*	*201*	*227*
Monnit cfm:	*178*	*216*	*247*
Difference [cfm]:	*-1*	*-15*	*-20*
Difference [%]:	*-0.8*	*-7.0*	*-8.2*

4 Indoor Air Temperature

Indoor air temperature was taken with Monnit Alta RH Sensor (that provides both relative humidity and temperature). It was installed with a solar screen because there was an adjacent south facing window.

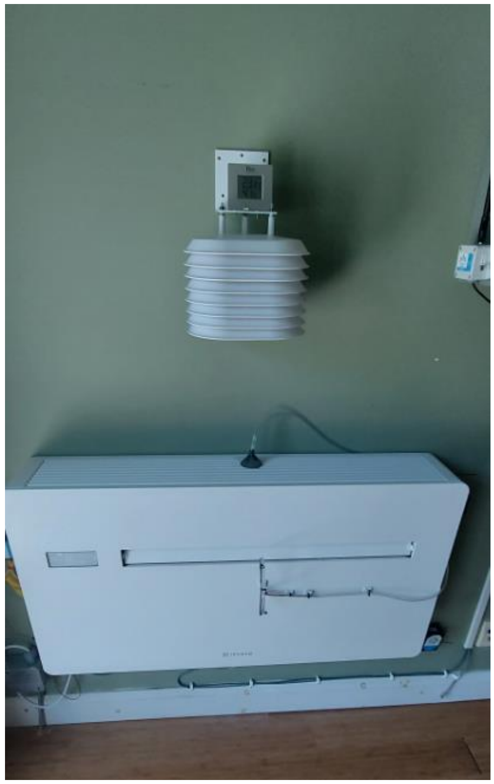


Figure 3. The indoor temperature/RH sensor was installed in a solar shield near the return to the heat pump.

4 Indoor Supply Air Temperature

The supply of the heat pump was measured using the same sensors as the outdoor intake and exhaust, an integrating grid of 5 Type K thermocouples read by a Monnit Alta thermocouple reader. It was verified using the same technique prior to deployment.

Table 2. Indoor supply temperature grid verification results.

Calibrator Set-point [^oC]	Monnit Alta Grid [^oC]
-10	-9.5
-5	-4.5
0	0.5
3	3.5
6	6.3
9	9.2
12	12.3
15	15.3
18	18.3
21	21.1
24	24.5
27	27.3

30	30.2
33	33.2
36	36.2
39	39.2
42	42.1

Figure 4. A linear grid of 5 sensors across the supply cross-section was used.

5 Outdoor Air Temperature

A Monnit Alta industrial RH sensor (which does temperature and RH) was installed outdoors in a solar screen and used for the outdoor temperature measurements (Figure 5).

Figure 5. The outdoor temperature sensor was installed in a solar screen above and adjacent to the intake and exhaust of the heat pump.

To verify the readings of the outdoor and indoor temperature sensors they were simply compared against eachother, both sitting indoors in room temperature and also placed in a fridge. When left indoors at room temperature the sensors read and 24 °C and 24.2 °C, for the indoor and outdoor sensors respectively. When left in the fridge, the read 5 °C and 4.7 °C respectively.

6 Electrical Energy Consumption

Electrical energy consumption was measured with an Acurev 1311 paired with a Monnit Alta pulse counter (MNS2-9-W2-PC-01-SW). It was verified by installing a Fluke 1730 logger in parallel with it and logging energy consumption over approximately one day of operation. It was possible to directly read the LCD display of the Acurev showing the totalized energy consumption, and also read the pulse recorded by the pulse counter (the Acurev was configured for 1000 pulses per kWh). The verification showed agreement with the Acurev and Fluke to within 1.5%.

Table 2. Energy meter verification results.

Device	Start [KWh]	End [kWh]	Consumption [kWh]
Acurev	371.54	380.176	8.636
Fluke	0	8.768	8.768
Monnit pulses	108344	116972	8628