

CEE 243 Week-3: Predicting and Measuring Building Energy Use

Wednesday: Energy Performance

W-4 Homework: announcement today

Homework for last week

Do a simple energy analysis of a (simple) building

1. Start

- Show and describe a simple BIM
- Make assumptions: location in the world; orientation; uses; ...

2. Predict energy use:

- choose an energy analysis tool, e.g.,
<http://www.stanford.edu/class/cee111/Labs/Lab4.htm>

3. Make a design change in your BIM that you predict should affect energy use, e.g., window area ratio, wall material type

- Annotate 3D renderings to show design differences

4. Compare predicted energy for baseline and intervention BIMs

- Annotate to show and explain differences

Some data

RESULTS TABLE FOR FLOW SETPOINT - EXHAUST CONSTANT VOLUME BOX								C of Variation
Point ID	Device	Point Type	Unit	Min	Max	Avg	STDDEV	
142	ECVB_56	AirFlowRateSetpoint	CFM	1850	1850	1850.00	0.00	0.00
145	ECVB_56	AirFlowRateSetpoint	CFM	1901	1901	1901.00	0.00	0.00
148	ECVB_56	AirFlowRateSetpoint	CFM	1199	1199	1199.00	0.00	0.00
151	ECVB_56	AirFlowRateSetpoint	CFM	392	2894	1829.58	54.97	0.03
154	ECVB_56	AirFlowRateSetpoint	CFM	790	790	790.00	0.00	0.00
157	ECVB_56	AirFlowRateSetpoint	CFM	839	839	839.00	0.00	0.00
160	ECVB_56	AirFlowRateSetpoint	CFM	621	621	621.00	0.00	0.00
163	ECVB_56	AirFlowRateSetpoint	CFM	1850	1850	1850.00	0.00	0.00
166	ECVB_56	AirFlowRateSetpoint	CFM	879	879	879.00	0.00	0.00
169	ECVB_56	AirFlowRateSetpoint	CFM	1799	1799	1799.00	0.00	0.00
172	ECVB_56	AirFlowRateSetpoint	CFM	301	301	301.00	0.00	0.00
359	ECVB_12	AirFlowRateSetpoint	CFM	371	371	371.00	0.00	0.00
362	ECVB_12	AirFlowRateSetpoint	CFM	231	231	231.00	0.00	0.00
386	ECVB_34	AirFlowRateSetpoint	CFM	350	350	350.00	0.00	0.00
389	ECVB_34	AirFlowRateSetpoint	CFM	301	301	301.00	0.00	0.00
392	ECVB_34	AirFlowRateSetpoint	CFM	82.004	1350	1349.99	3.32	0.00
395	ECVB_34	AirFlowRateSetpoint	CFM	0	600	600.00	1.57	0.00
398	ECVB_34	AirFlowRateSetpoint	CFM	82.004	1100	1099.99	2.66	0.00
401	ECVB_34	AirFlowRateSetpoint	CFM	0	901	900.99	2.36	0.00
404	ECVB_34	AirFlowRateSetpoint	CFM	0	1799	4.70	1798.99	382.60
426	ECVB_34	AirFlowRateSetpoint	CFM	2	1799	1798.99	4.70	0.00

Some data

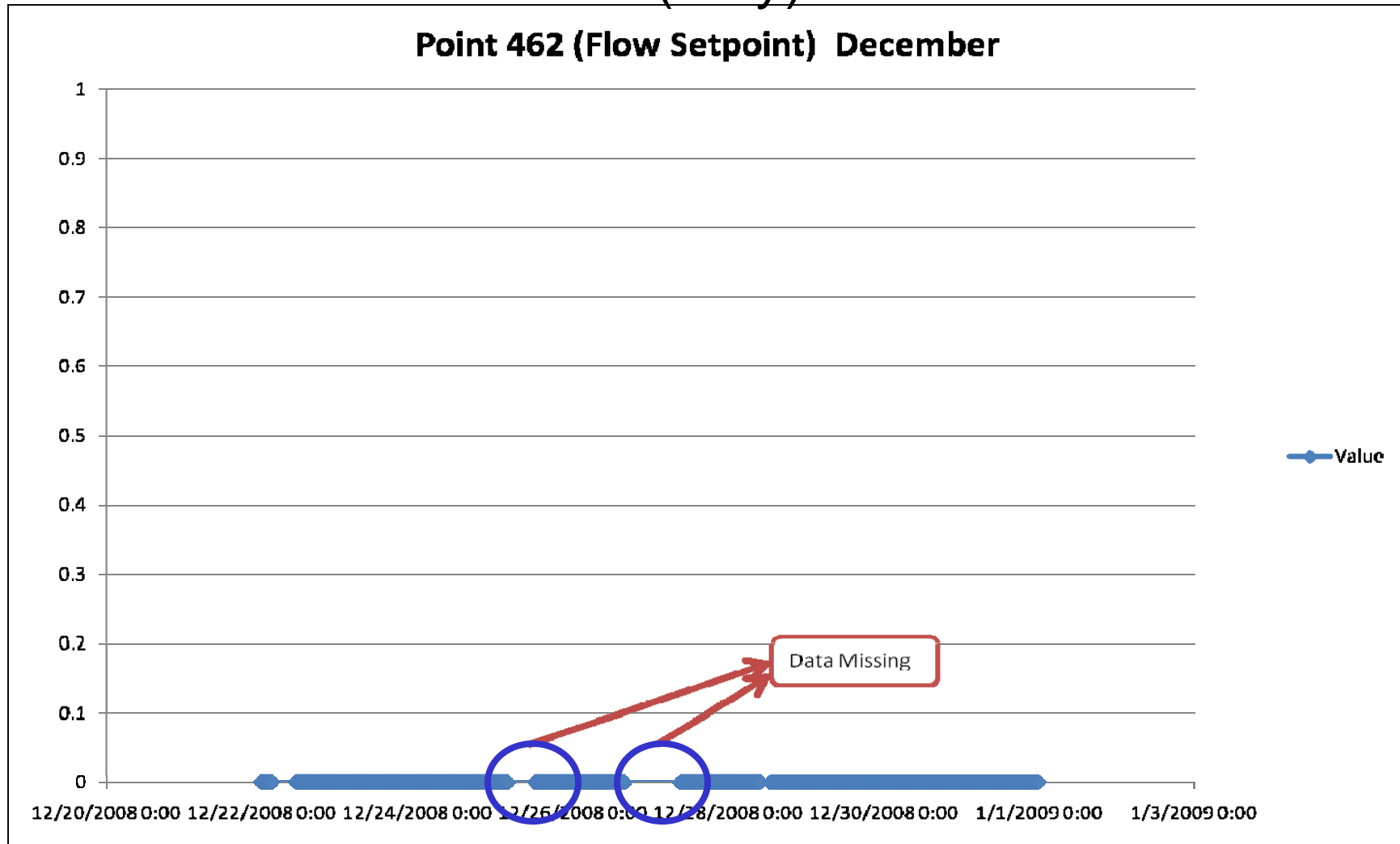
Point	Max	Min	Count	Average	Standard Deviat	Cv
140	3547	0	147256	1834.36	58.97	0.03
143	3066	0	147254	1875.97	50.53	0.03
146	1653	0	147253	1180.71	37.65	0.03
149	400	15	147241	298.12	10.34	0.03
152	1208	0	147242	782.02	24.01	0.03
155	1235	0	147237	823.66	25.60	0.03
158	585	0	147230	433.47	18.00	0.04
161	2894	392	147226	1829.23	54.86	0.03
164	1377	0	147219	871.76	30.51	0.03
167	2477	271	147204	1776.82	49.49	0.03
170	585	0	147200	299.47	9.09	0.03
357	473	0	147663	369.99	10.59	0.03
360	500	0	147672	231.06	7.22	0.03
384	460	0	147715	346.89	16.62	0.05
387	347	0	147719	298.91	13.48	0.05
390	2144	0	147720	1340.64	65.98	0.05
393	703	0	147721	585.61	25.96	0.04
396	1521	0	147724	1089.75	47.47	0.04
399	1316	0	147735	894.44	35.45	0.04
402	2324	0	147737	1783.31	82.46	0.05
424	2524	0	147763	1788.20	78.42	0.04
427	2714	0	147764	1787.85	72.82	0.04
430	2492	0	147762	1785.35	67.95	0.04
433	2416	0	147761	1788.57	73.16	0.04
436	1252	55.3	147763	894.56	35.88	0.04
439	778	0	147759	619.75	30.66	0.05
460	818	0	147781	334.41	291.91	0.87

Some data

- How to interpret 0: 0 or missing?

RESULTS TABLE FOR FLOW SETPOINT - EXHAUST CONSTANT VOLUME BOX								C of
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142	ECVB_56	AirFlowRateSetpoint	CFM	1850	1850	1850.00	0.00	0.00
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163	ECVB_56	AirFlowRateSetpoint	CFM	1850	1850	1850.00	0.00	0.00
166	ECVB_56	AirFlowRateSetpoint	CFM	879	879	879.00	0.00	0.00
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Example graph: DA system shows performance (only)



Example comment: Example graph: DA system shows performance (only)

Point 426 December

Timestamp Value

12/26/2008 15:57	0
12/26/2008 15:58	0
12/26/2008 15:59	0
12/26/2008 16:00	0
12/26/2008 16:03	0
12/27/2008 9:19	0
12/27/2008 9:21	0
12/27/2008 9:22	0
12/27/2008 9:23	0

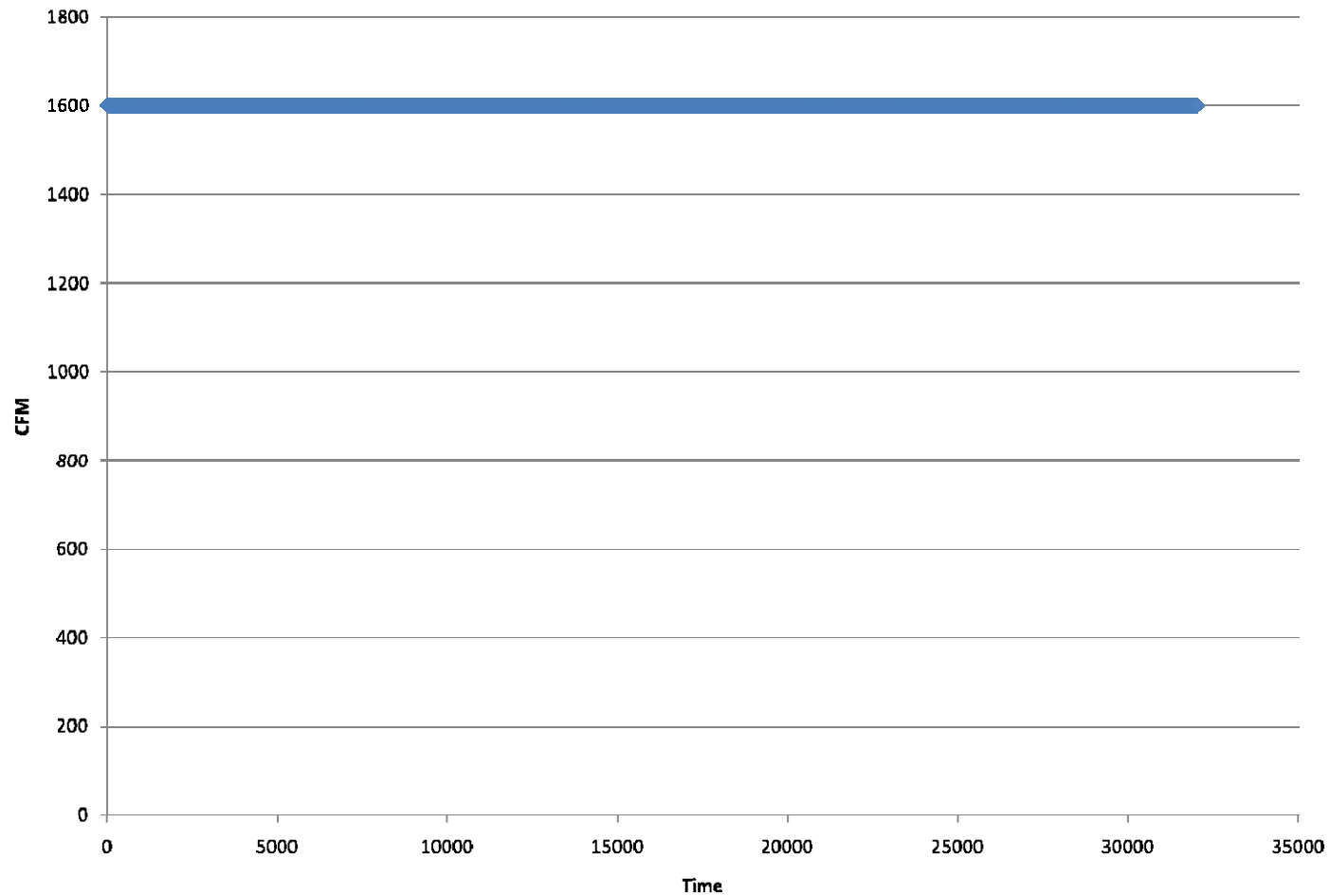
Data Missing Between
12/26/2008 16:04 and 12/27/2008 9:19

Example data table

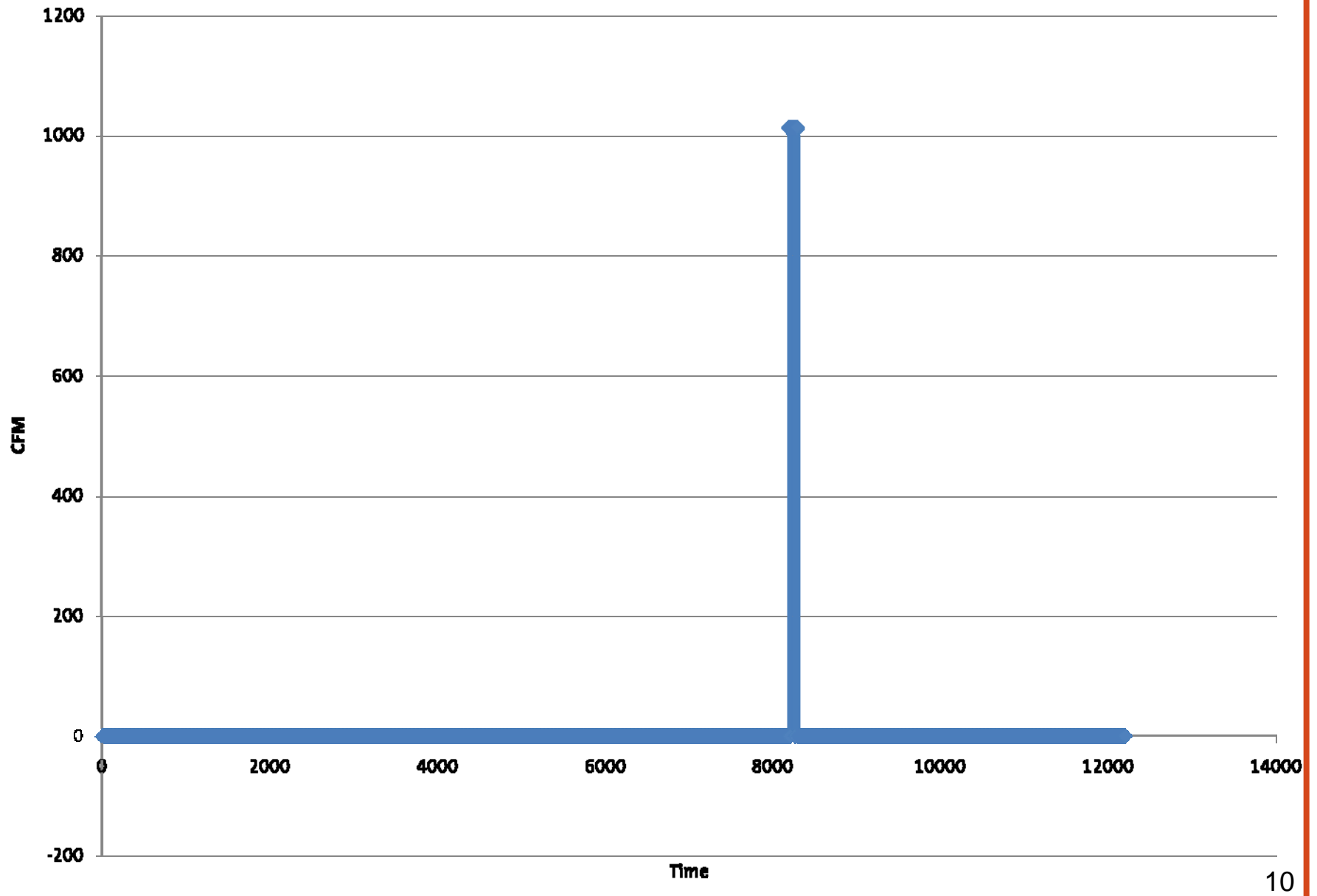
Point	Device	Max	Min	Avg	STDDEV	Count	First Timestep	Last Timestep
4	CVB_3_4	1621	67.028	1620.989	4.0482	147352	'2008-12-21 23:36:45'	'2009-04-07 22:34:00'
8	CVB_3_1	400	400	400	0	147349	'2008-12-21 23:36:46'	'2009-04-07 22:47:00'
15	CVB_3_2	59	19	36.82524	12.30248	147343	'2008-12-21 23:36:47'	'2009-04-07 22:50:00'
20	CVB_3_5	720	720	720	0	147329	'2008-12-21 23:36:48'	'2009-04-07 22:51:01'
25	CVB_3_7	750	750	750	0	147326	'2008-12-21 23:36:49'	'2009-04-07 22:52:01'
30	CVB_3_8	1000	1000	1000	0	147321	'2008-12-21 23:36:50'	'2009-04-07 22:54:01'
35	CVB_3_9	481	481	481	0	147303	'2008-12-21 23:36:51'	'2009-04-07 22:57:01'
40	CVB_3_11	1081	1081	1081	0	147292	'2008-12-21 23:36:52'	'2009-04-07 23:00:02'
45	CVB_3_12	265	265	265	0	147273	'2008-12-21 23:36:53'	'2009-04-07 23:01:02'
52	CVB_3_6	1621	1621	1621	0	147283	'2008-12-21 23:36:54'	'2009-04-07 23:02:02'
54	CVB_3_13	1600	1600	1600	0	147288	'2008-12-21 23:36:54'	'2009-04-07 23:04:02'
59	CVB_3_15	400	400	400	0	147290	'2008-12-21 23:36:55'	'2009-04-07 23:08:03'
64	CVB_3_19	1725	1725	1725	0	147284	'2008-12-21 23:36:56'	'2009-04-07 23:06:03'
69	CVB_3_20	239	239	239	0	147270	'2008-12-21 23:36:57'	'2009-04-07 23:10:03'
74	CVB_3_25	301	301	301	0	147265	'2008-12-21 23:36:58'	'2009-04-07 23:11:03'
253	CVB_2_10	350	350	350	0	147561	'2008-12-21 23:46:33'	'2009-04-07 23:12:00'
260	CVB_2_13	441	441	441	0	147570	'2008-12-21 23:46:34'	'2009-04-07 23:14:00'
265	CVB_2_14	231	231	231	0	147589	'2008-12-21 23:46:35'	'2009-04-07 23:17:00'
272	CVB_2_17	1301	1301	1301	0	147592	'2008-12-21 23:46:37'	'2009-04-07 23:19:01'

Example graph: DA system shows performance (only)

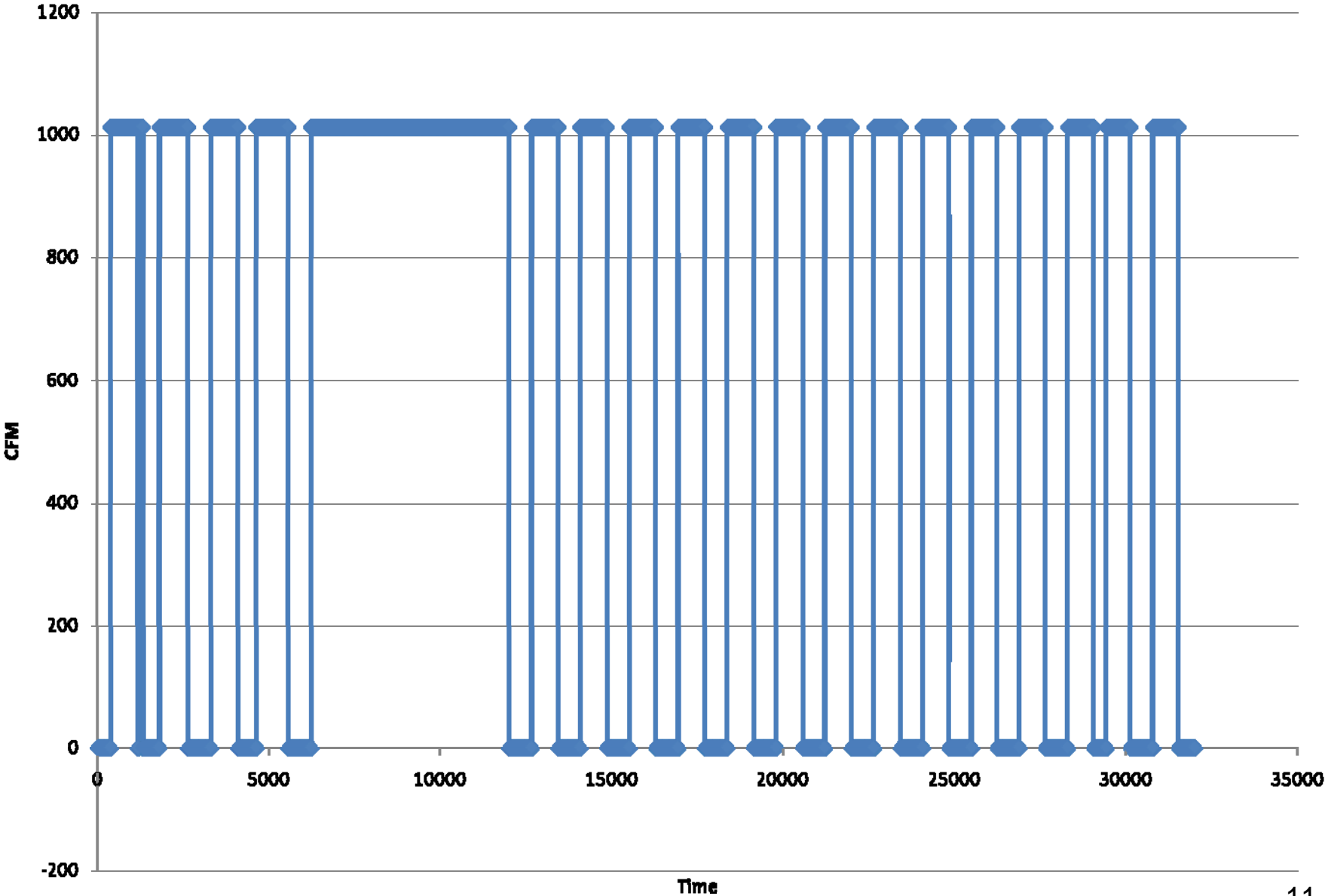
Point 54 March



Point 555 December



Point 555 February



Data Explanation

- For most of the basement data points, airflow set point is constant throughout the measured time frame
 - Within these points, there are a few with a slight deviation, but this must only be a few outliers probably from erroneous measurements *because the standard deviation is very small*
- Points not in the basement vary more, fluctuating between a maximum value and zero
 - The basement has labs there, so there may be a stipulation to keep a constant airflow throughout the day and night at all times in order to not interfere with experiments.
 - On the other floors the air may be turned off at night or certain days.

Data and comments

Point #	Type	Point	Max	Min	Average	Count	StdDev	min time	max time
1	SpaceTemp Setpoint	4580006	73	69.8	72.8	147687	0.298	12/20/2004 23:47	4/6/2005 22:08
2		4580008	70.8	69.4	69.6	147687	0.456	12/20/2004 23:47	4/6/2005 22:10
3		6370002	75	72	74.9	147429	0.207	12/20/2004 23:52	4/6/2005 22:10
4		6370004	71.1	71.1	71.1	147430	0	12/20/2004 23:52	4/6/2005 22:11
5		6370006	74.7	72	72	147431	0.146	12/20/2004 23:52	4/6/2005 22:11
6		6370008	72	71.9	71.97	147431	0.048	12/20/2004 23:52	4/6/2005 22:11
7		6390002	72.1	71.9	72	147417	0.042	12/20/2004 23:52	4/6/2005 22:12
8		6390004	76.7	70.1	76	147417	1.389	12/20/2004 23:52	4/6/2005 22:12
9		6390006	72.1	72	72	147418	0.0368	12/20/2004 23:52	4/6/2005 22:14
10		6390008	75	69.1	73.7	147418	1.911	12/20/2004 23:52	4/6/2005 22:14
11		6390010	75	69.1	73.7	147419	1.52	12/20/2004 23:52	4/6/2005 22:16
12		6410002	75	71.4	72.4	147389	0.849	12/20/2004 23:52	4/6/2005 22:16
13		6410004	72.2	72.2	72.2	147390	0	12/20/2004 23:52	4/6/2005 22:16
14		6410006	73.4	69.9	72.3	147391	0.58	12/20/2004 23:52	4/6/2005 22:16
15		6410008	86.5	7	72.6	147391	3.75	12/20/2004 23:52	4/6/2005 22:17
16		6430002	75	74.7	74.81	147367	0.036	12/20/2004 23:52	4/6/2005 22:17
17		6430004	71.7	71.7	71.7	147367	0	12/20/2004 23:52	4/6/2005 22:17
18		6430006	74.9	74.8	74.9	147368	0.049	12/20/2004 23:52	4/6/2005 22:18
19		6450002	75	73.5	74.6	147333	0.489	12/20/2004 23:52	4/6/2005 22:18
20		6450004	74.6	69.1	72.08	147334	1.97	12/20/2004 23:52	4/6/2005 22:18

The unexpected data contains:

- Points in which the control values did not change during the measured time interval
- Points that contains unrealistic low control values.

Almost 40% (15/40) of the points have unexpected values so I do not consider all the data to be reliable. However, the majority of the points (60%) have reasonable and similar values so those points do contain believable data.

The typical and atypical points I selected to plot between Dec-Mar are the ones shown in green. These points seemed to be good examples of typical and atypical points, but the graphs and the data do not show the irregularities in the atypical point. I checked this inconsistency in the database, and even though the min(value) search revealed that the atypical point had a 0, that 0 is not in the data. I also checked that the data matched the count number of the point, and it did. The count is 147209, and when I compiled the entire data there were 147209 entries. I wanted to see the difference between the typical and atypical points, but I could not determine what was the source of the inconsistency in the data.

The meaning of the graphical data shown in the next pages represents adjustments made to temperature set points. As can be seen from the graphs the adjustments were typically very small, sometimes adjusting less than a degree in a 1-month period.

One recommendation to the building operator: To check the data collection sensors and equipment to make sure all the data is being recorded properly.

Comments

An energy cost represents unexpected data.

Point	Tag	Value	Min	Max	Average	Count	StdDev	Min time	Max time
441000	10	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	11	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	12	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	13	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	14	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	15	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	16	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	17	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	18	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	19	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	20	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	21	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	22	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	23	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	24	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	25	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	26	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	27	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	28	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	29	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	30	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	31	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	32	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	33	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	34	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	35	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	36	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	37	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	38	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	39	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	
441000	40	75.0	75.0	75.0	14720	0.00	18/05/2004 23:10	16/05/2005 23:10	

The unexpected data contains:
 - Points in which the control values did not change during the measured time interval
 - Points that contains unrealistic low control values.

Points that contains unrealistic low control values:
 - Almost 40% (15/40) of the points have unexpected values so I do not consider all the data to be reliable.
 - However, the majority of the points (26%) have realistic and similar values so these points do contain believable data.

The legend and legend points I selected to get additional data. See the view screen to graph.

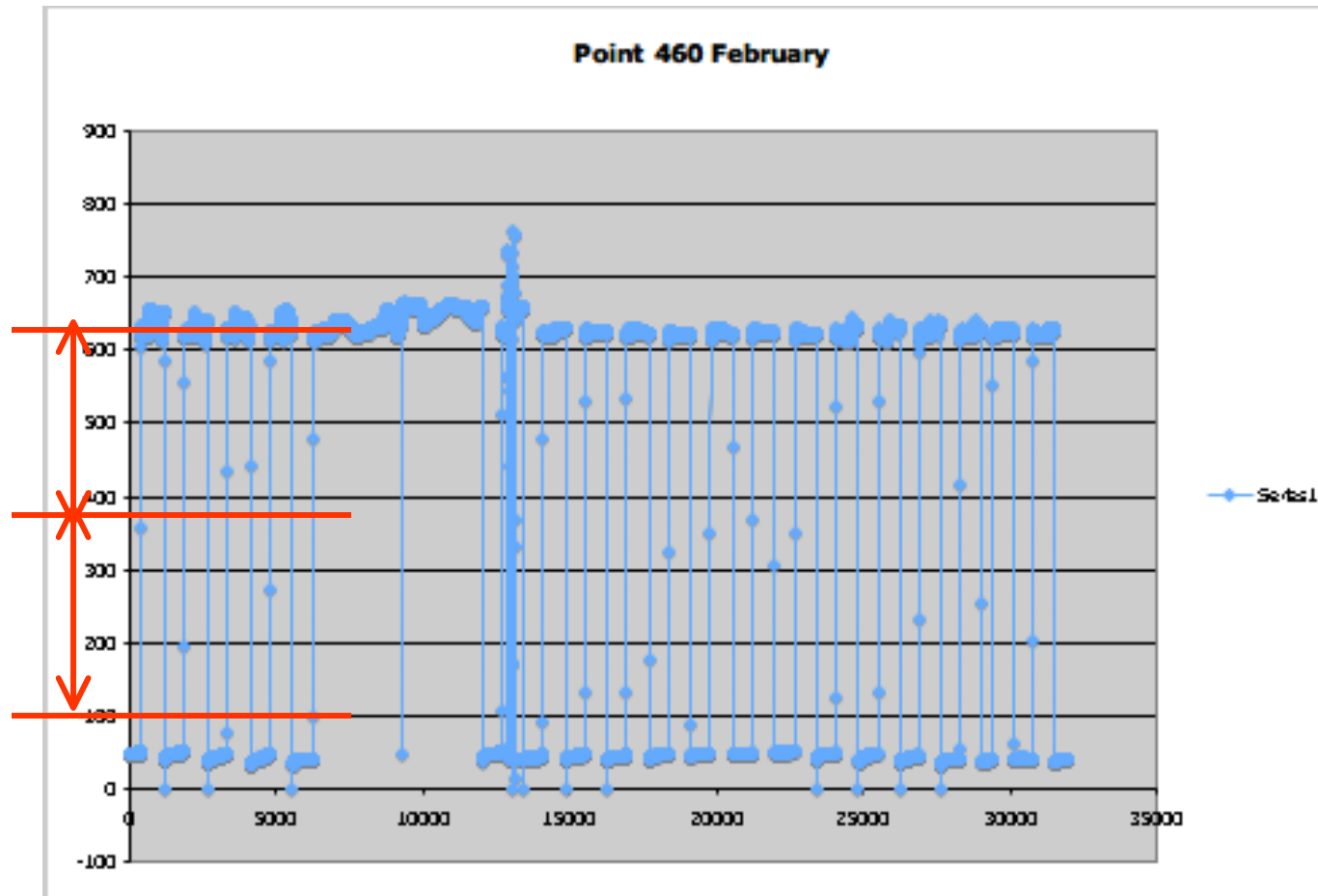
These points seemed to be good examples of typical and atypical points, but the graphs and the data do not show the irregularities in the atypical points.
 I checked the irregularities in the graphs, and even though the irregularities seemed to be the same, the data did not show the irregularities in the data.
 I also checked that the data matched the count number of the points, and it did. The count is 14720, and when I compiled the entire data there were 14720 entries.
 I wanted to see the difference between the typical and atypical points, but I could not determine what was the source of the inconsistency in the data.

The meaning of the graphical data shown in the real graph represents adjustments made to temperature set points.
 As can be seen from the graphs, the adjustments were typically very small, sometimes adjusting less than a degree in a 1-month period.

One recommendation to the building operator: To check the data collection sensors and equipment to make sure all the data is being recorded properly.

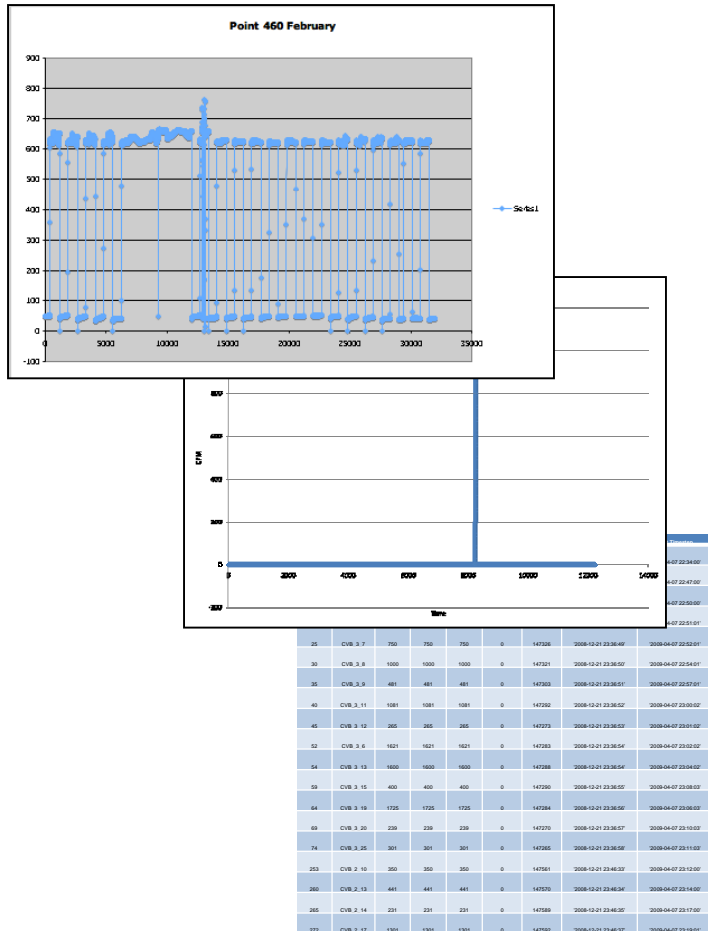
- Legend explains colors
- Explanation for why data unexpected:
 - Points in which the control values did not change during the measured time interval
 - Points that contains unrealistic low control values.
- Almost 40% (15/40) of the points have unexpected values so I do not consider all the data to be reliable.
- Adjustments were typically very small, sometimes adjusting less than a degree in a 1-month period.
- One recommendation to the building operator: To check the data collection sensors and equipment to make sure all the data are being recorded properly.

$Cv = \text{Standard deviation} / \text{mean}$
 How to interpret these data?



Point	Max	Min	Count	Average	Standard Deviat	Cv
460	818	0	147781	334.41	291.91	0.87

What knowledge and information do need to interpret these data?



Background reading

- GSA 2009: "GSA Building Information Modeling Guide Series 05 – Energy Performance"





GSA energy performance objective

- Reduce facility energy use per square foot (including industrial and laboratory facilities) by 3 percent per year through the end of 2015 or by 30 percent by the end of FY 2015, relative to 2003 baseline
- Must construct all new facilities to be net zero energy buildings by 2030
- Exploring the use of BIM in energy modeling practices to strengthen the reliability, consistency, and usability of predicted energy use and energy cost results

Big deal!



Thermal zone for energy analysis

- Single **space** or group of indoor spaces that has uniform thermal load profiles and conditioning requirements.
- Comments:
 - a **space that can effectively be conditioned using one thermostat**
 - Thermal zoning of a building helps the engineer determine the number and type of HVAC systems required
 - Defining thermal zones requires engineering judgment
 - e.g., perimeter offices all facing a similar orientation (N, S, E, W), in separate thermal zones
 - Others for Y2E2 ? ...
 - Space-based energy modeling (normal BIM practice) assumes each space = thermal zone



Energy analysis limitations

- Geometric model transfer is imperfect.
 - building elements missing, misplaced, or deformed on transport from authoring to analysis tools
 - data transfer quality depends on quality of:
 - Building model (e.g., no missing elements or invalid wall connections)
 - BIM-authoring tool writer/exporter,
 - Data schema (e.g., IFC) used to clearly organize the information,
 - Building analysis tool translator/importer



Modeling methods

- In authoring tool, use native BIM elements for spaces, interior walls, exterior walls, doors, windows (including skylights), slabs, beams, columns, and shading devices
- Create window objects using Window tool in the BIM-authoring tool
 - Insert into a wall component and
 - Do not extend outside wall boundary



Space boundaries

- 1st level space boundaries typically correspond to “architectural” space boundaries,
 - defined from the perspective of a single space, irrespective of adjoining spaces.
- 2nd level space boundaries take into account adjacent spaces -- sometimes referred to as “thermal” space boundaries.
 - Adjacencies: Horizontal
 - Vertical

