



Ducted “Mini-split” Heat Pumps

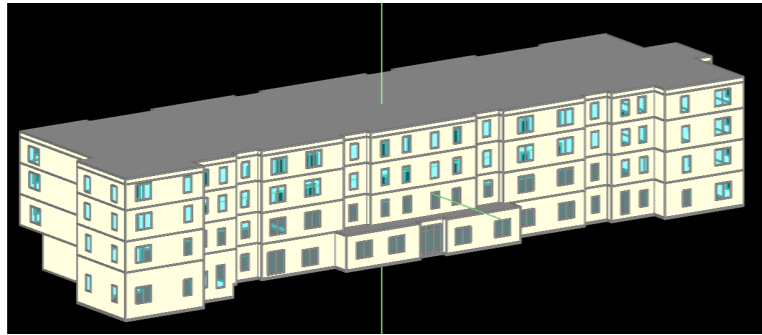
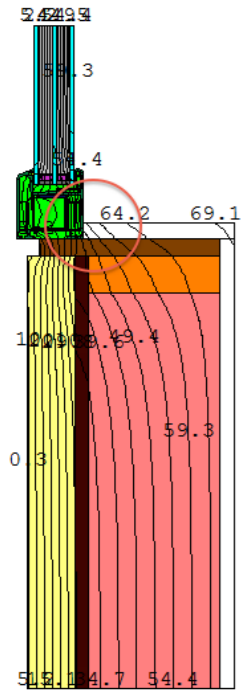
Design, Test, Monitor.
Lessons learned from
~200 systems

Benjamin Knopp +
John Semmelhack

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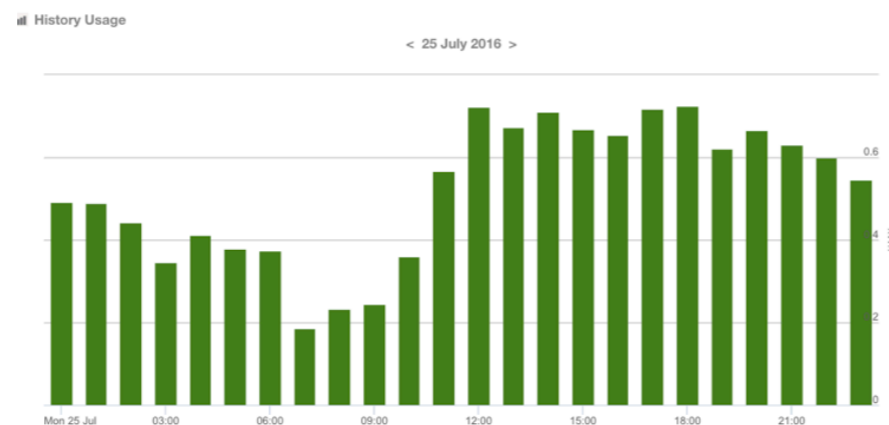
Evidence-based Continuous Improvement



Design

Test + verify

Measure + monitor



Project Examples











200

201







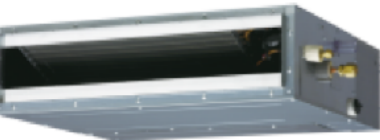
HEATING DATA

SSZ140181A* / CA*F3131*6A* +TXV / MBR800**-1



	OUTDOOR AMBIENT TEMPERATURE																	
	65	60	55	50	47	45	40	35	30	25	20	17	15	10	5	0	-5	-10
MBh	22.6	21.4	20.2	18.8	18.0	17.4	16.2	14.9	12.8	11.8	10.9	10.3	9.9	8.9	7.9	6.9	5.9	4.8
ΔT	34.9	33.1	31.1	29.1	27.8	26.9	25.0	23.1	19.7	18.2	16.8	15.8	15.3	13.7	12.1	10.6	9.0	7.4
kW	1.56	1.53	1.50	1.47	1.45	1.44	1.41	1.38	1.39	1.36	1.32	1.31	1.29	1.26	1.23	1.20	1.17	1.14
Amps	7.0	6.5	6.1	5.7	5.5	5.4	5.1	4.9	4.7	4.5	4.2	4.1	4.1	3.9	3.6	3.4	3.2	2.9
COP	4.23	4.09	3.93	3.75	3.62	3.54	3.36	3.16	2.70	2.55	2.40	2.30	2.24	2.06	1.87	1.67	1.47	1.23
EER	14.5	14.0	13.4	12.8	12.4	12.1	11.5	10.8	9.2	8.7	8.2	7.9	7.6	7.0	6.4	5.7	5.0	4.2
Hi PR	385	369	355	339	331	325	312	300	287	274	263	257	252	243	234	224	216	208
Lo PR	149	138	129	118	112	108	99	88	80	71	62	58	56	47	41	34	30	24

MODEL: ARU12RLF

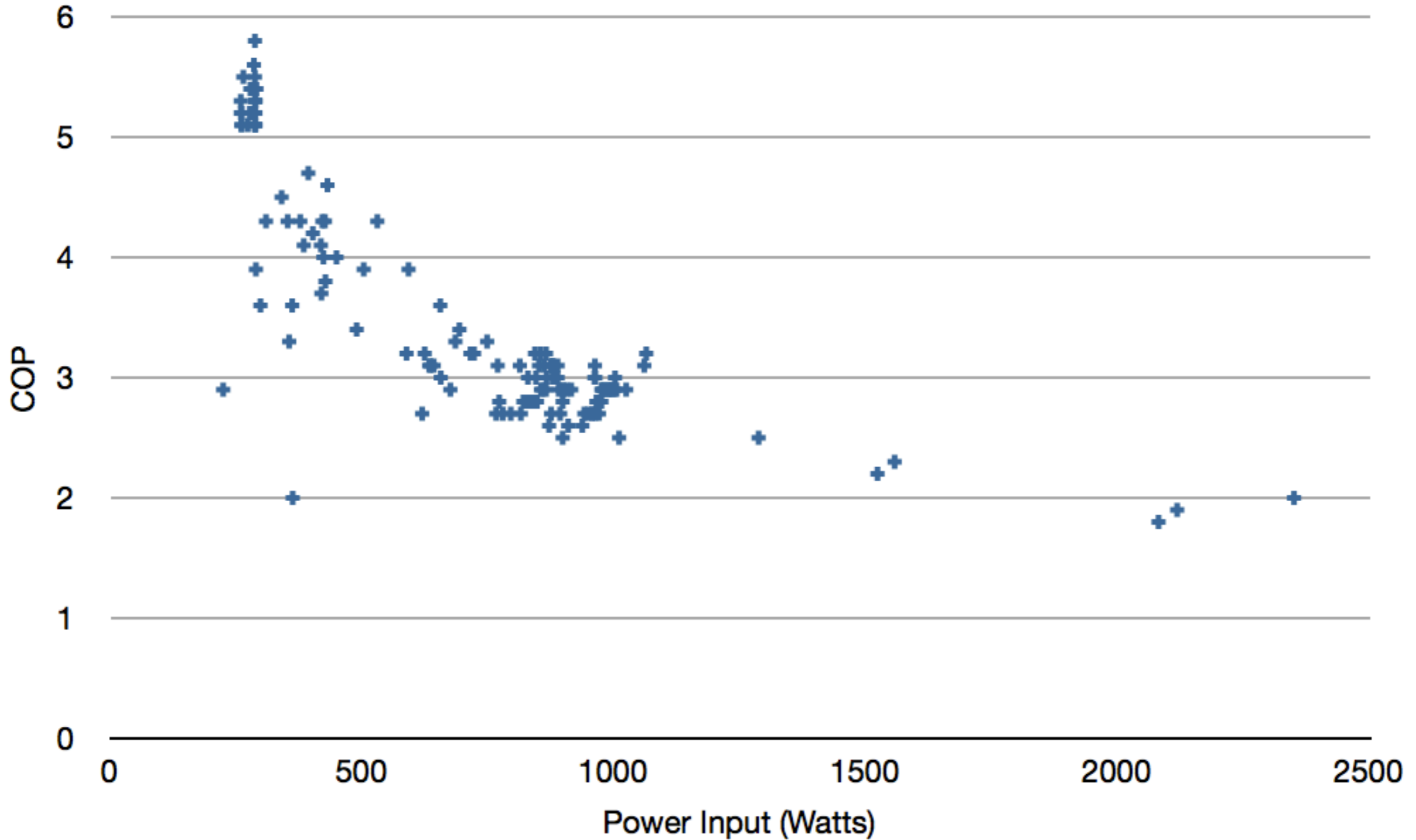


AFR	383
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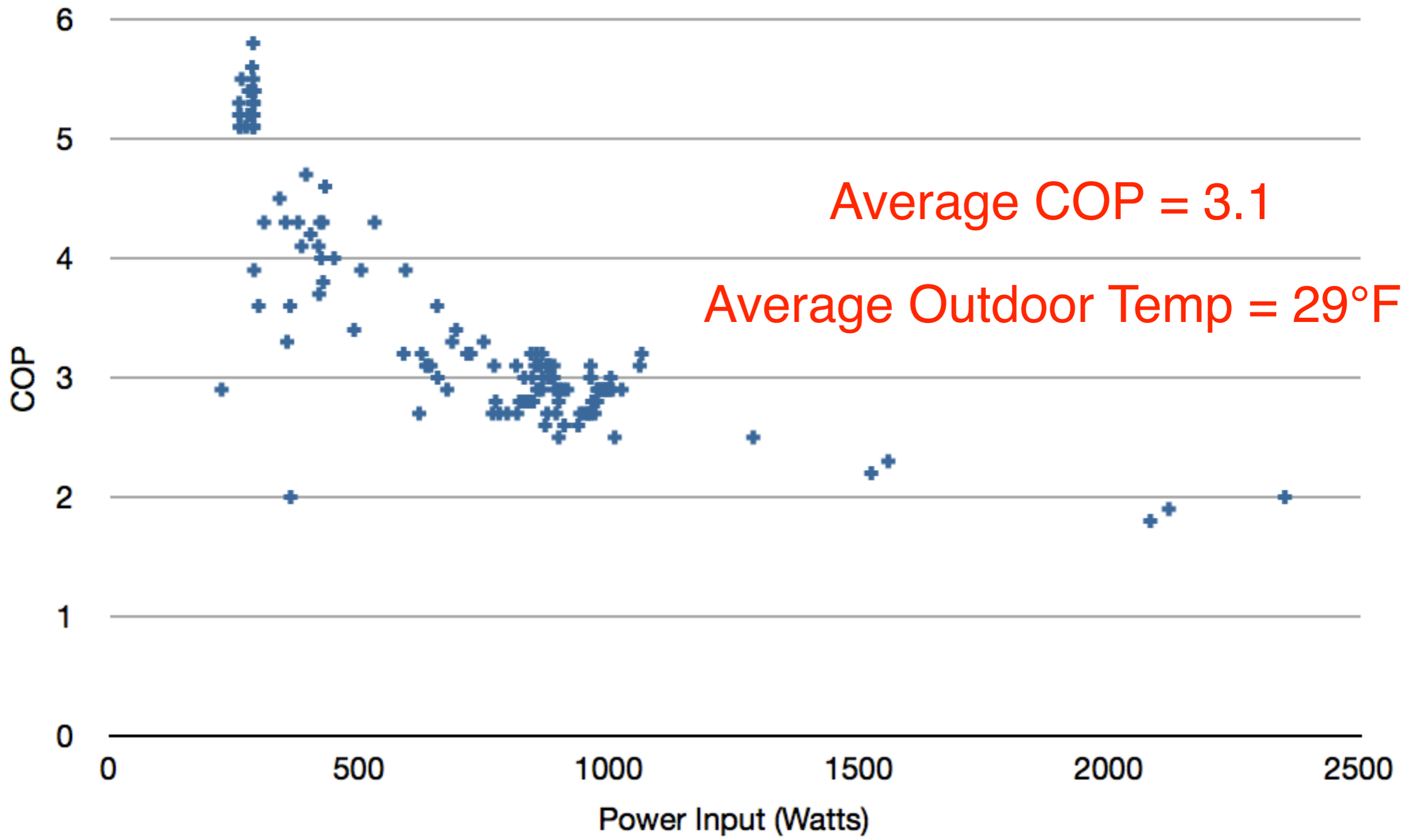
		Indoor temperature								
		°FDB		60		65		70		75
Outdoor temperature	°FDB	°FWB	TC	IP	TC	IP	TC	IP	TC	IP
	-5	-7	15.8	2.23	15.4	2.27	15.0	2.32	14.3	2.36
	5	3	17.6	2.16	17.2	2.21	16.8	2.25	15.9	2.34
	14	12	18.3	2.09	17.8	2.13	17.4	2.17	16.5	2.26
	23	19	19.2	2.01	18.7	2.05	18.2	2.10	17.3	2.18
	32	28	19.5	1.95	19.0	1.99	18.5	2.03	17.6	2.11
	41	37	19.7	1.86	19.2	1.90	18.8	1.94	17.8	2.02
	47	43	20.4	1.92	19.9	1.96	19.4	2.00	18.4	2.08
	50	47	22.5	1.94	22.0	1.98	21.4	2.02	20.4	2.10
	59	50	23.3	1.95	22.8	1.99	22.2	2.03	21.1	2.11

COP = 2.35 (and 70% more capacity)

Power Input (Watts) and Heating COP



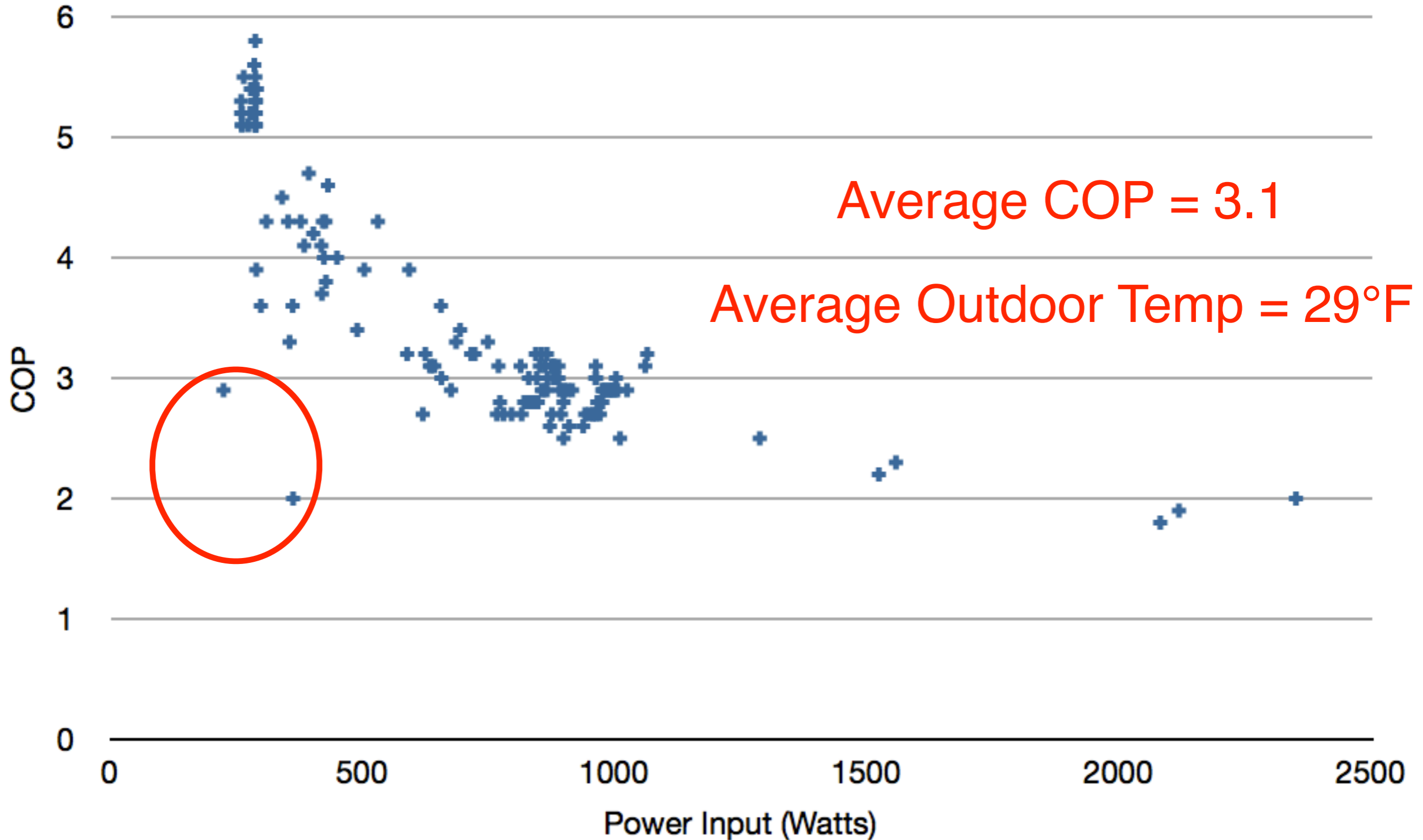
Power Input (Watts) and Heating COP



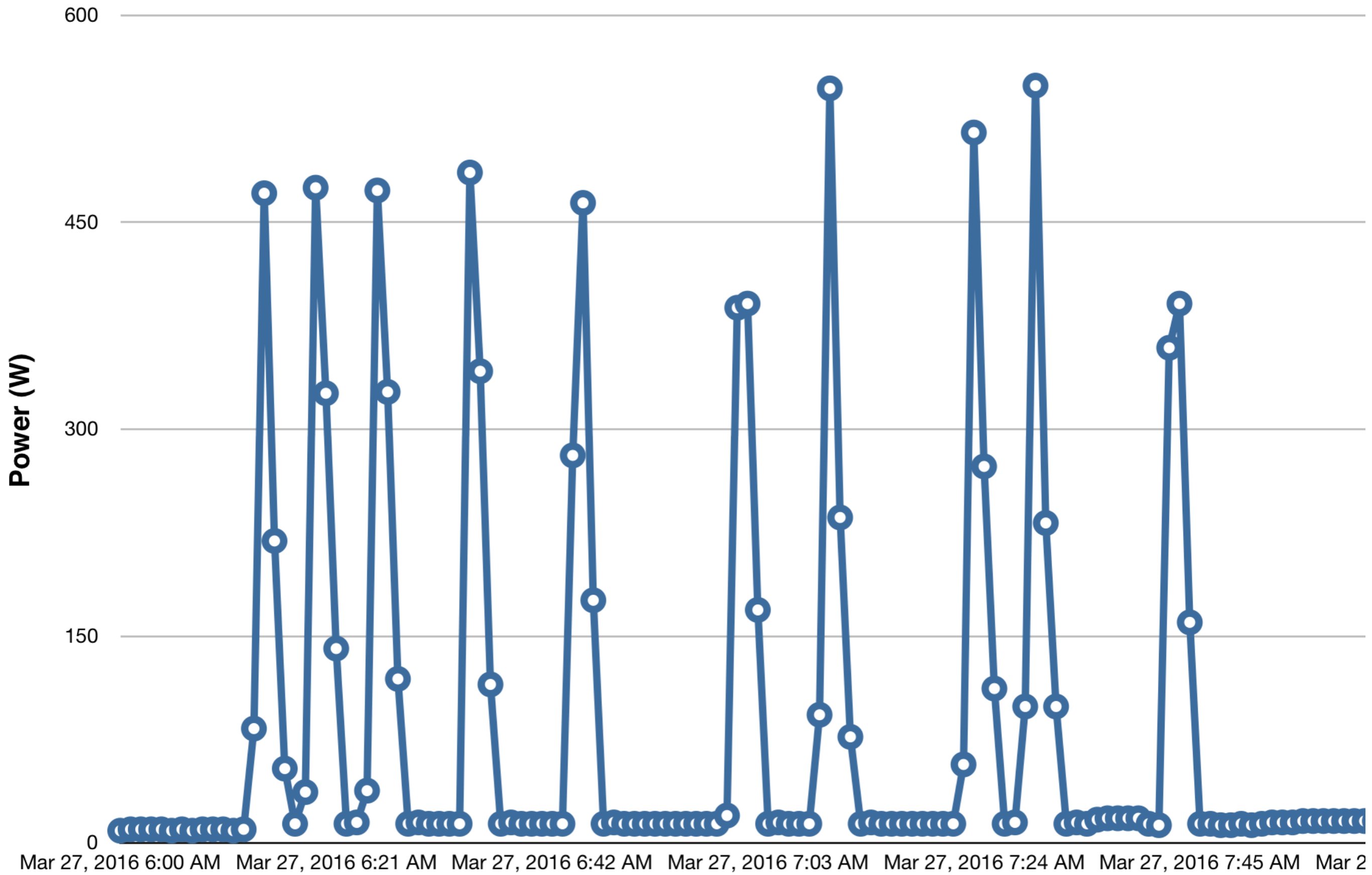
Average COP = 3.1

Average Outdoor Temp = 29°F

Power Input (Watts) and Heating COP



Short-cycling

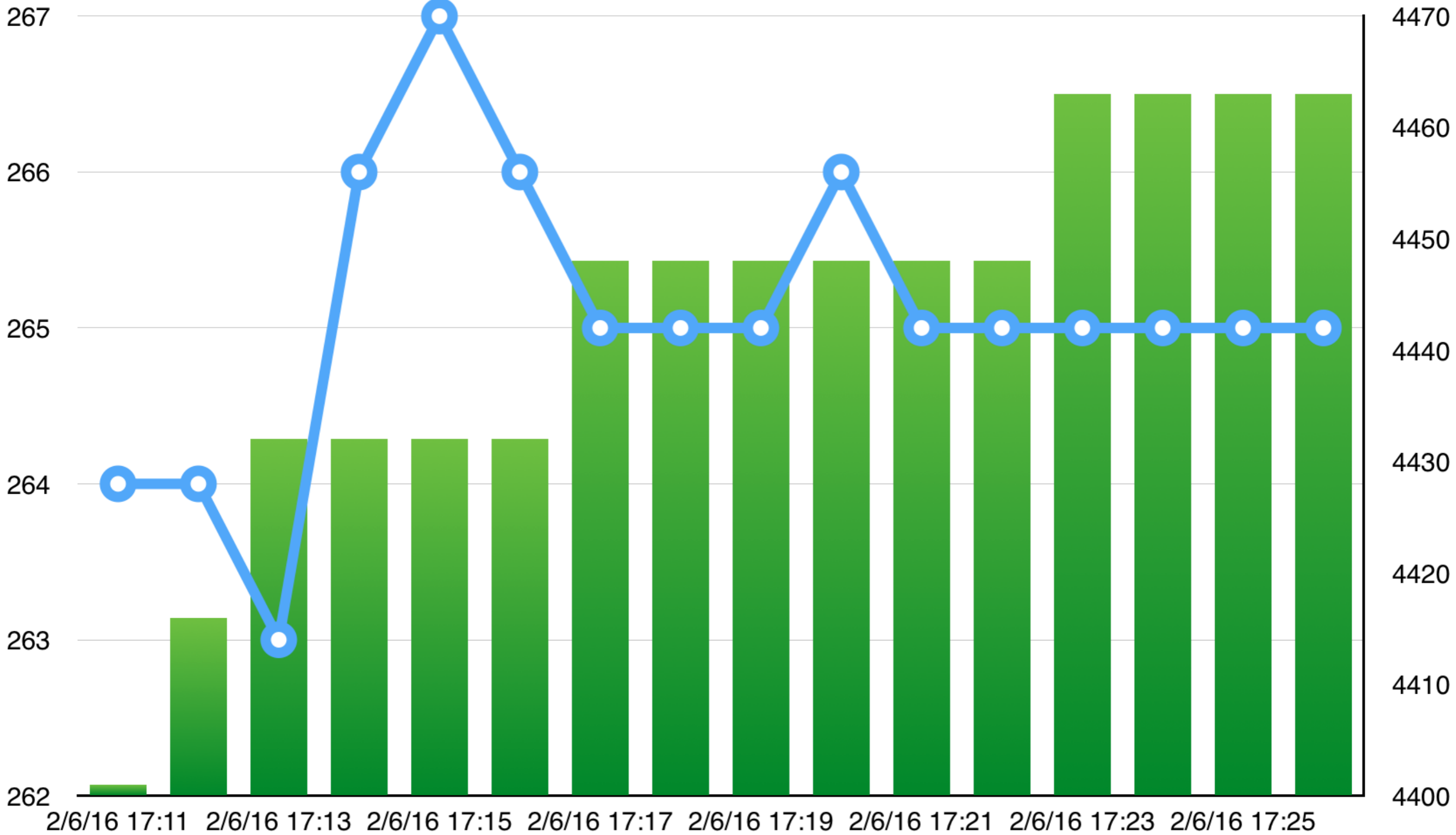


			ARU9RLF
Cooling	Rated	kW	2.64
		Btu/h	9,000
	Min.–Max.	kW	0.90–3.60
		Btu/h	3,100–12,000
Heating	Rated	kW	3.52
		Btu/h	12,000
	Min.–Max.	kW	0.90–5.28
		Btu/h	3,100–18,000

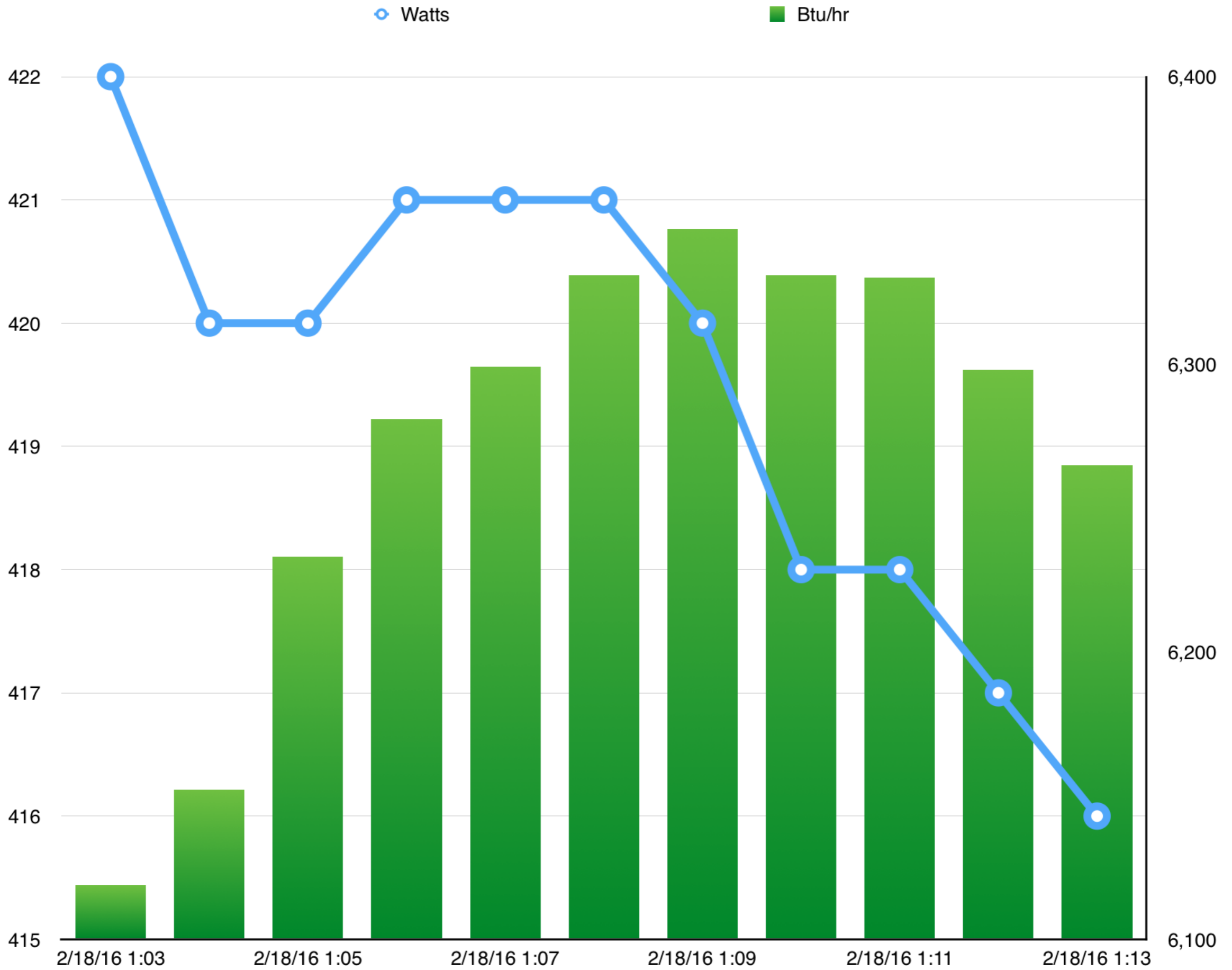
Minimum output - "mild"

Watts

Btu/hr

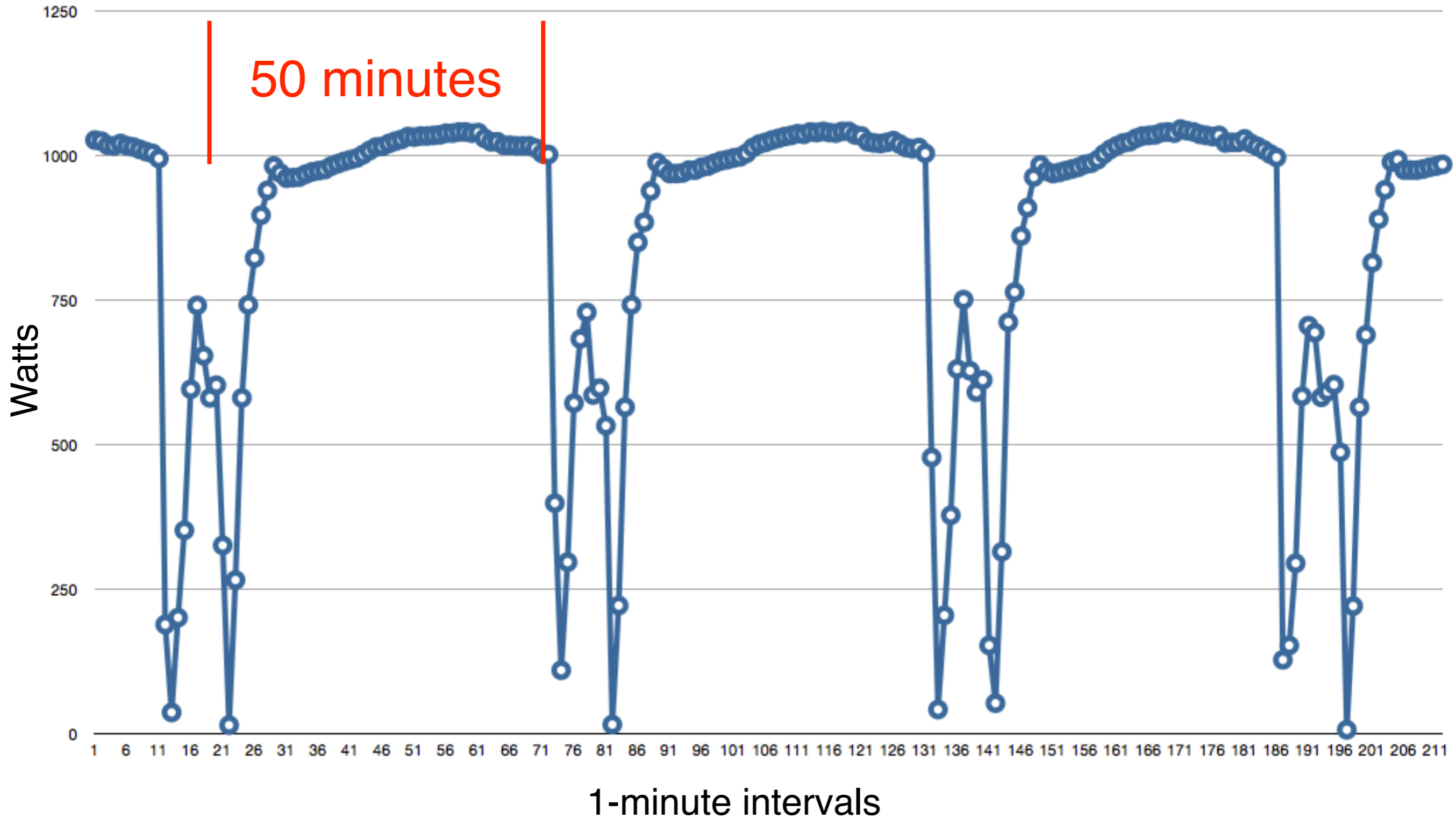


Minimum output - "colder"

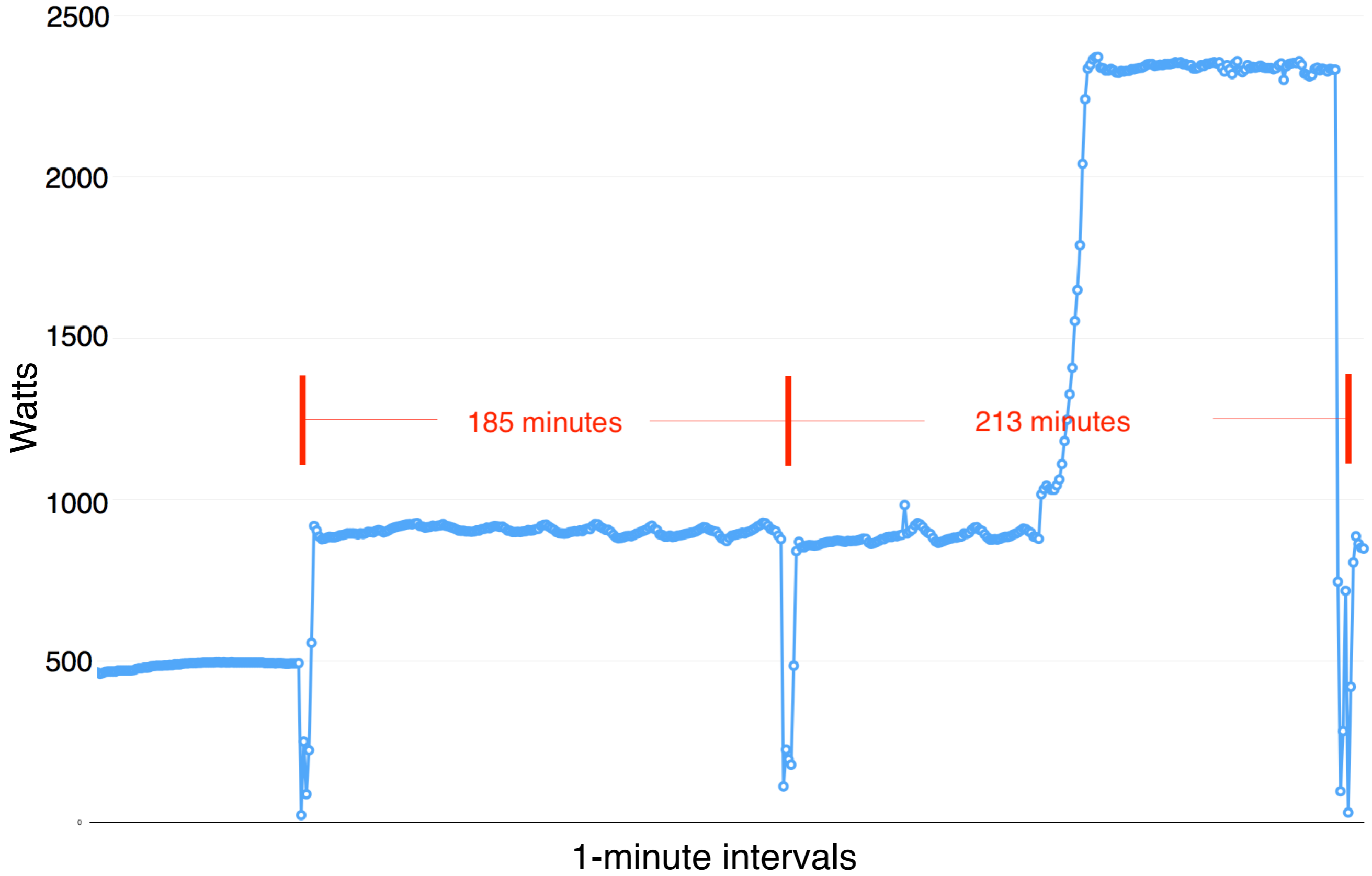


Defrost - "worst case"

4 Defrost Cycles - 2/16/16 3:00am to 6:30am, ODT ~33F, DP~31F

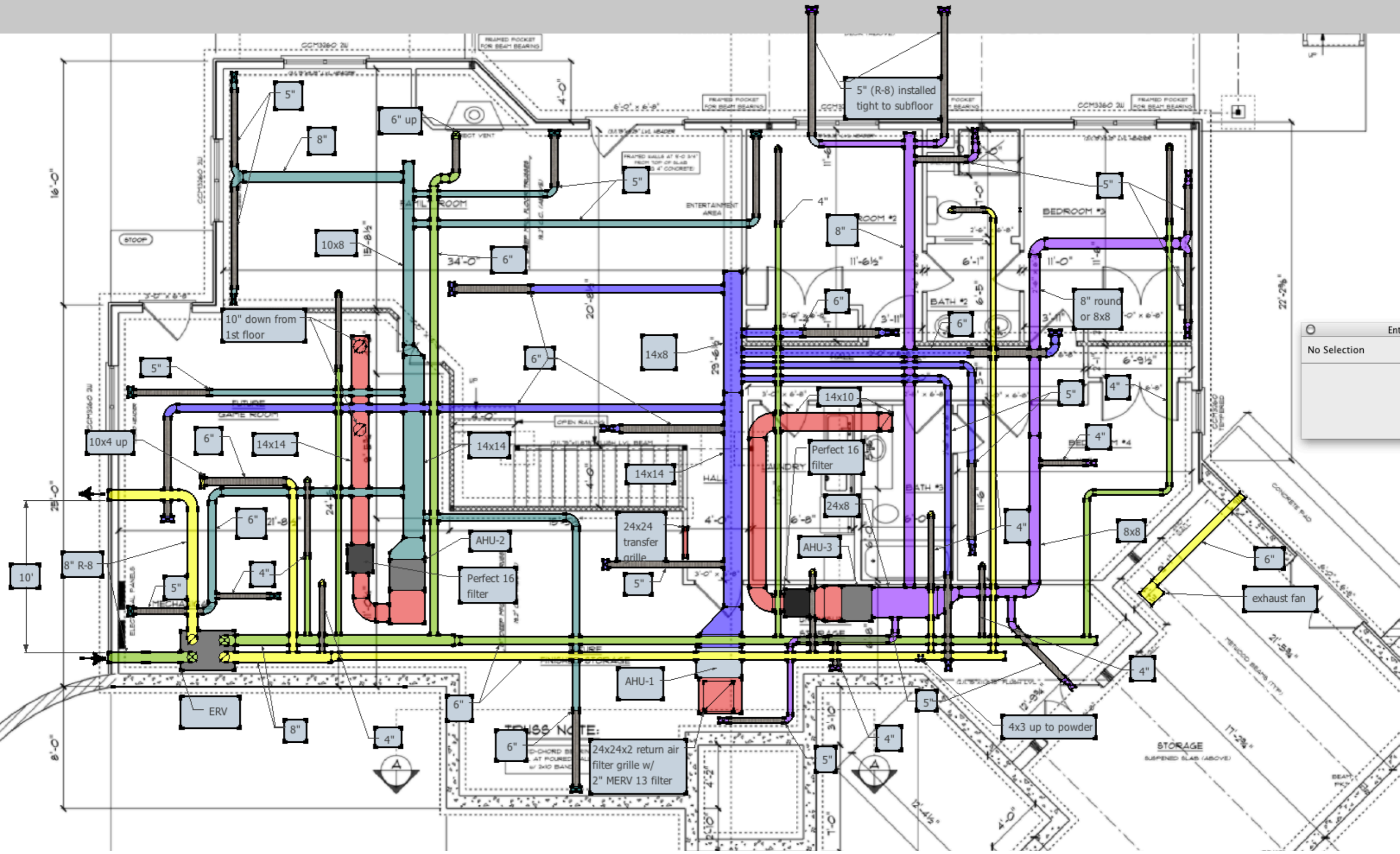


Defrost - "cold" outdoor temperatures (10F)

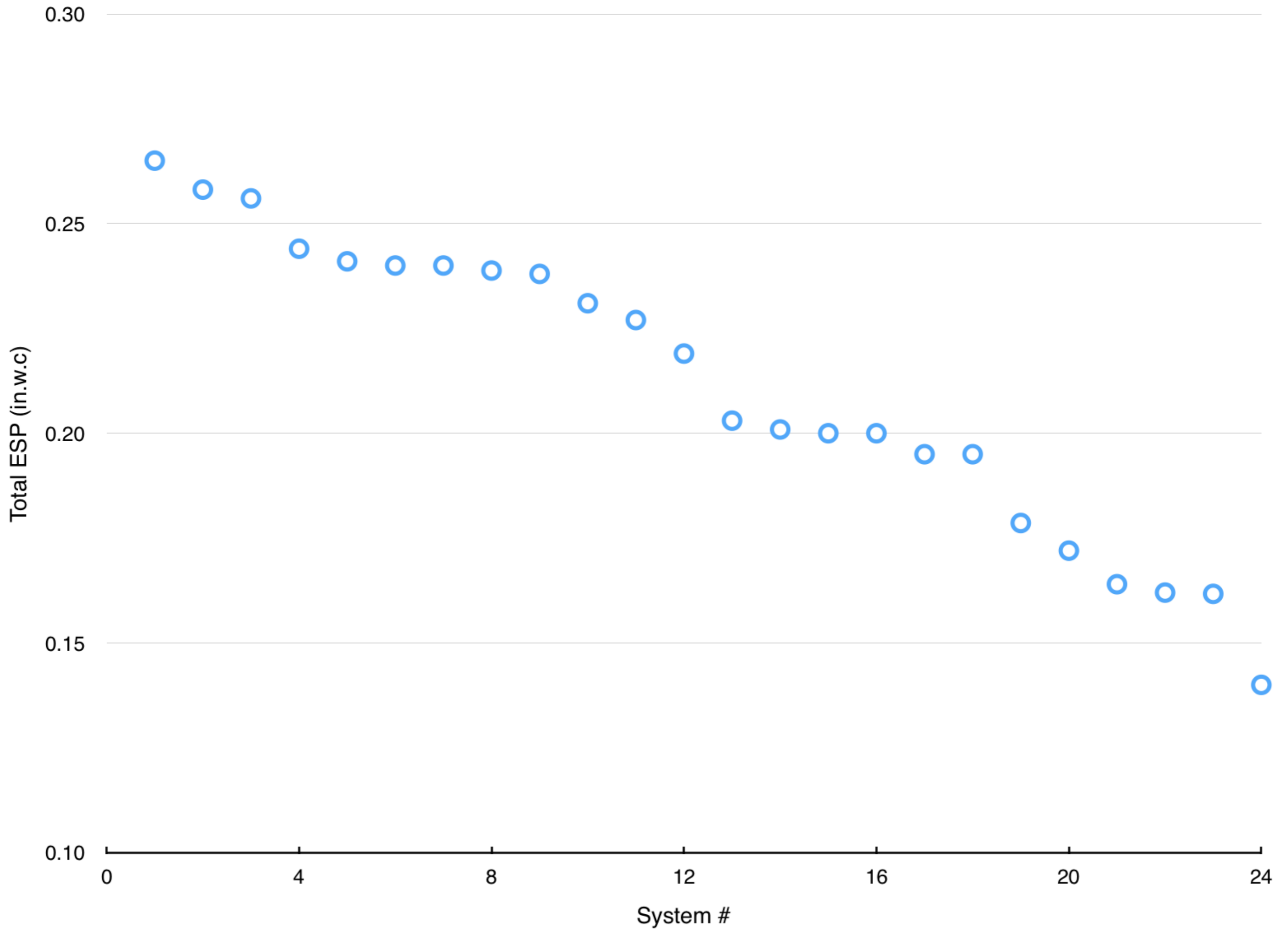




3 Systems in Basement Ceiling (6000 sf)

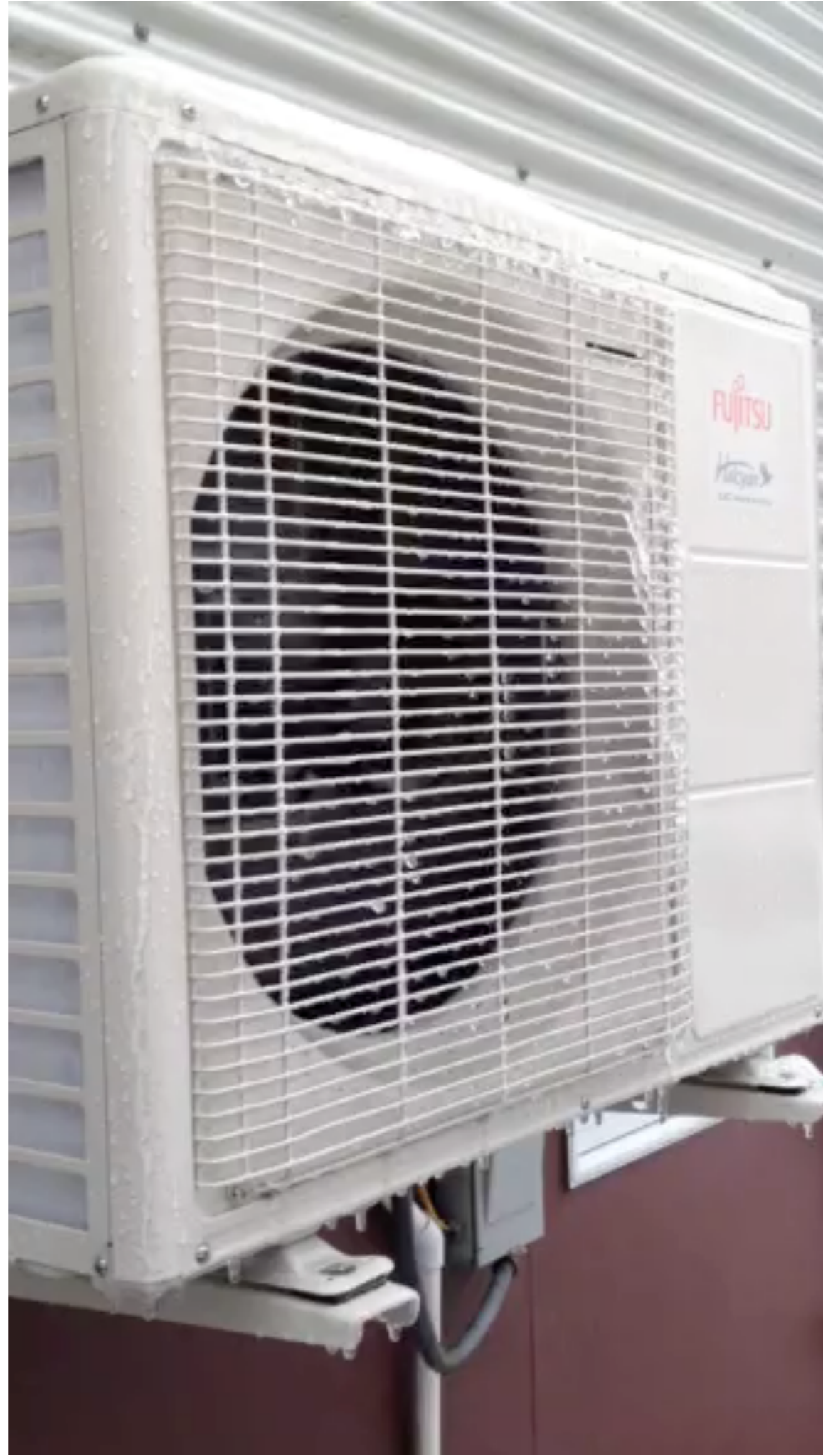


○ Total ESP (in.w.c)



Duct System Design “Rules”

- All ducts in conditioned space
- Central returns
- Smooth turns for all trunks
- No turns with flex duct
- 450 fpm in-duct velocity
- Standard/mediocre takeoffs and boots
- Size supply registers for throw (but don't hit people)
- High-efficiency, “over-sized” filter
- Balance every system, learn from mistakes





Fun with Filters!

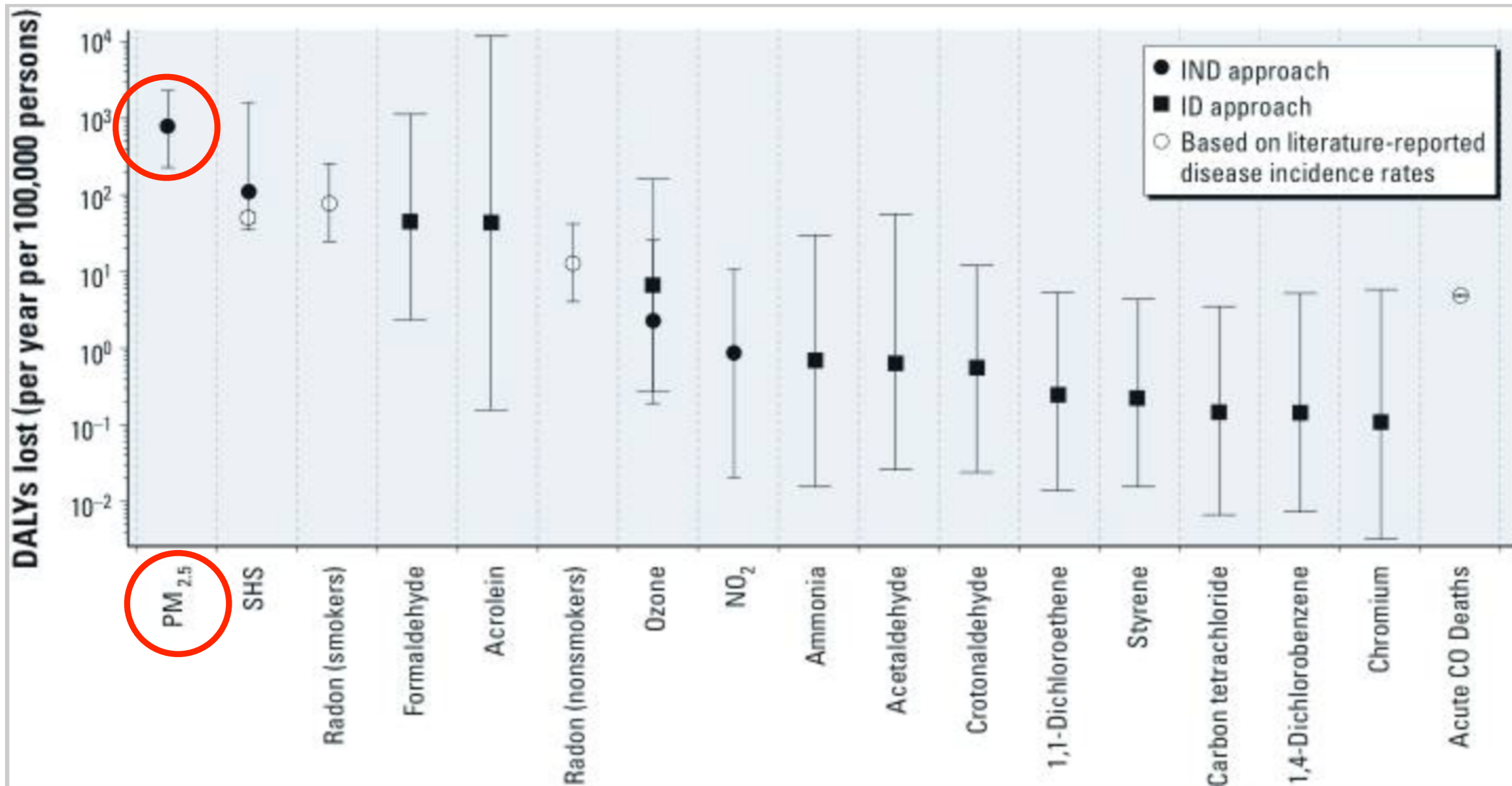
MERV-13

Super-clean ducts!
What's too dirty?

Benjamin Knopp
John Semmelhack

www.think-little.com





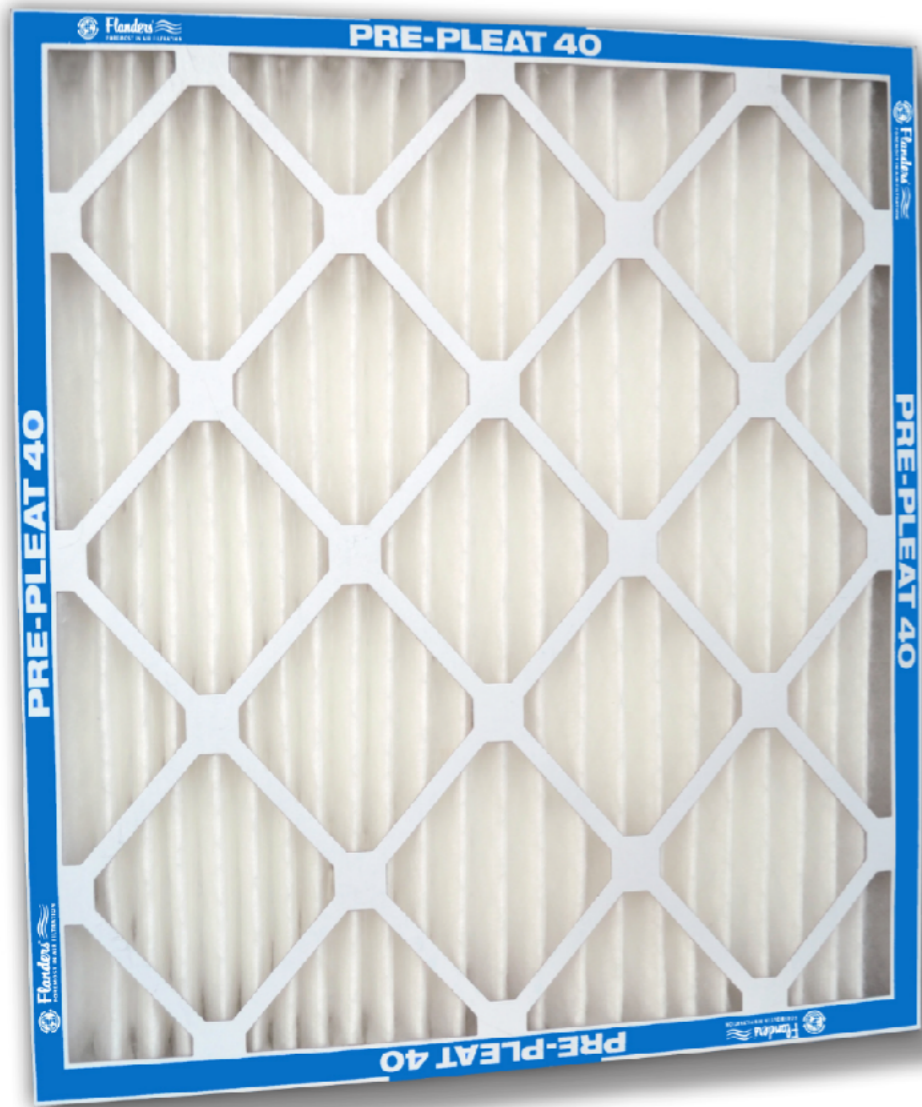
Logue et al, 2012, A Method to Estimate the Chronic Health Impact of Air Pollutants in U.S. Residences

“DALY” = Disability-adjusted Life-Year

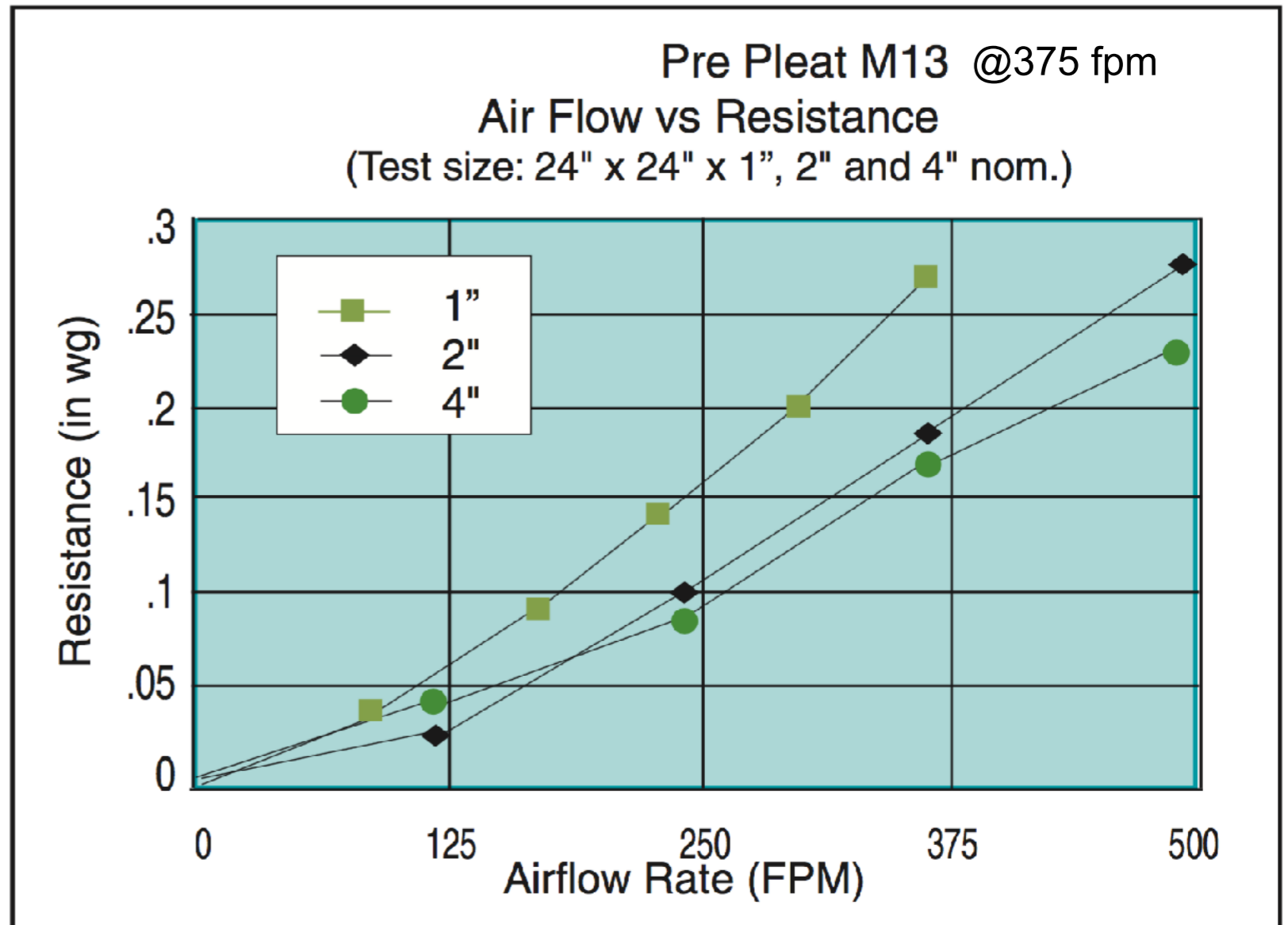
	Minimum % of particles trapped		
	"PM 2.5 Zone"		
MERV Rating	0.3 - 1.0 Microns	1.0 - 3.0 Microns	3.0 - 10.0 Microns
MERV-1	-	-	<20%
MERV-2	-	-	<20%
MERV-3	-	-	<20%
MERV-4	-	-	<20%
MERV-5	-	-	20% - 34%
MERV-6	-	-	35% - 49%
MERV-7	-	-	50% - 69%
MERV-8	-	-	70% - 85%
MERV-9	-	<50%	>85%
MERV-10	-	50% - 64%	>85%
MERV-11	-	65% - 79%	>85%
MERV-12	-	80% - 89%	>85%
MERV-13	<75%	>90%	>85%
MERV-14	75% - 84%	>90%	>85%
MERV-15	85% - 94%	>90%	>85%
MERV-16	>95%	>90%	>85%

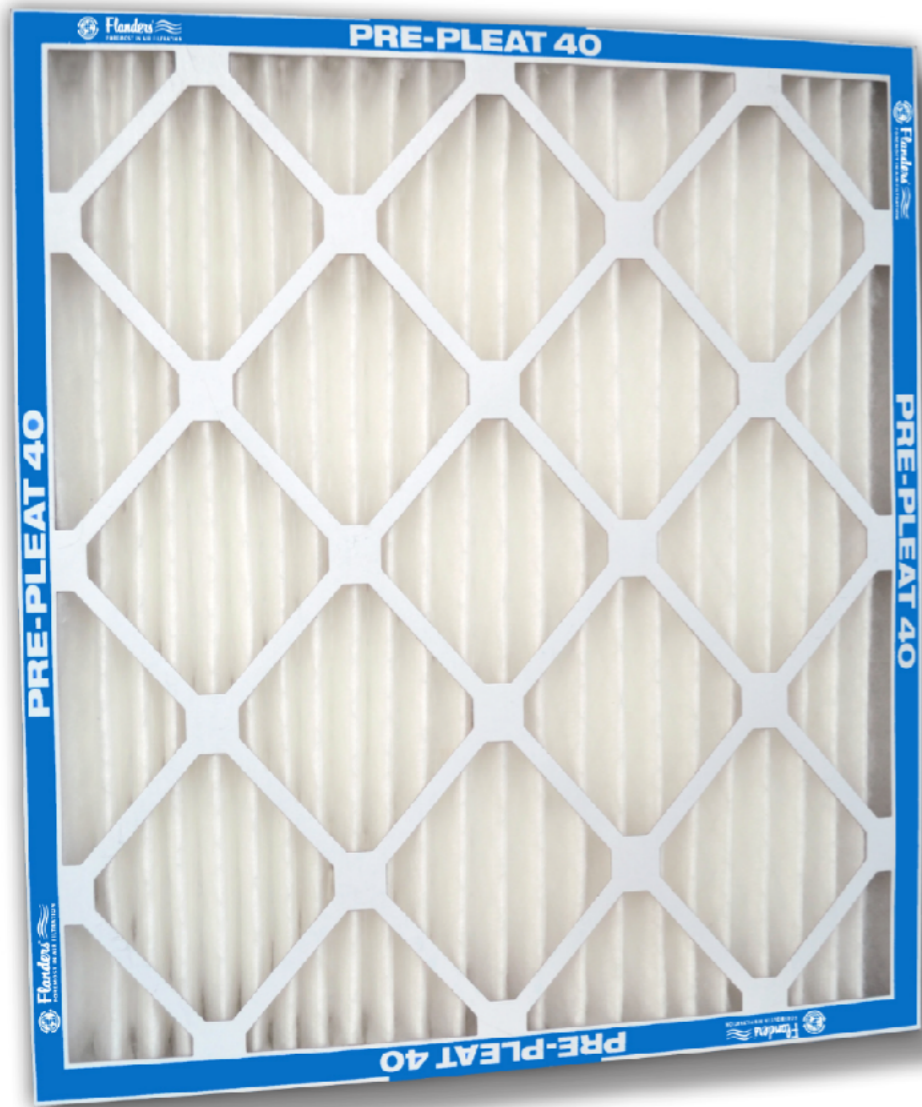
20x20x1 MERV-2 "filter"

MERV	(μm)	0.30-1.0	1.0-3.0	3.0-10	Airflow Rate (CFM)	410	615
2	PSE (%)	1	9	5	Débit d'air (pi ³ /min)		
					Initial Resistance (IWC)	0.04	0.07
					Résistance initiale (IWC)		

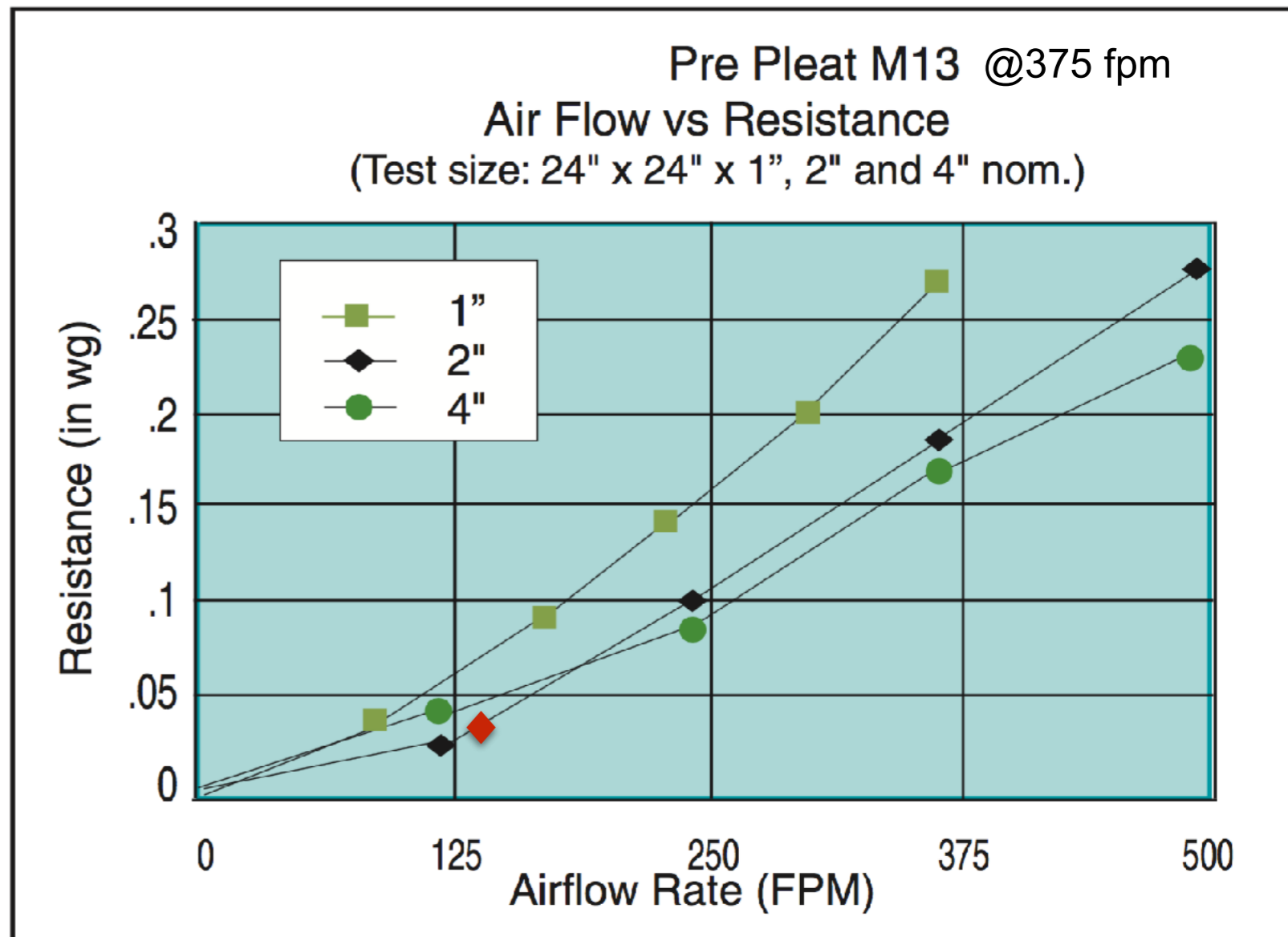


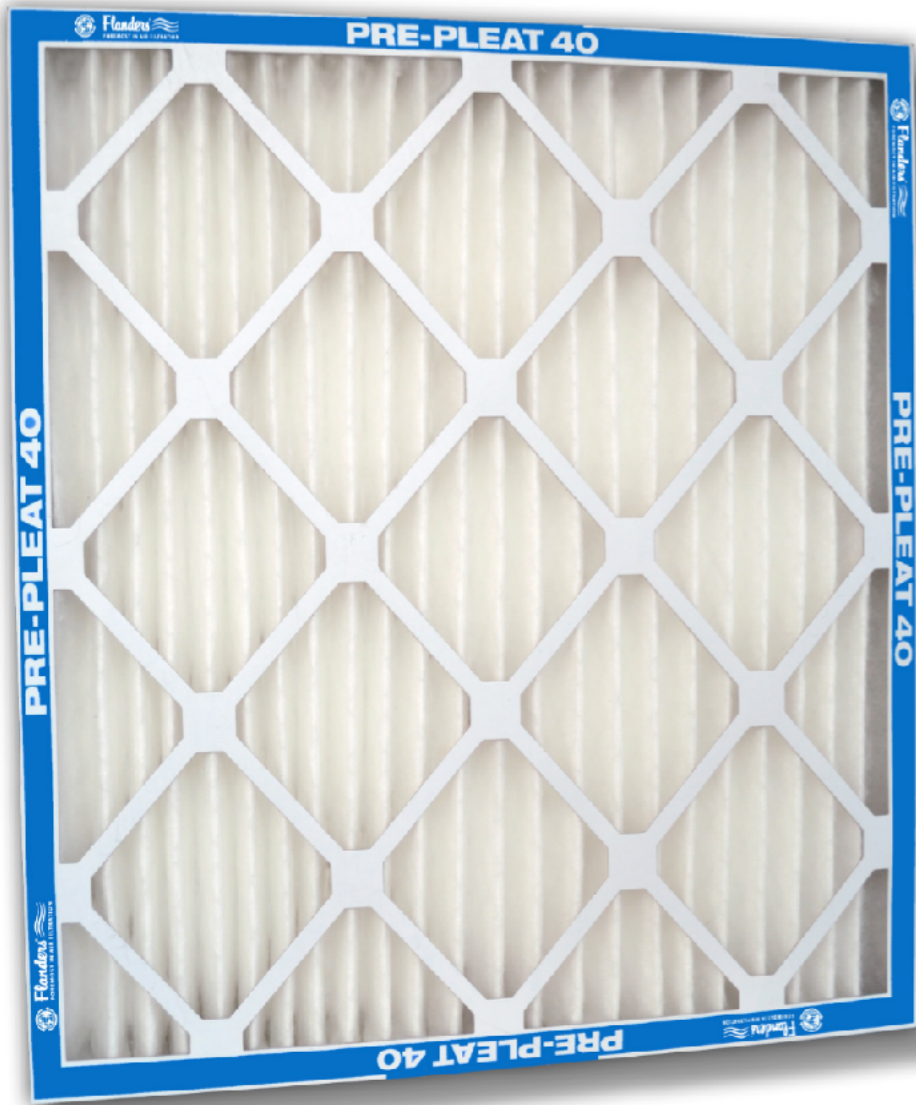
Size	CFM	IWC
10x20x1	417	0.25
20x20x2	833	0.15





Size	CFM	IWC
10x20x1	417	0.25
20x20x2	833	0.15
20x20x2	400	0.03





Size

CFM

IWC

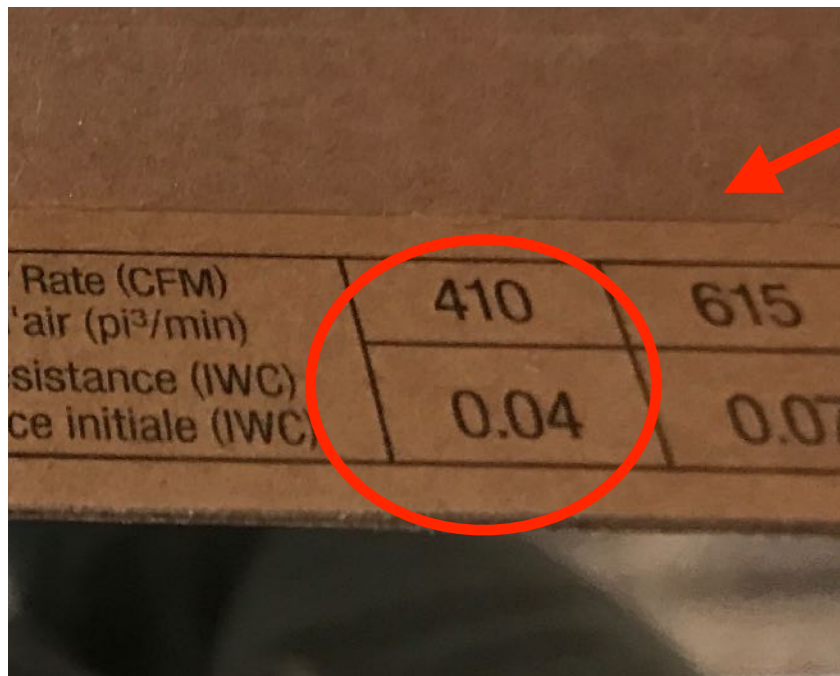
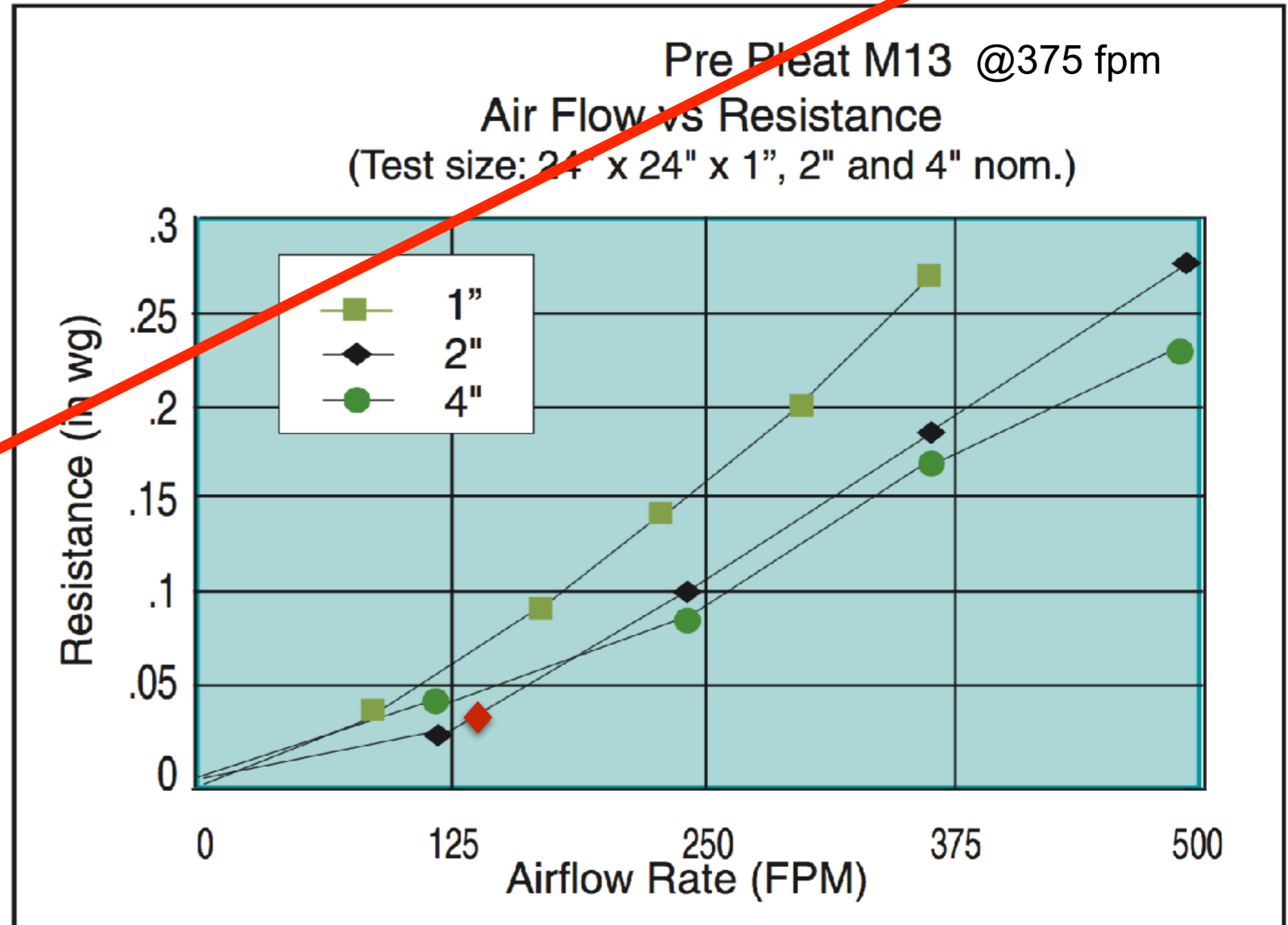
10x20x1	417	0.25
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20x20x2	833	0.15
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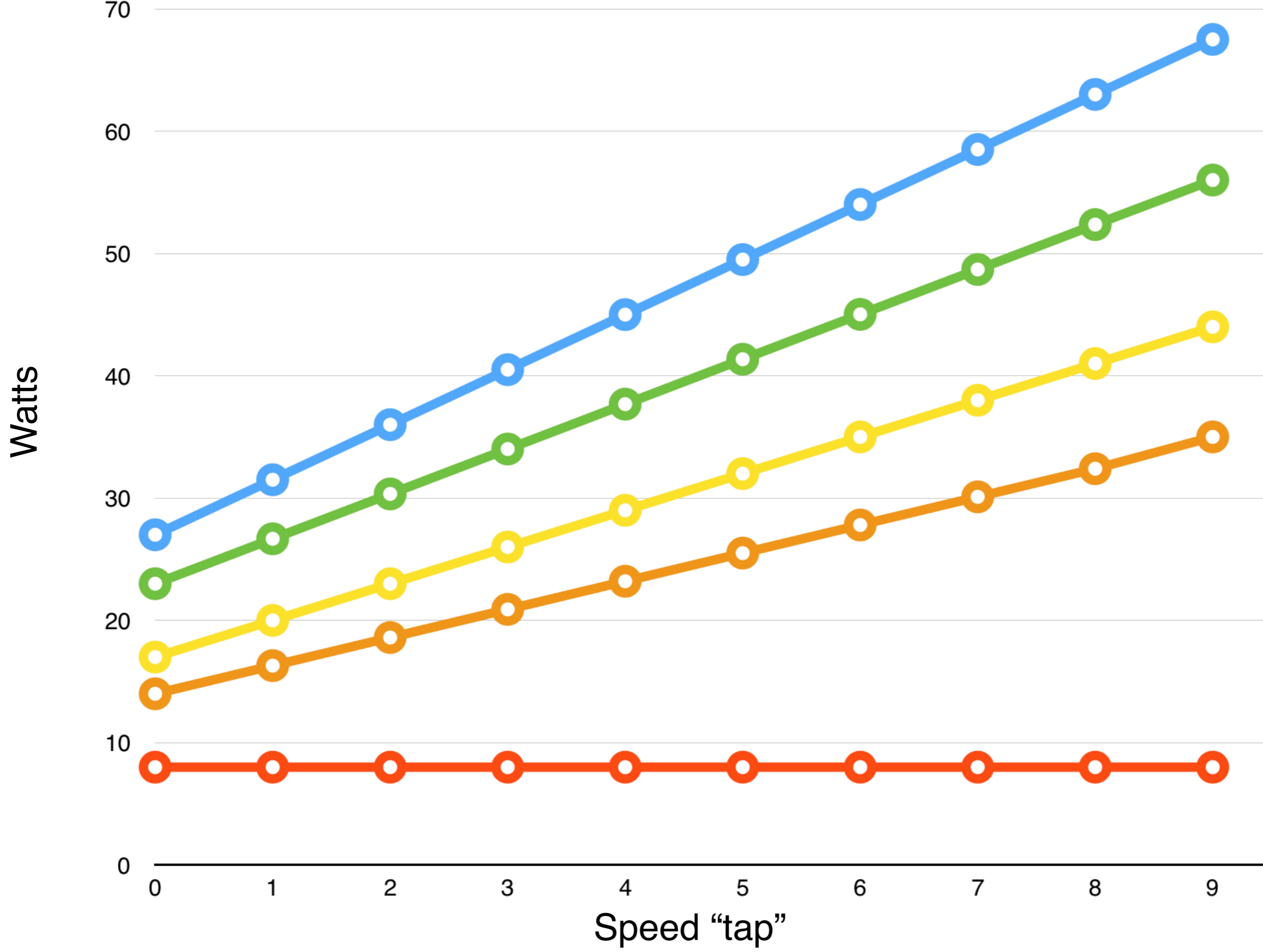
20x20x2

400

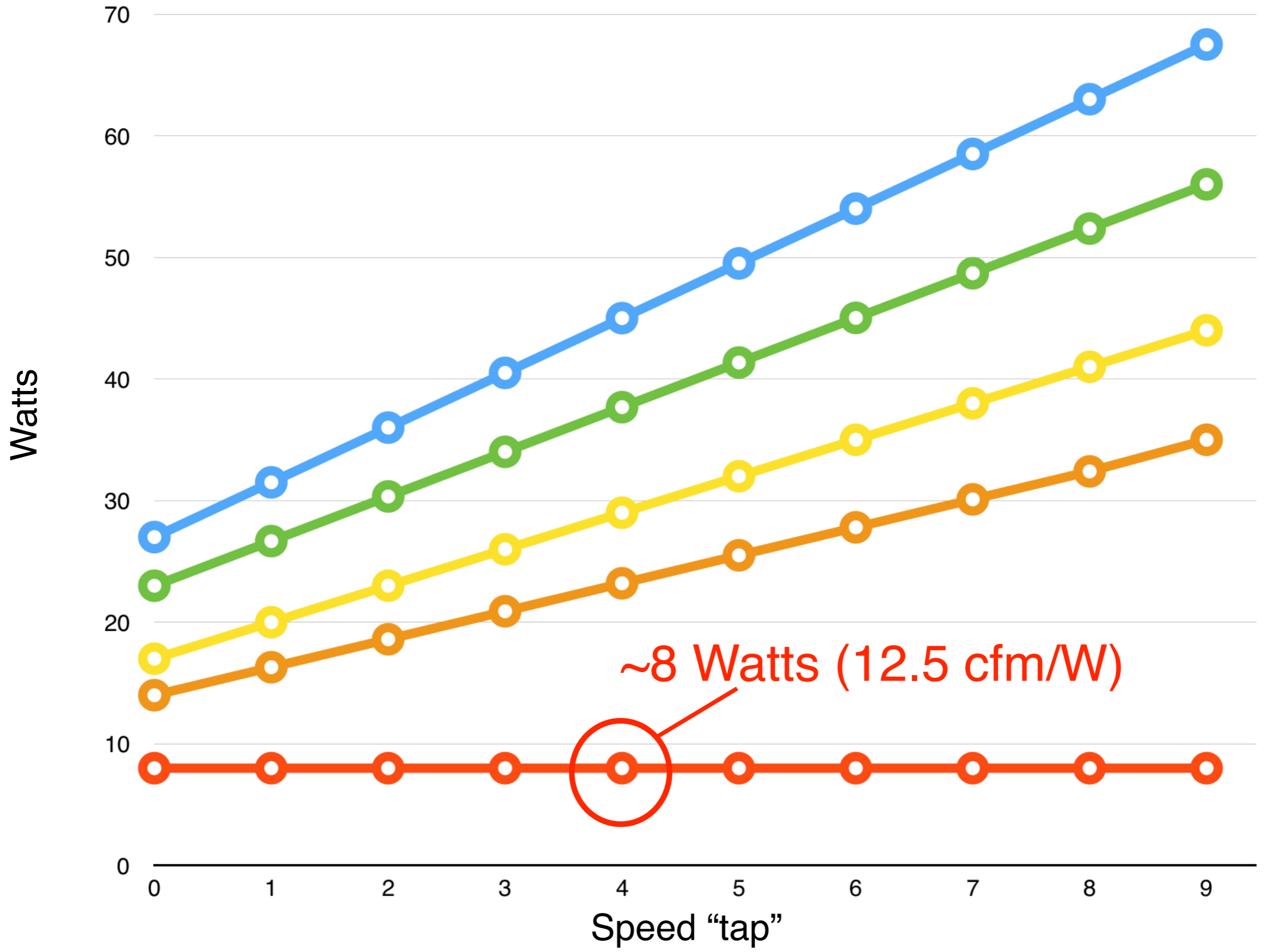
0.03



High Medium Low Quiet S-Low



High Medium Low Quiet S-Low



~8 Watts (12.5 cfm/W)

Standalone HEPA air purifier w/ Eco mode



- Initial cost: \$230
- Electricity cost: \$6/yr
- Filter cost: \$50/yr

Larger 2" return grille + MERV-13 filter



- Initial added cost: ~\$15
- Electricity cost: ~\$1/yr
- Extra Filter cost: ~\$10/yr



9/12

EM

2112

1782-4002
Classic

AFPA
SPE 1/2
1000

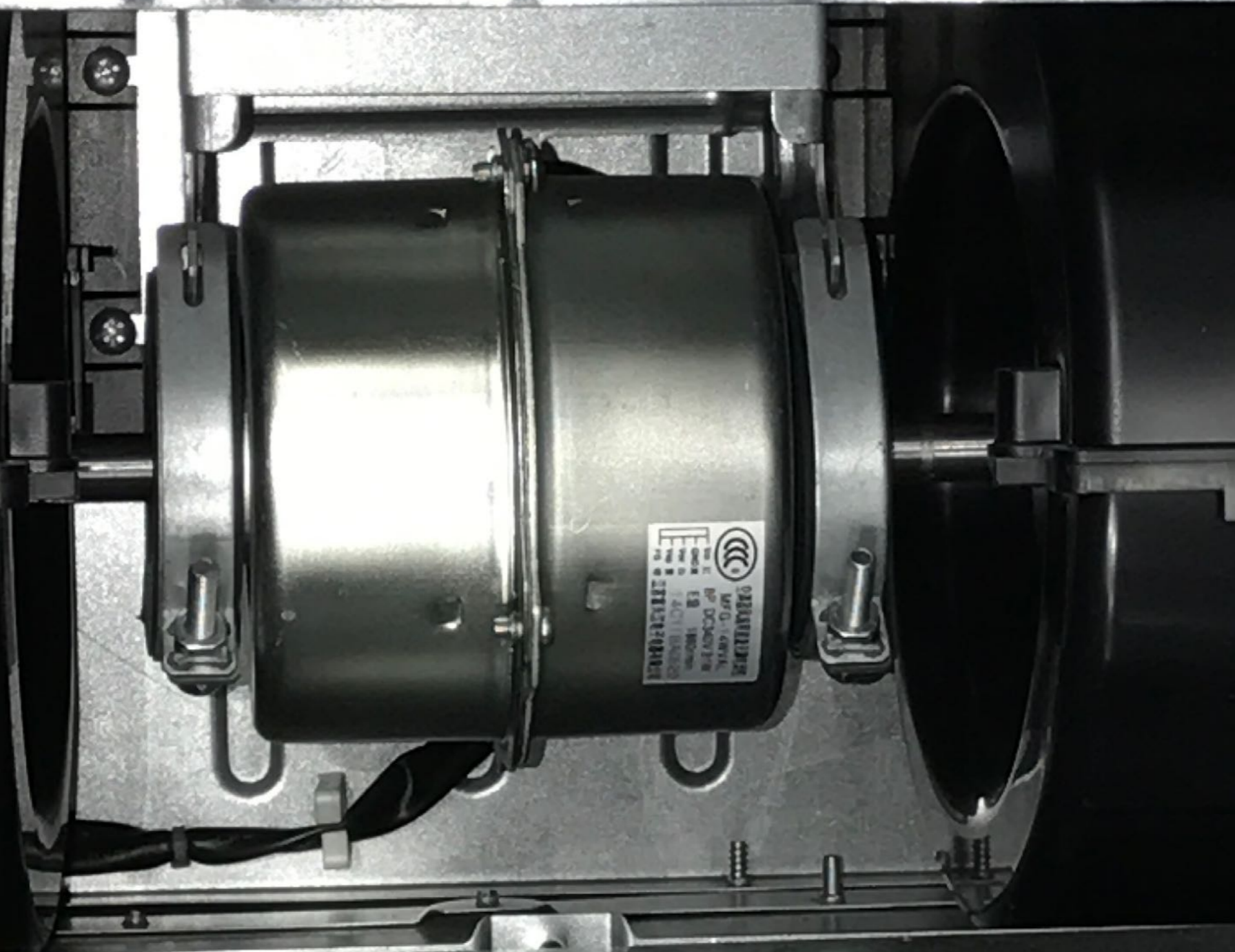
mtis
1000





20 x 20 x 2
PRE-PLEAT 40
PRE-PLEAT 40

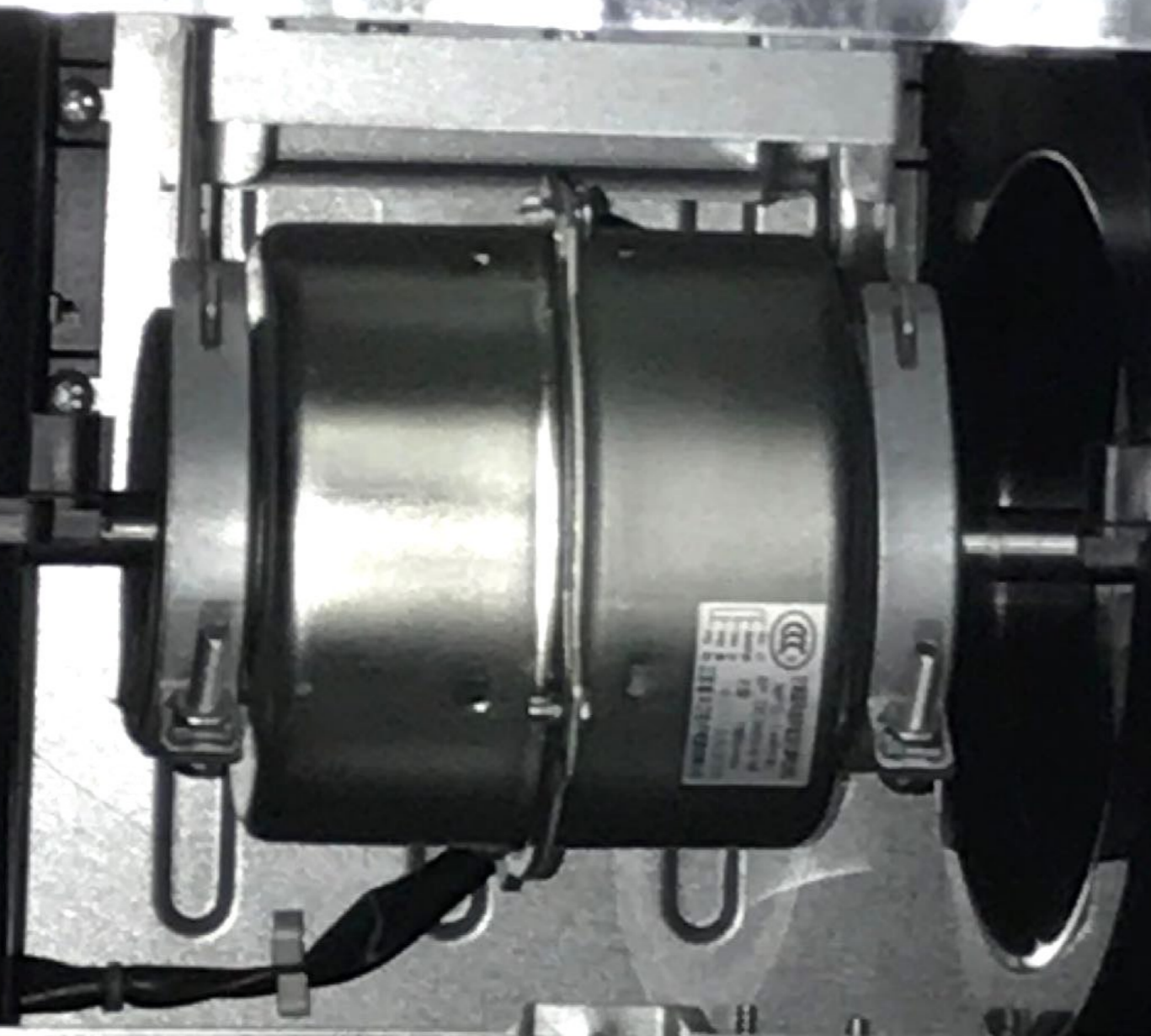

2-10-17

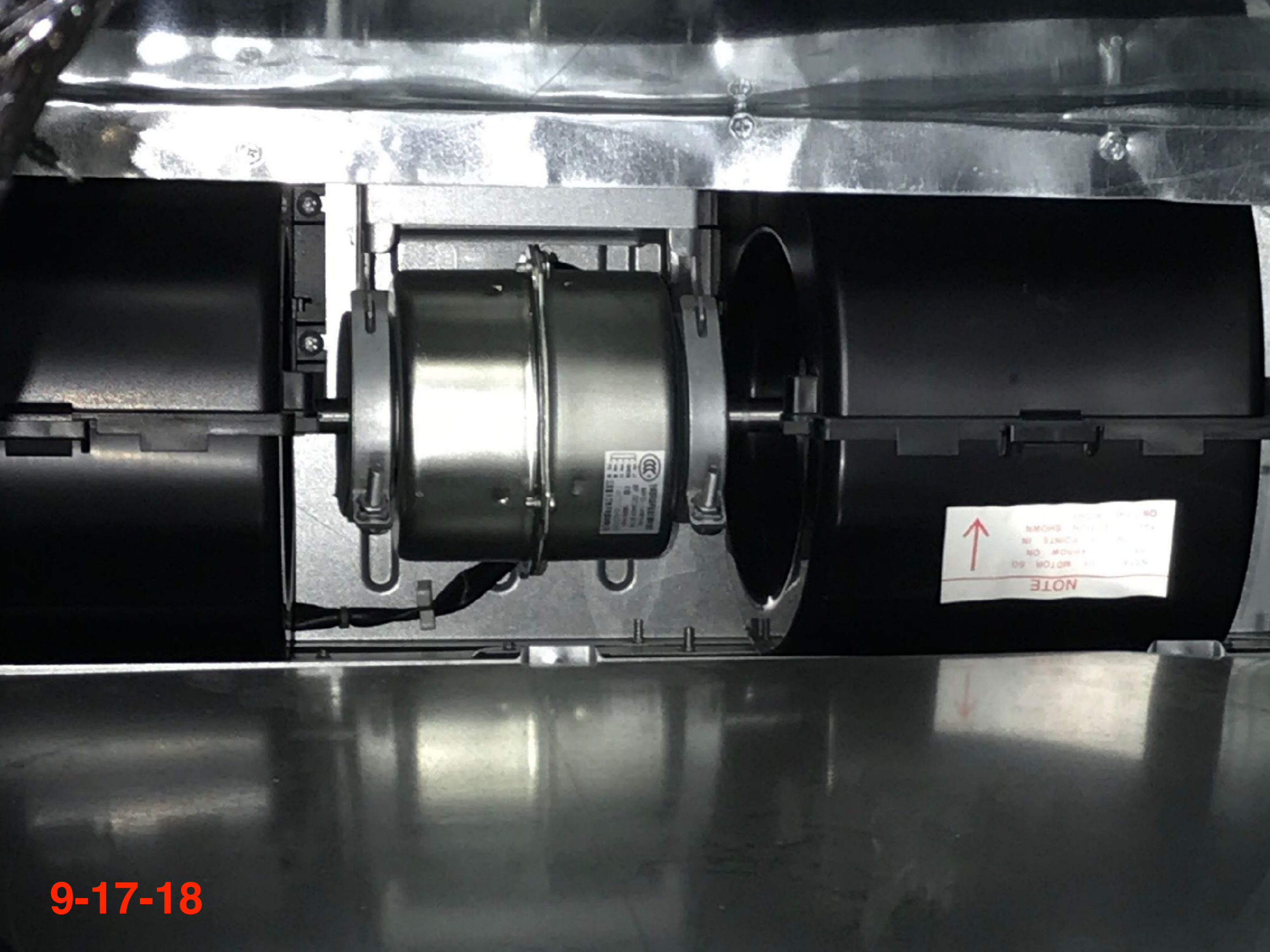


↑
N
NI
N
OS

12-18-17

NOTE
INSTALL THE MOTOR SO
THAT THE ARROW ON
THE MOTOR POINTS IN
THE DIRECTION SHOWN
ON THE RIGHT





NOTE: THE MOTOR IS
MOUNTED ON THE
FRONT OF THE UNIT IN
THE POSITION SHOWN
ON THE DRAWING

↑

NOTE

9-17-18



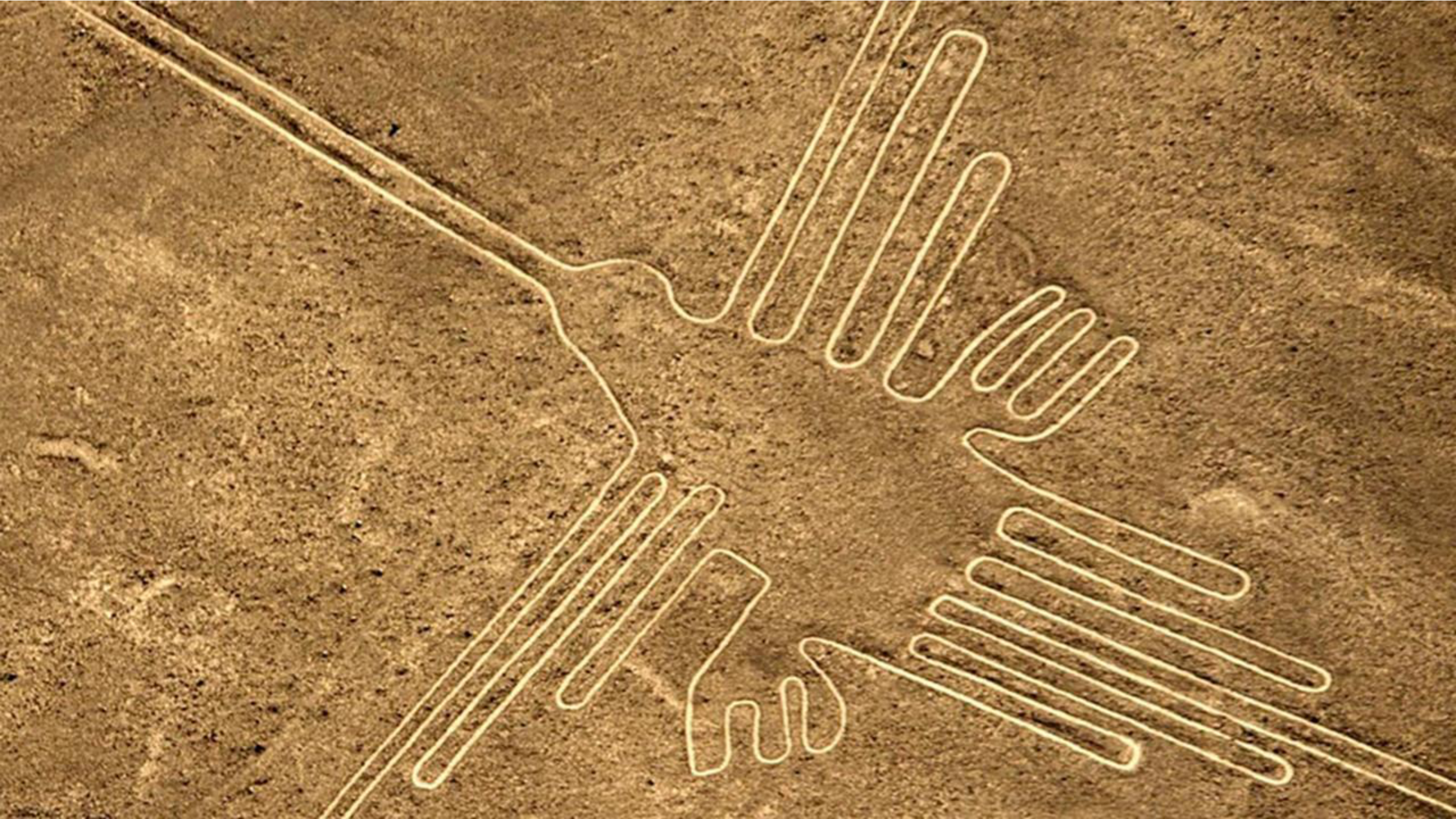
2-2-18



2-10-17



12-18-17



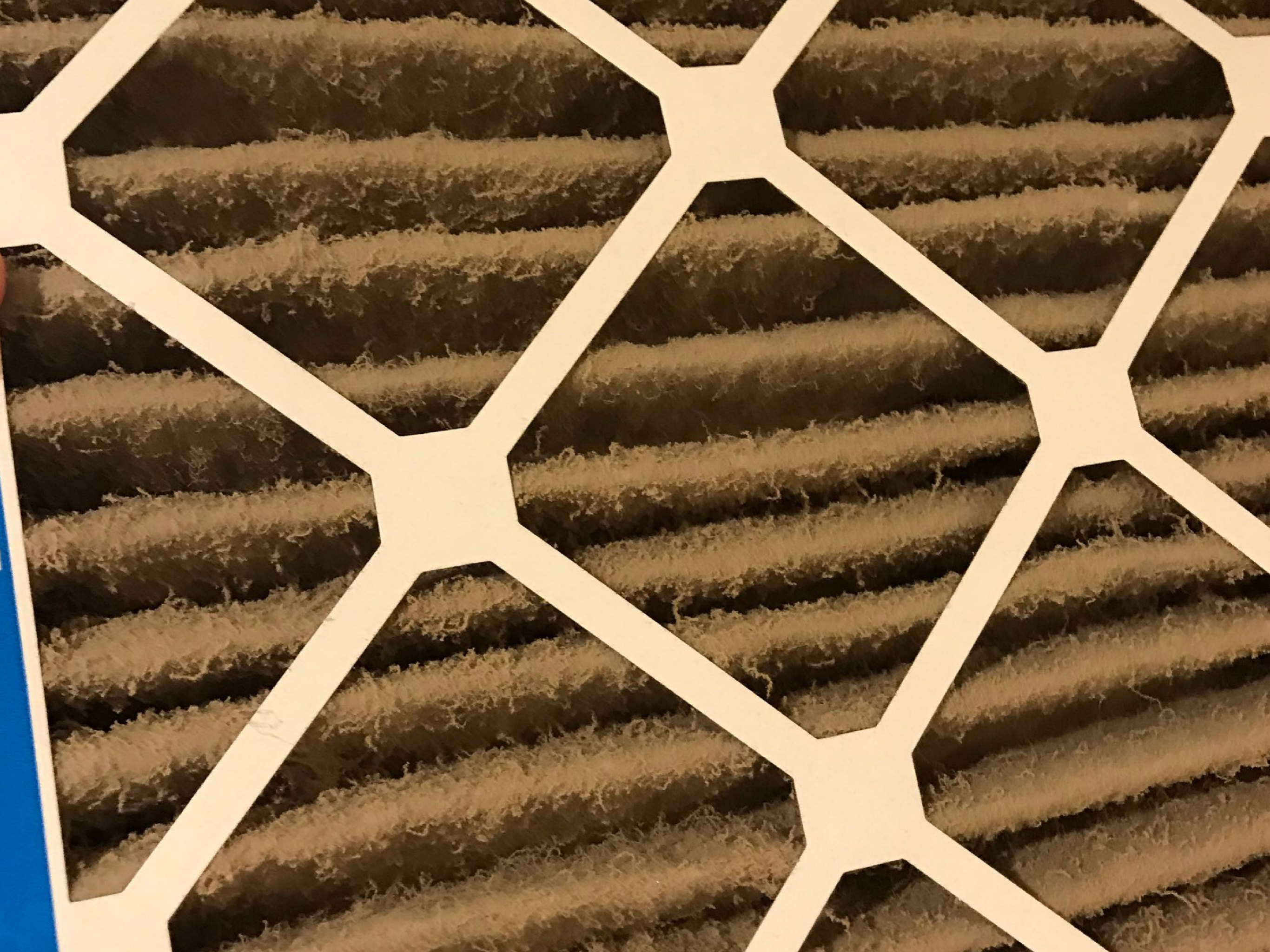




PREMIUM



12-18-17



DG-700 Pressure & Flow

DEVICE

CON

-135.8

in w.c.

PR/PR

-0.0

in w.c.

10

MODE

TIME

DEVICE

CONFIG

-1358

in W.C.

PR/PR

MODE

DEVICE

UN

MODE

CLE

Sto
Fa

DG-700 Pressure

DEVICE

-1084

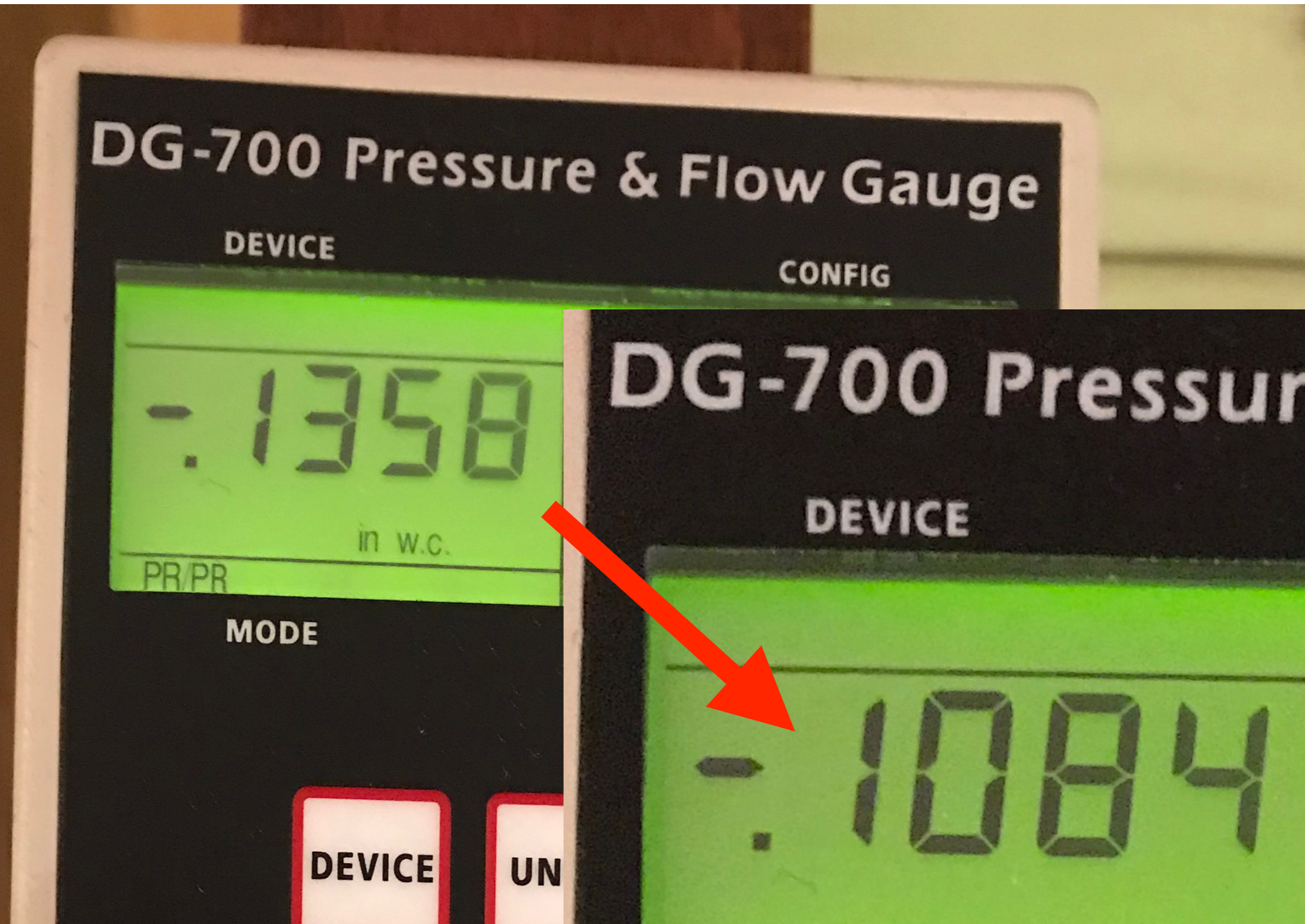
in W.C.

PR/PR

MODE



delta-P = 0.0274 in.w.c.





**Thank you for your
attention!**

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