Fans, Ducts and Air Handling Systems: Design, Performance and Commissioning Issues

Fans

Instructor:

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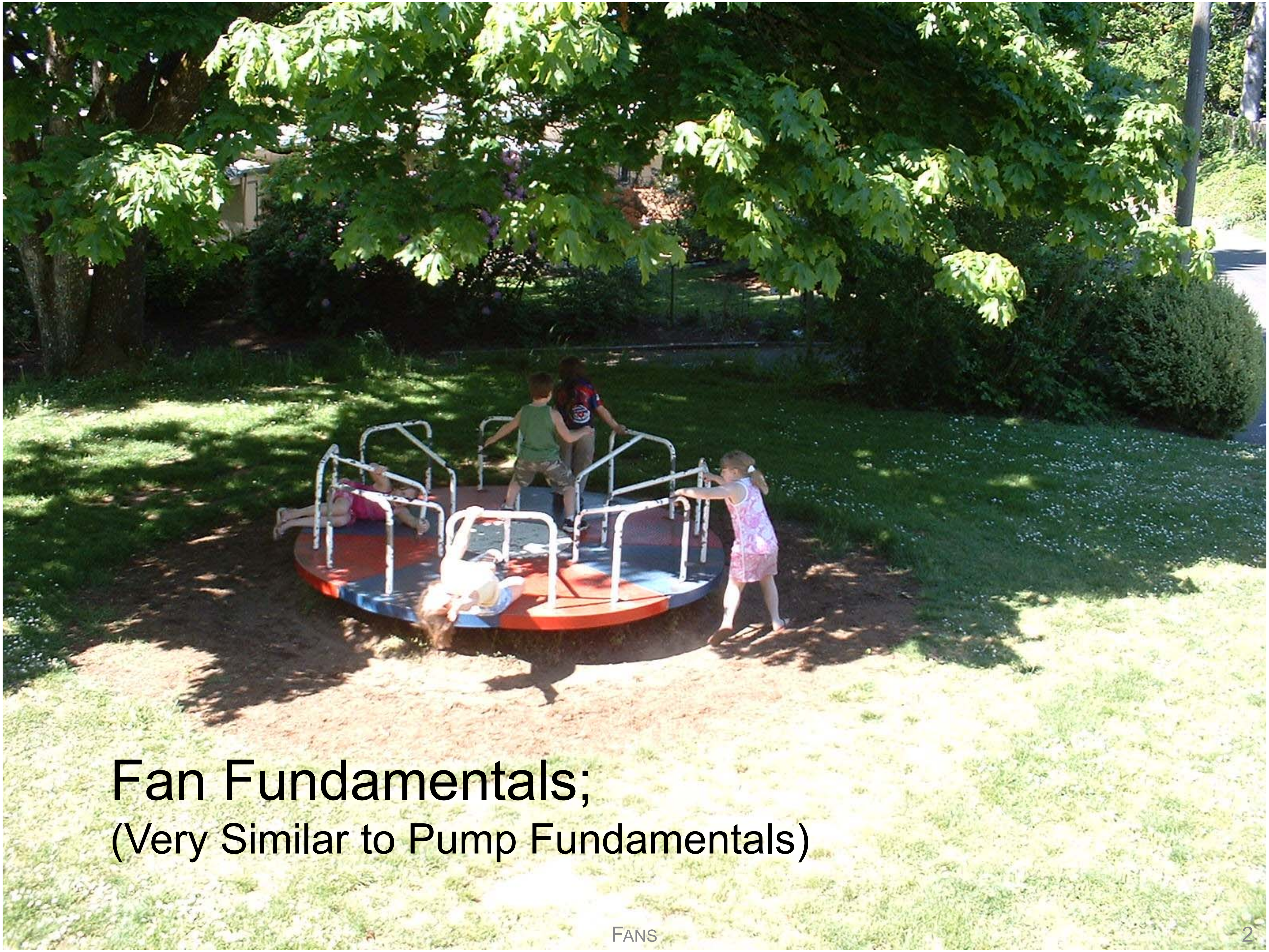
Facility Dynamics Engineering

November 7, 2017

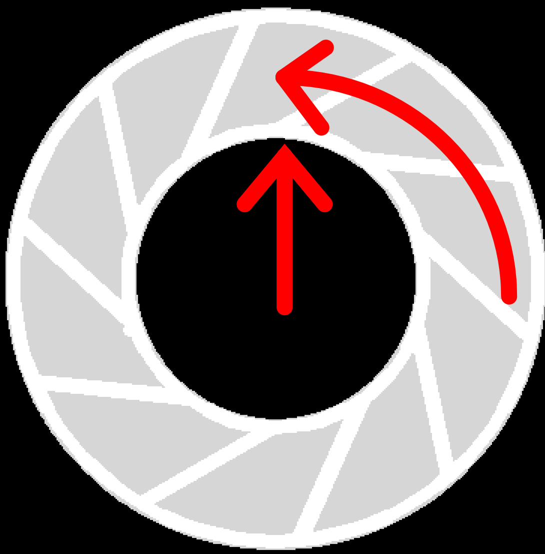


Fan Fundamentals;

(Very Similar to Pump Fundamentals)

Centrifugal Fan Operation

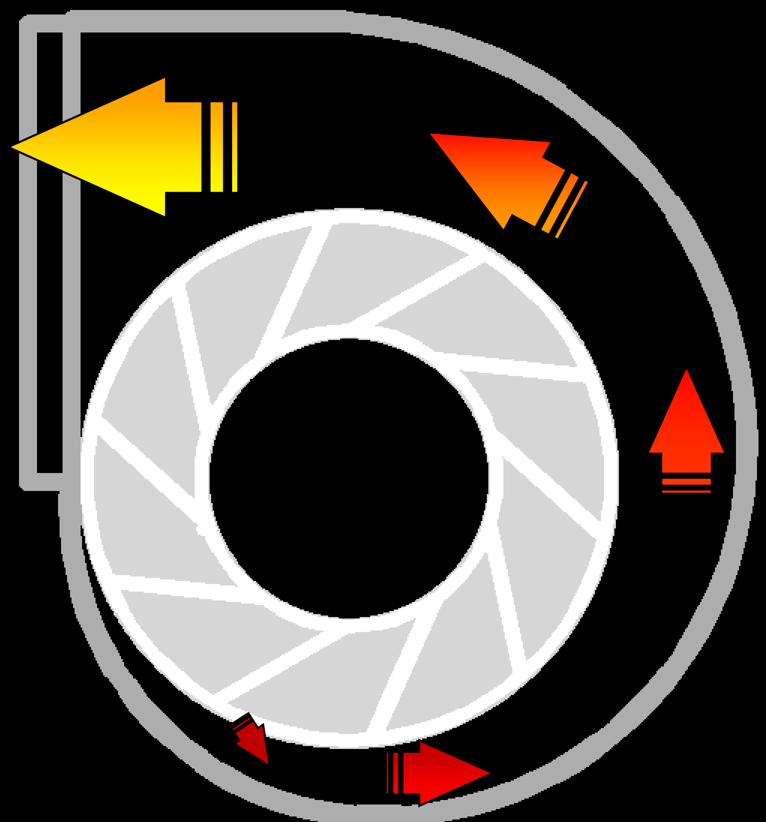
Spin the wheel …



… and air is thrown from the center to the perimeter

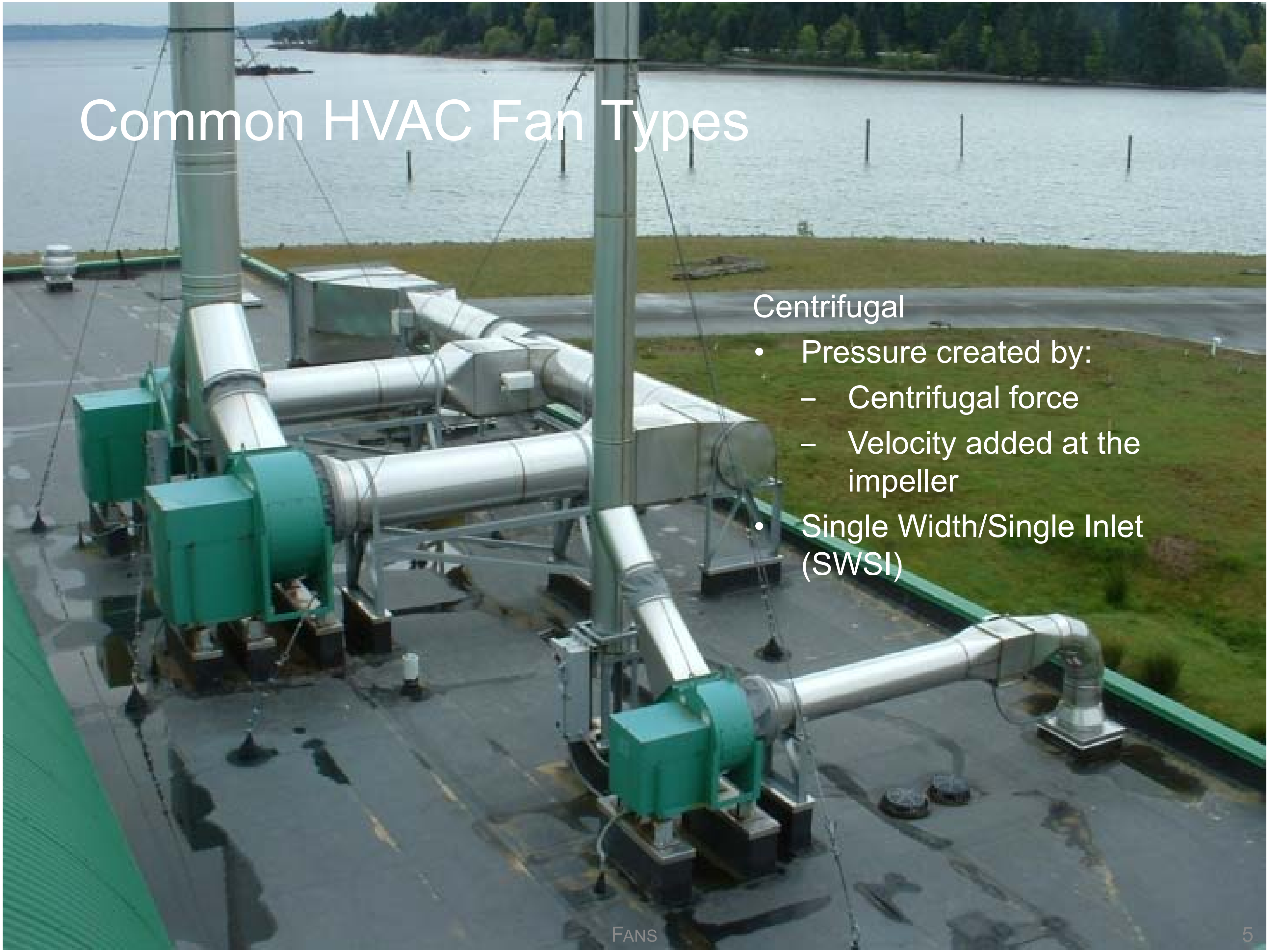
Centrifugal Fan Operation

Adding a scroll …



… collects and distributes the air and recovers some of the velocity pressure

Common HVAC Fan Types



Centrifugal

- Pressure created by:
  - Centrifugal force
  - Velocity added at the impeller
- Single Width/Single Inlet (SWSI)

Common HVAC Fan Types

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- Plenum or Plug

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- Axial

Common HVAC Fan Types

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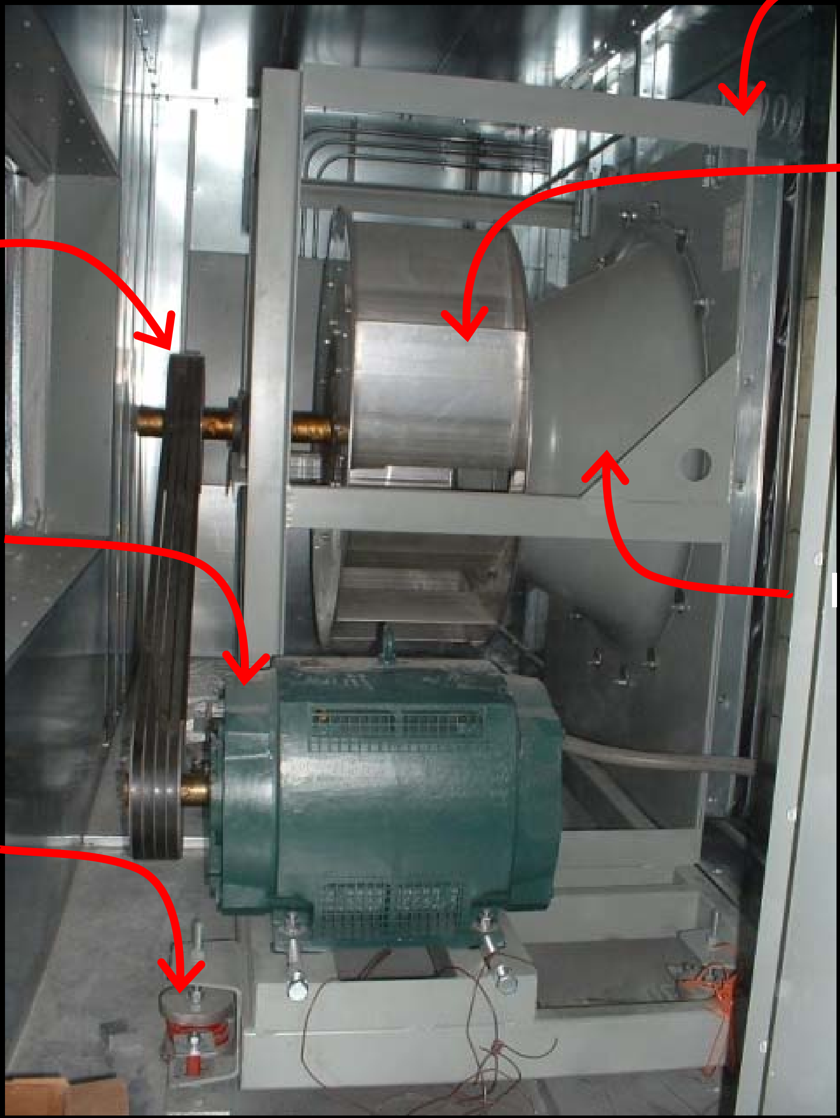
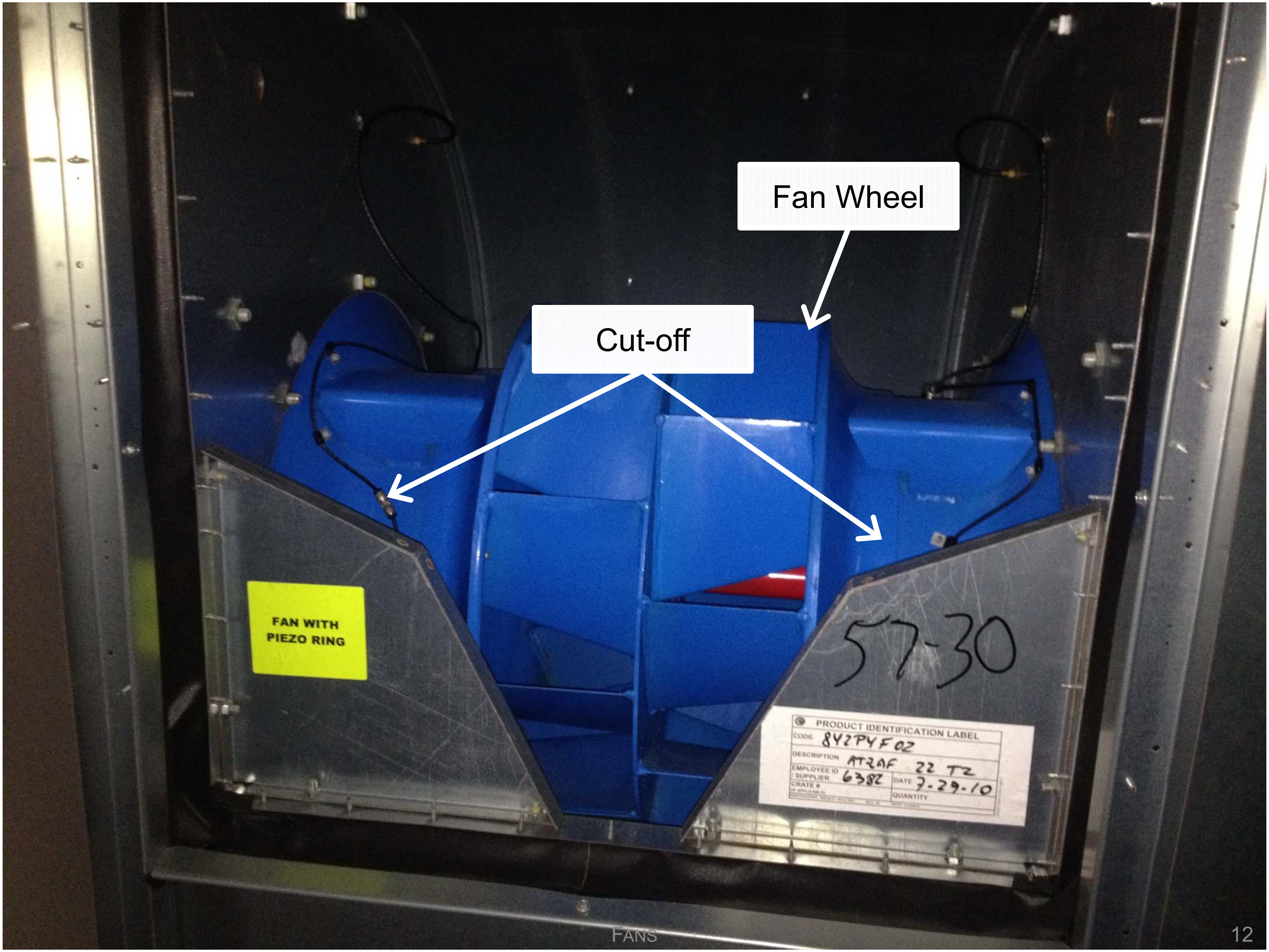
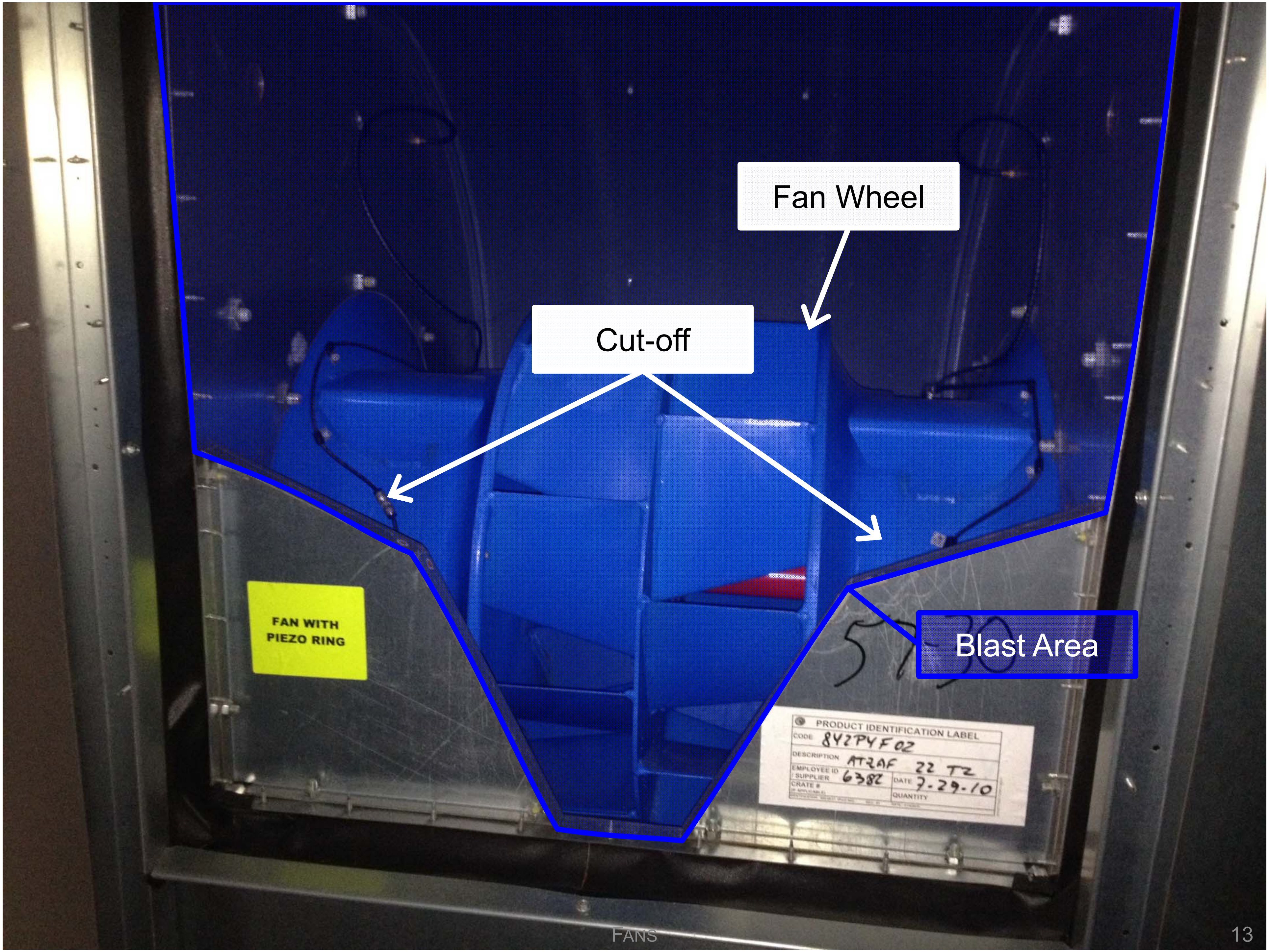
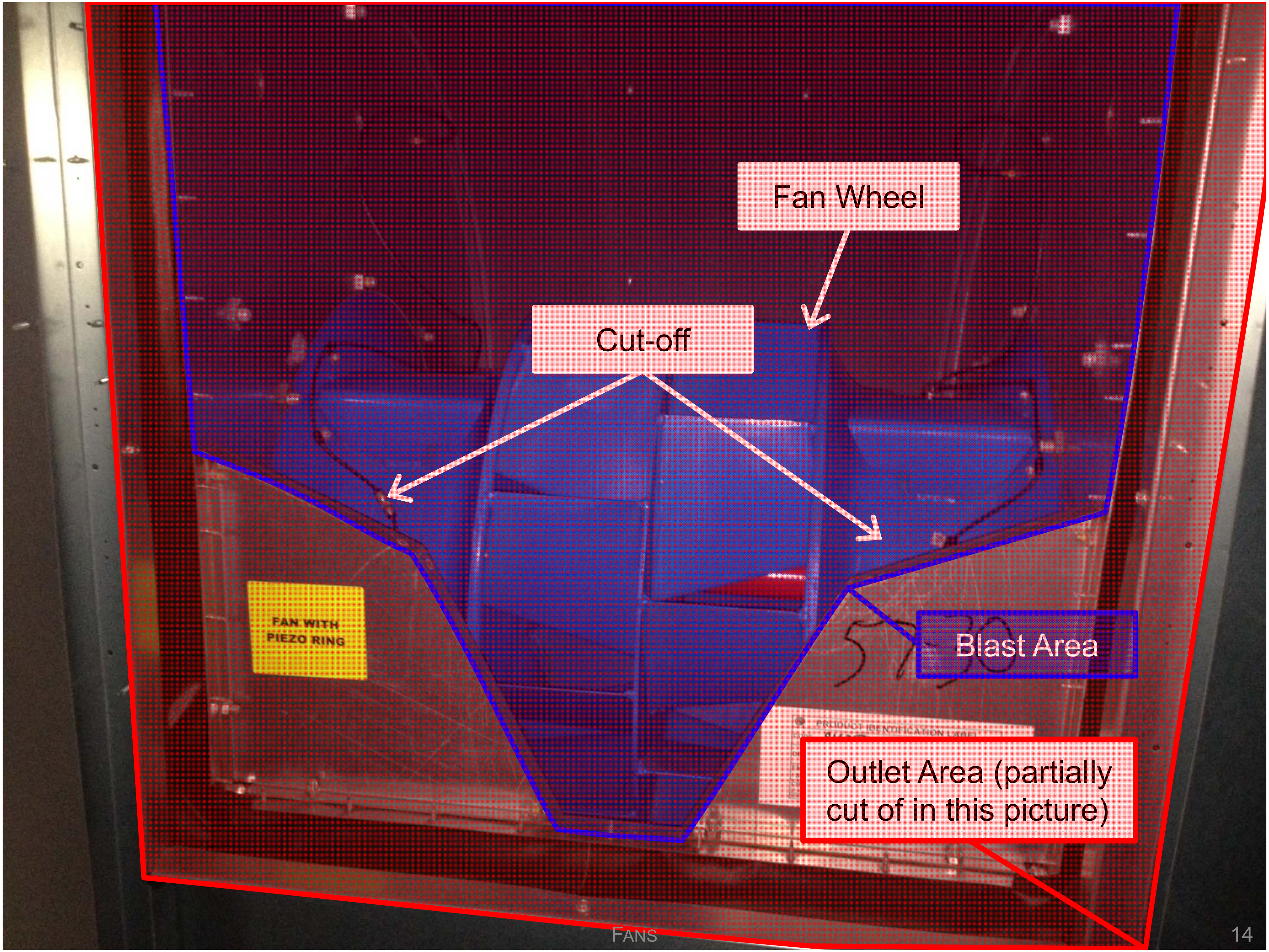
Fan Terminology

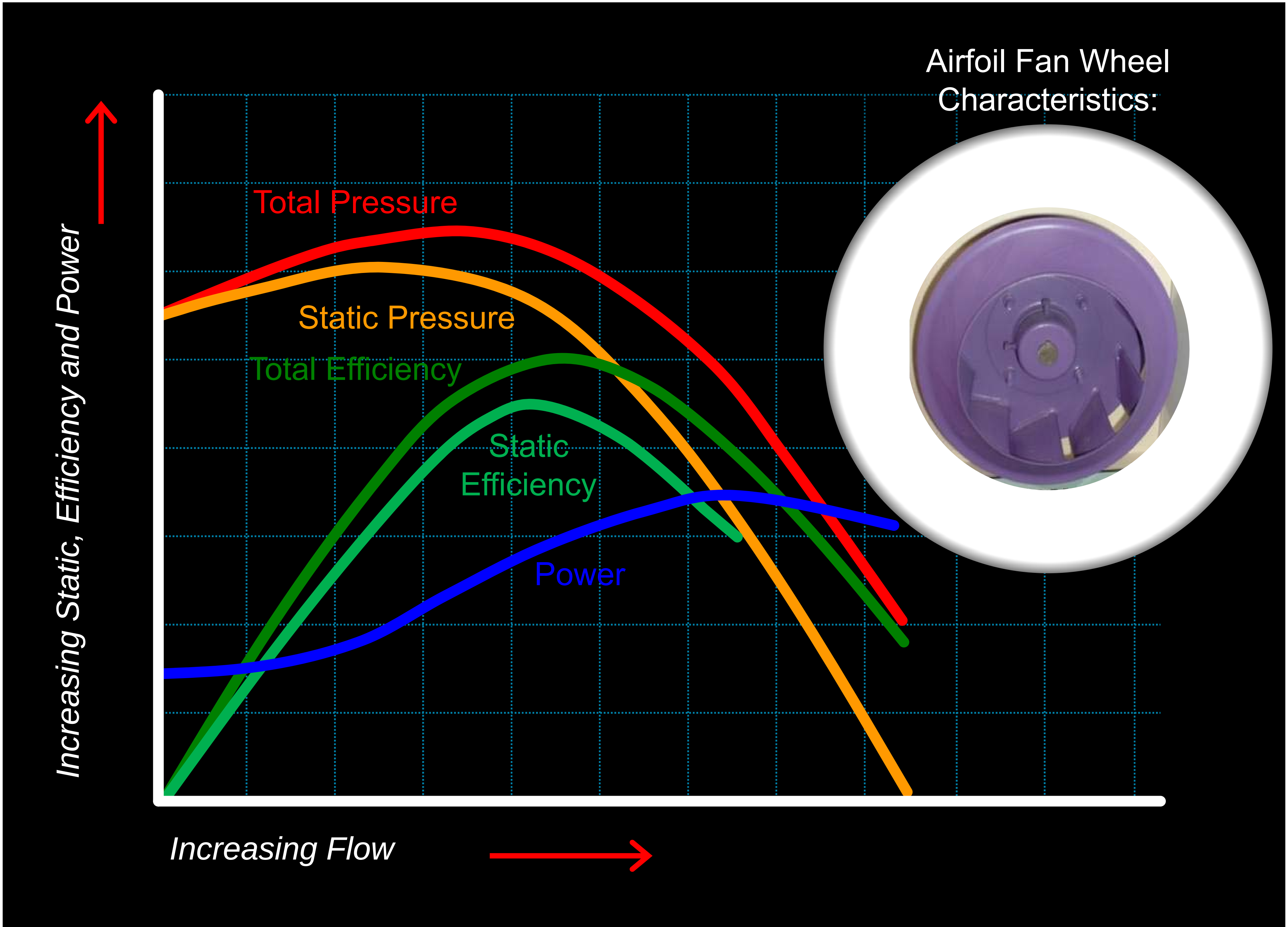



FAN WITH
PIEZO RING
L-240-7

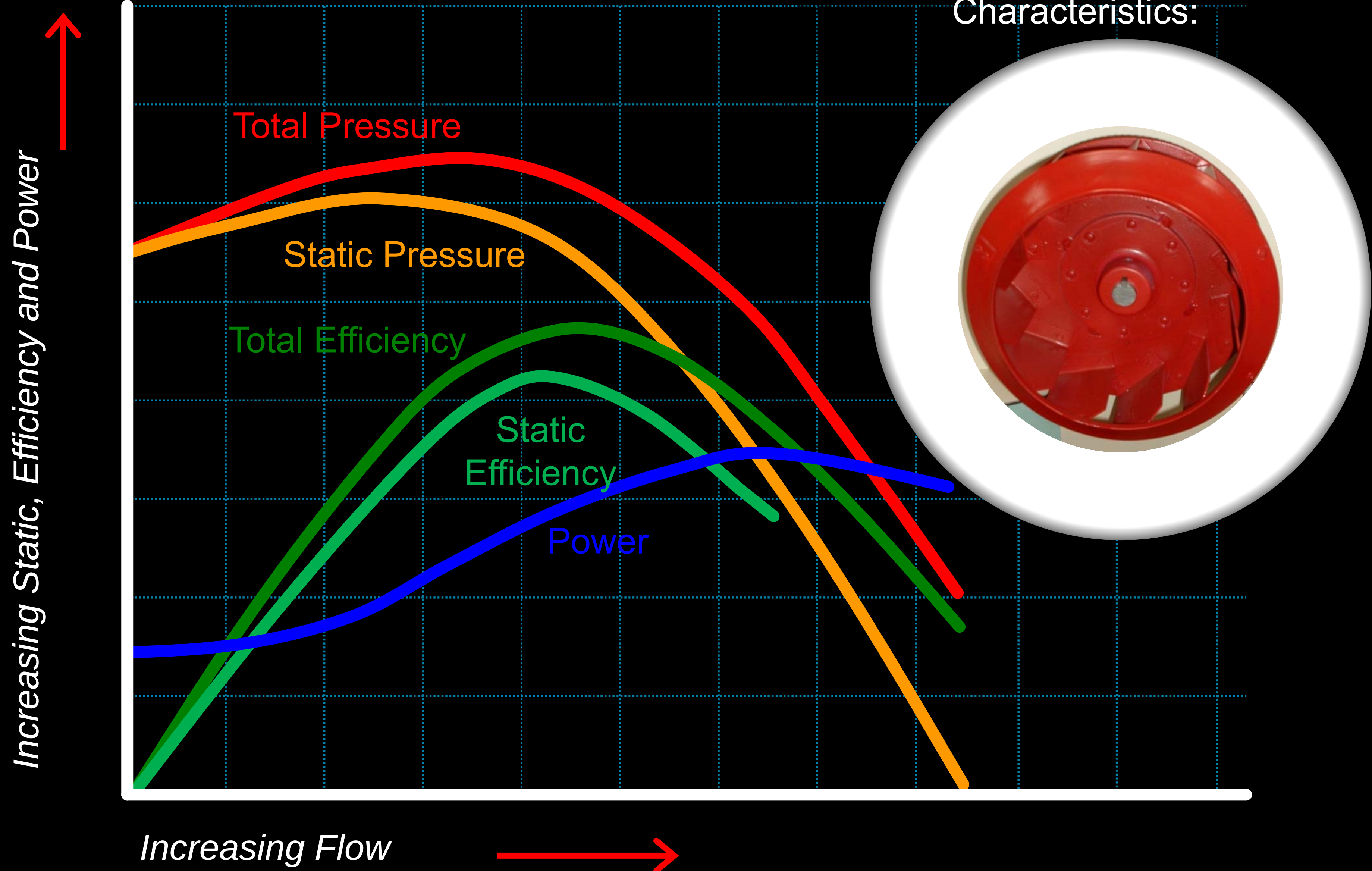

Fan Wheel
Cut-off
FAN WITH
PIEZO RING
57-30
PRODUCT IDENTIFICATION LABEL

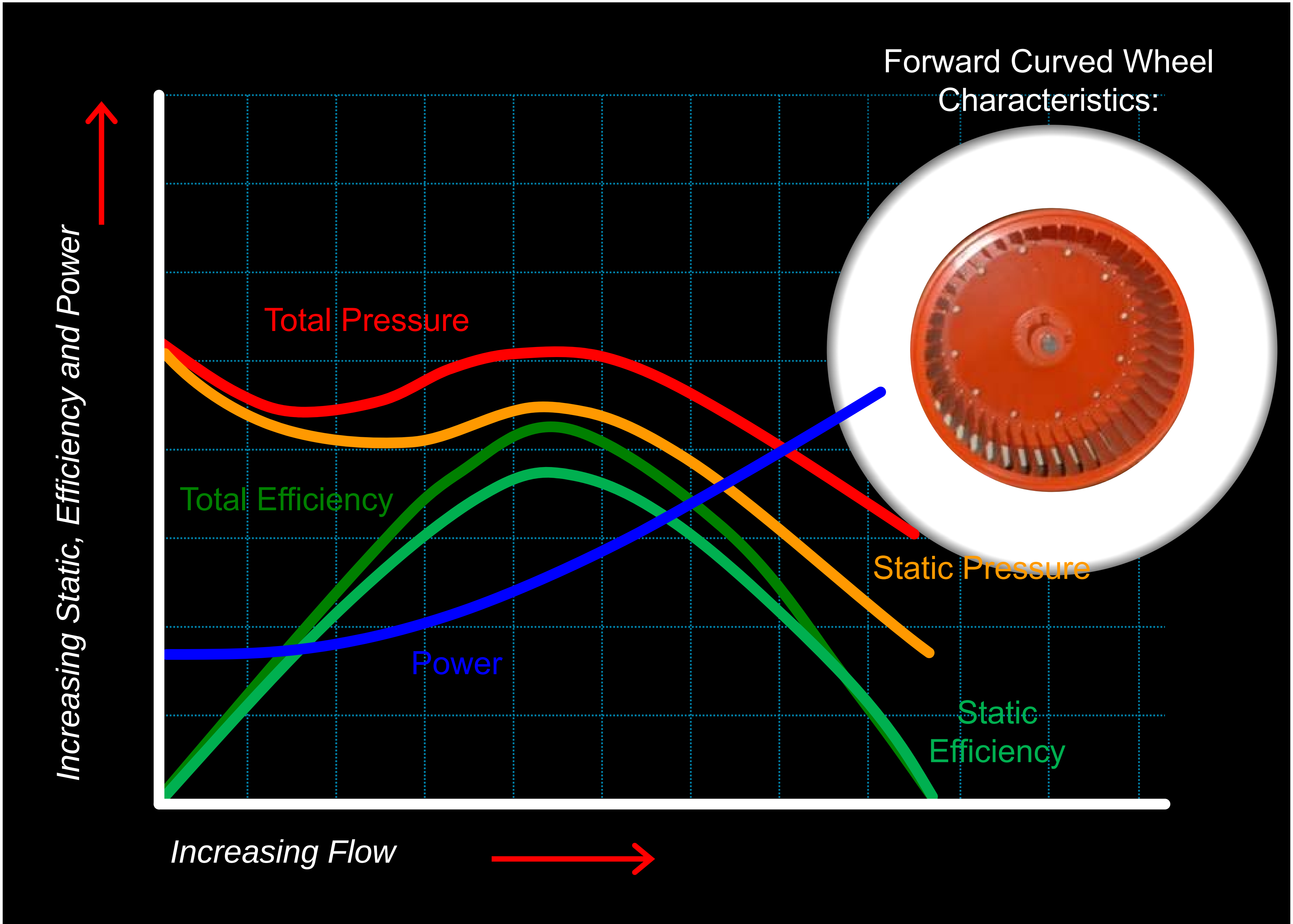

Fan Wheel
Cut-off
Blast Area
FAN WITH
PIEZO RING
PRODUCT IDENTIFICATION LABEL
CODE
DESCRIPTION
EMPLOYEE ID
SUPPLIER
CRATE #
DATE
QUANTITY


Fan Wheel
Cut-off
Blast Area
Outlet Area (partially cut of in this picture)
FAN WITH PIEZO RING
PRODUCT IDENTIFICATION LABEL

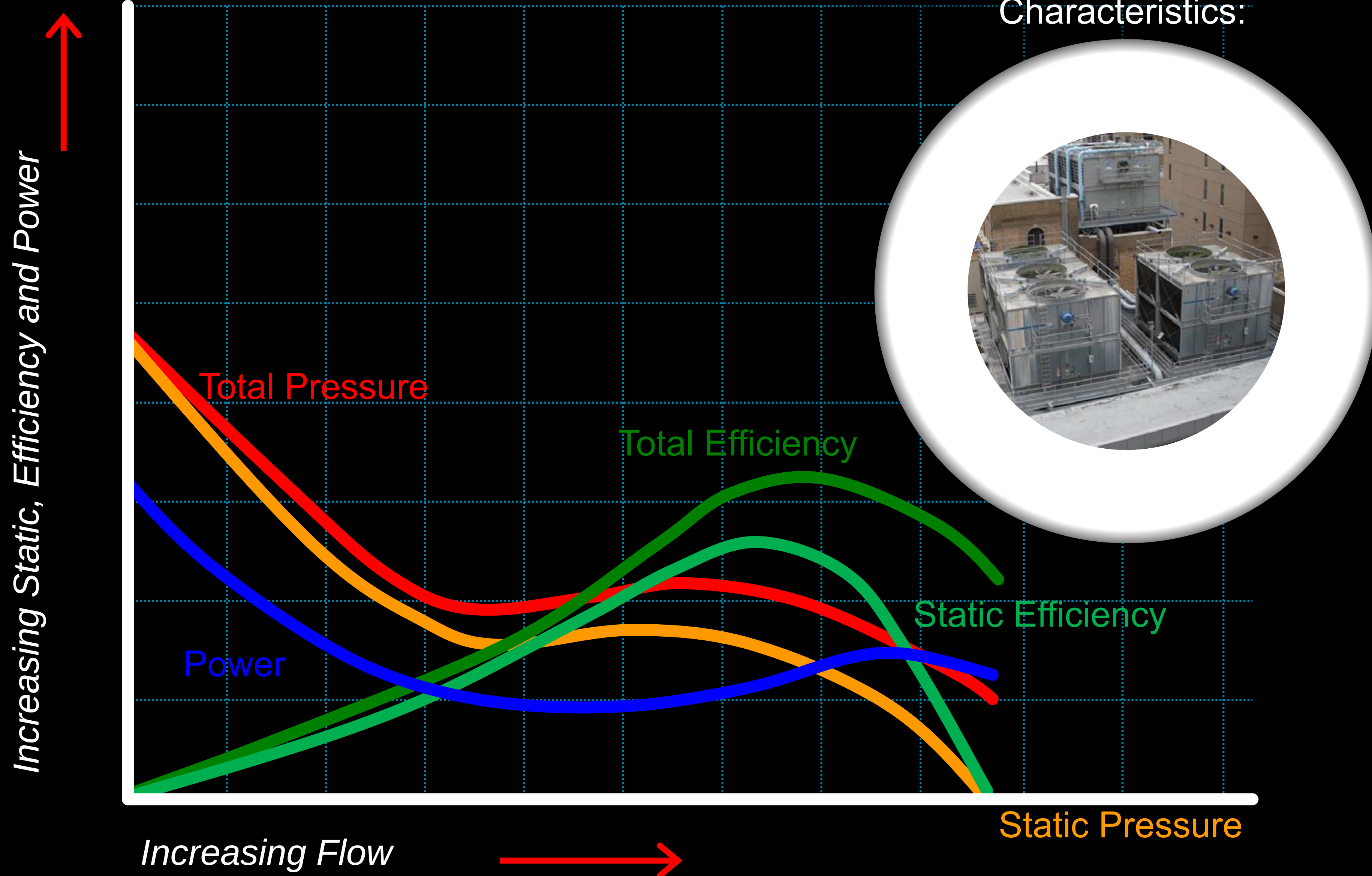

Airfoil Fan Wheel Characteristics:
Increasing Static, Efficiency and Power
Total Pressure
Static Pressure
Total Efficiency
Static Efficiency
Power
Increasing Flow

Backward Inclined Fan Wheel Characteristics:



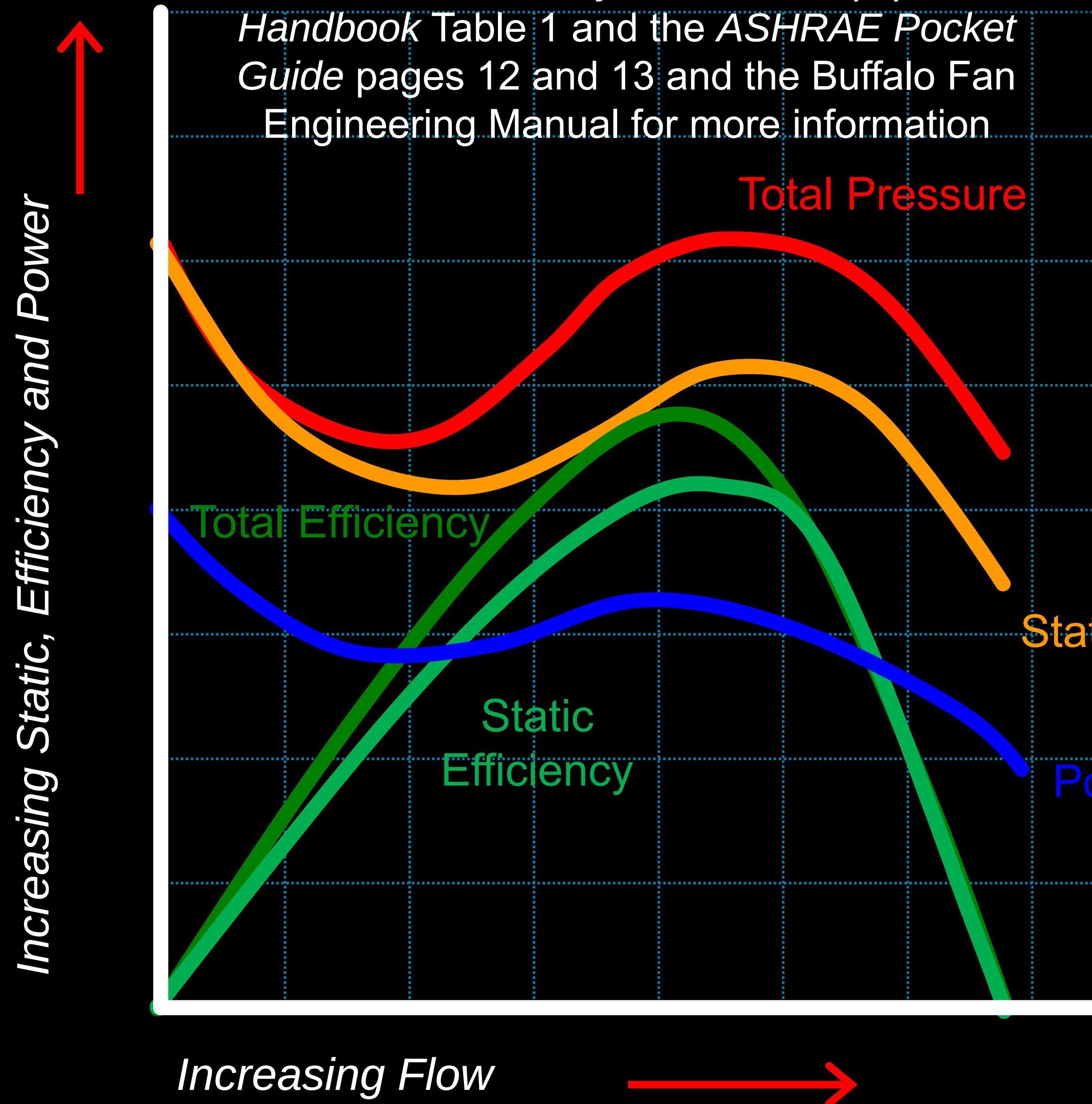

Forward Curved Wheel Characteristics:
Total Pressure
Total Efficiency
Static Pressure
Power
Static Efficiency
Increasing Static, Efficiency and Power
Increasing Flow

Forward Curved Wheel Characteristics:

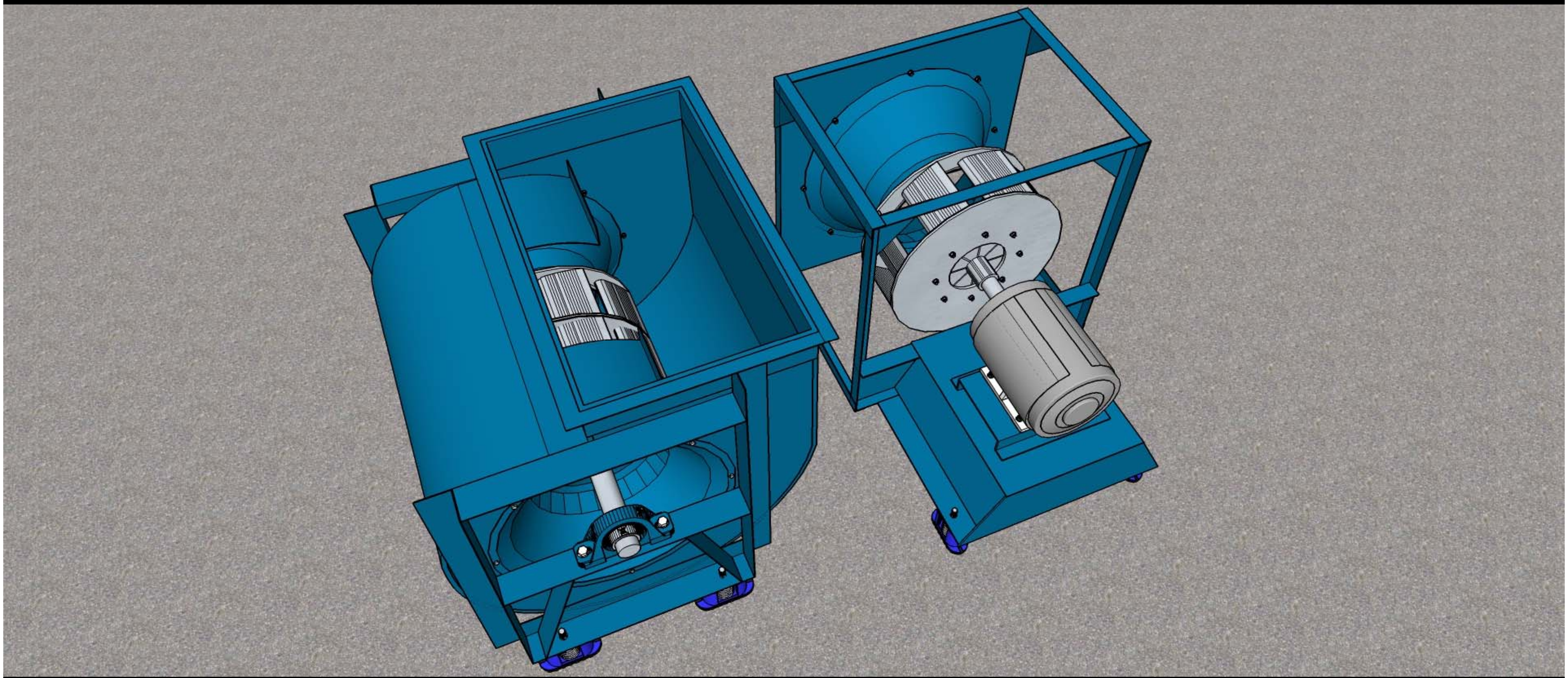


Vane Axial Fan Characteristics:

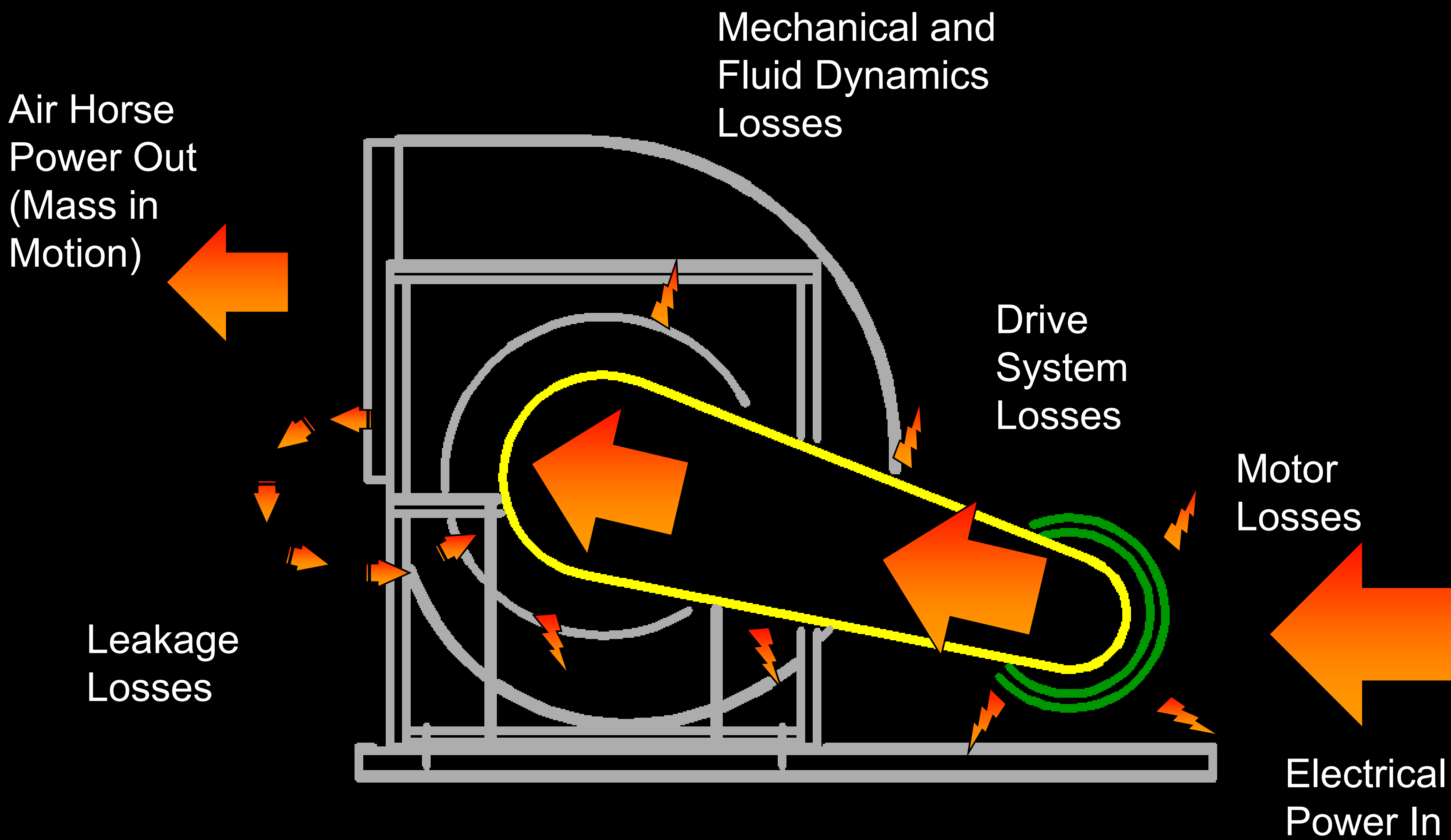
See the ASHRAE Systems and Equipment Handbook Table 1 and the *ASHRAE Pocket Guide* pages 12 and 13 and the Buffalo Fan Engineering Manual for more information



Images courtesy of NASA; http://www.nasa.gov/centers/langley/images/content/221601main_image-0222-2008_full.jpg



Fan Efficiency



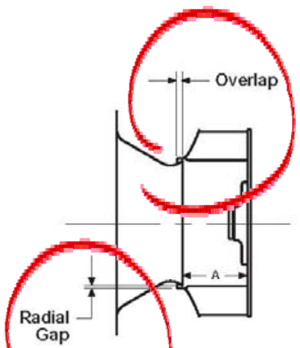
A Field Issue Affecting Fan Efficiency

RADIAL GAP, OVERLAP & WHEEL ALIGNMENT

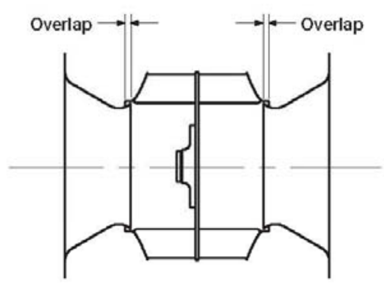
Efficient fan performance can be maintained by having the correct radial gap, overlap and wheel alignment. These items should be checked after the fan has been in operation for 24 hours and before start-up when the unit has been disassembled. Radial gap and overlap information applies to models: BISW, AFSW, BIDW, AFDW, PLN, and PLG.

Inlet Cone to Backplate Distance
(inches)

Unit Size	A dim. ± Tolerence	
7 - 10	3 5/8	± 1/8
12	4	± 1/8
13	4 7/16	± 1/8
15	5	± 1/8
16	5 7/16	± 1/8
18	6 3/8	± 1/8
20	7	± 3/16
22	7 13/16	± 3/16
24	8 5/8	± 1/4
27	9 7/16	± 1/4
30	10 9/16	± 3/8
33	11 7/16	± 3/8
36	12 3/4	± 3/8
40	14 3/16	± 3/8
44	15 9/16	± 3/8
49	17 1/8	± 1/2
54	18 13/16	± 1/2
60	20 15/16	± 1/2
66	22 7/8	± 1/2
73	25 1/2	± 1/2



BISW, AFSW, PLN, PLG



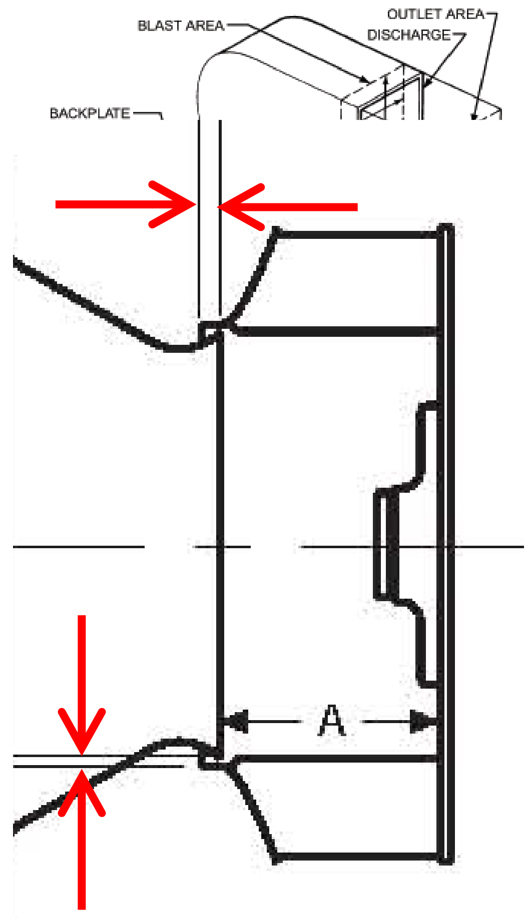
BIDW, AFDW

RADIAL GAP

Radial gap is adjusted by loosening the inlet cone/ring bolts and centering the cone/ring on the wheel. If additional adjustment is required to maintain a constant radial gap, loosening the bearing bolts and centering wheel is acceptable as a secondary option.

OVERLAP

Overlap is adjusted by loosening the wheel hub from the shaft and moving the wheel to the desired position along the shaft. The Inlet Cone to Backplate Distance chart lists the distance between the wheel and the inlet cone spacing for non-double width fans. Overlap on double width fans is set by having equal spacing on each side of the wheel.



Imagess courtesy of Greenheck (left) and ASHRAE 2008 Handbook of Systems and Equipment, Chapter 20 (right)

Inlet Cones, Inlet Vanes, and VFD Retrofits

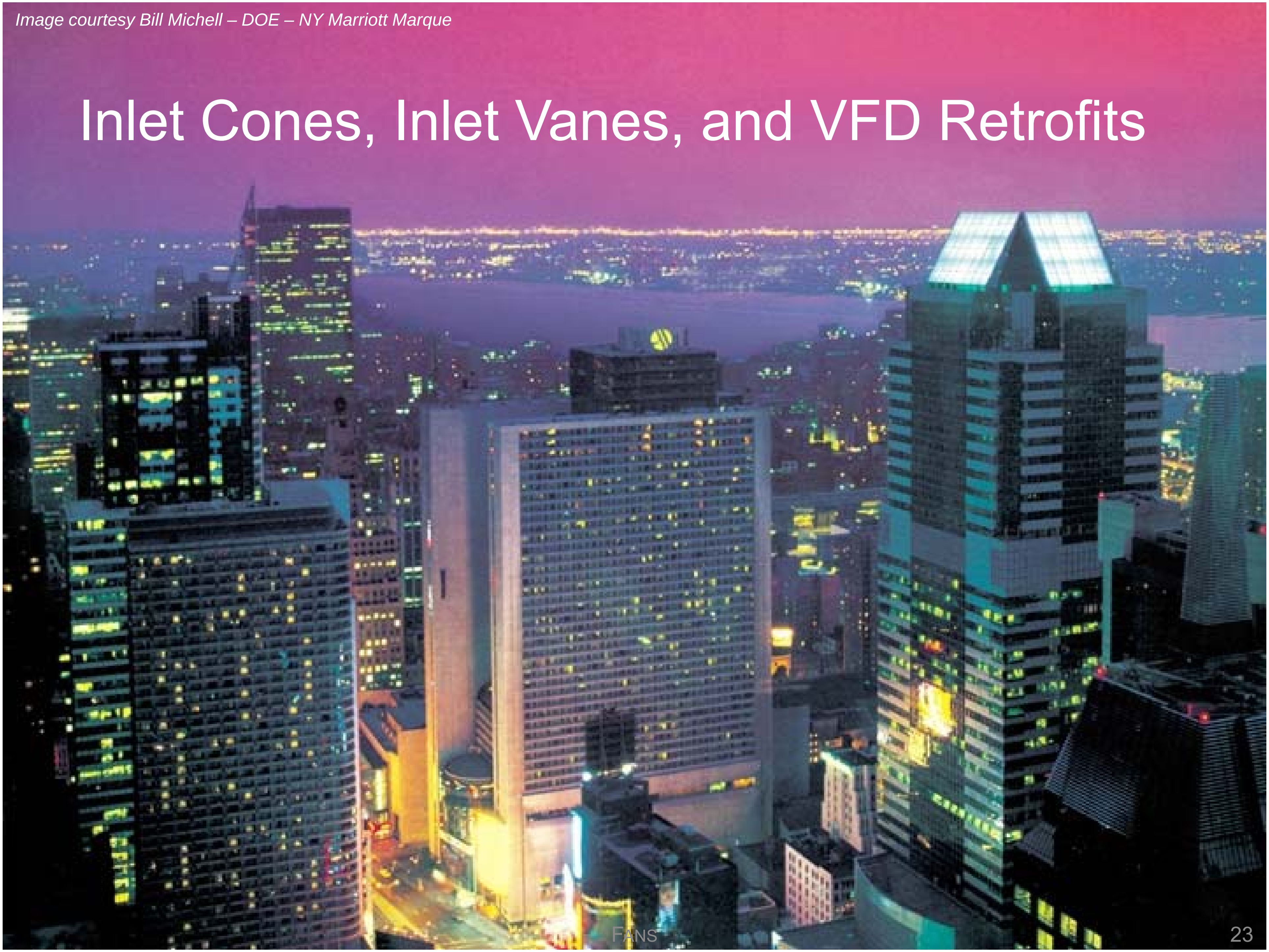


Image courtesy Bill Michell – DOE – NY Marriott Marque

Image courtesy Bill Michell – DOE – NY Marriott Marque

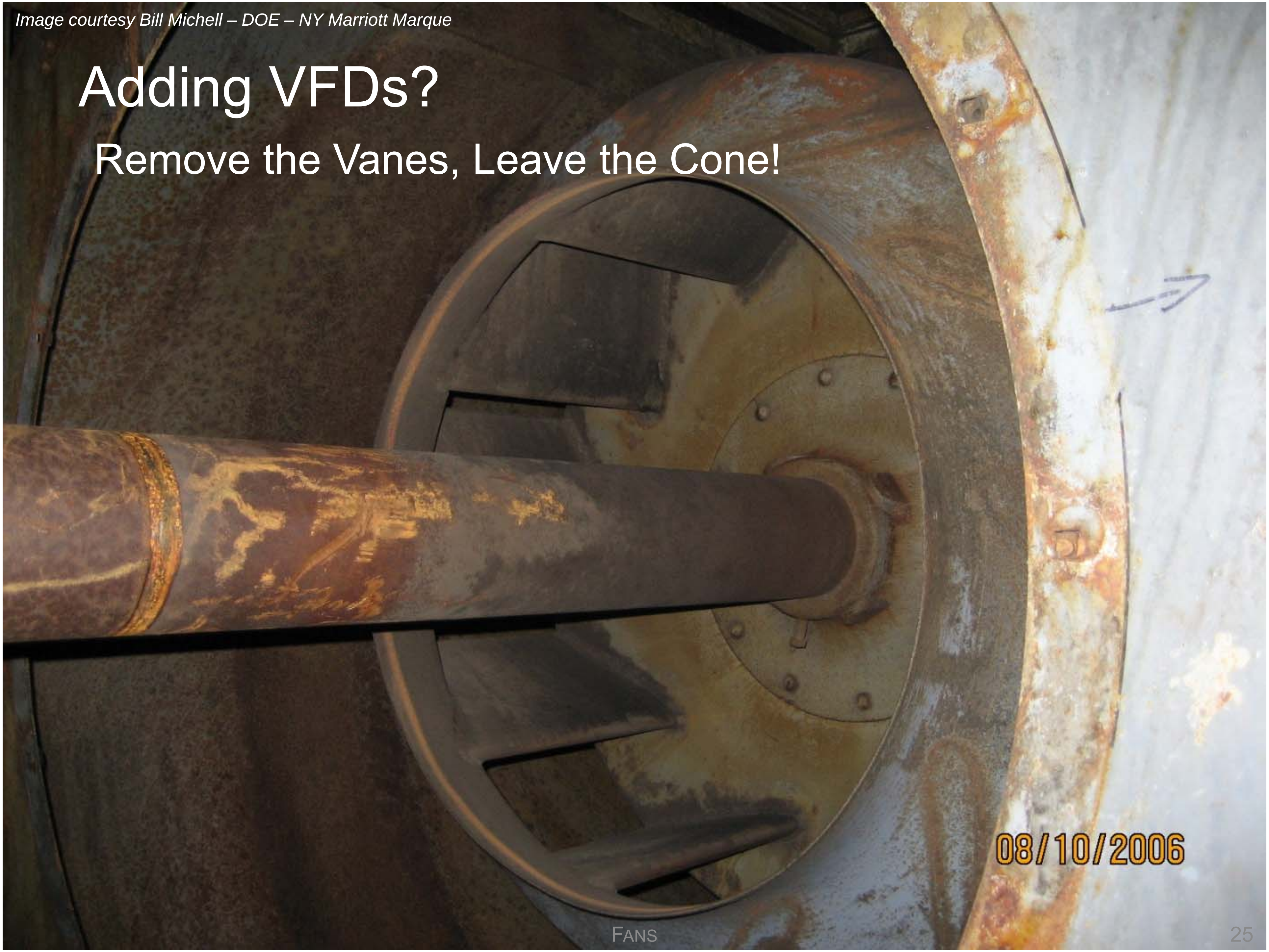
Inlet Vanes are Supported by Inlet Cones

Image courtesy Bill Michell – DOE – NY Marraiott Marque

Image courtesy Bill Michell – DOE – NY Marriott Marque

Adding VFDs?

Remove the Vanes, Leave the Cone!



DW Airfoil

Selected Fans

Cataloged

Type	Size	Cl.	% dia	% wid	% peak	Drive	RPM	Max RPM	Std. BHP	Op. BHP	OV	S.E.	M.E.	In.LwA	Out.LwA	$$
BAE-DW	182	I	100	100	93.50	BD	1371	2248	2.07	2.07	1449	75.89	80.85	82	83	1.00
BAE-DW	165	I	100	100	72.49	BD	1793	2761	2.47	2.47	1773	63.54	69.76	87	88	0.93
BAE-DW	150	I	100	100	49.49	BD	2298	3232	2.85	2.85	2146	55.15	63.06	90	91	0.85
BAE-DW	135	I	100	100	45.87	BD	2755	3374	3.11	3.11	2646	50.49	61.51	91	93	0.79

Fan Details

Sound Details

Octave Bands

Reports

Curves

AMCA Stmts

DW Backward Inclined Wheel

Selected Fans

Cataloged

Fan Details

Sound Details

Octave Bands

Type	Size	Cl.	% dia	% wid	% peak	Drive	RPM	Max RPM	Std. BHP	Op. BHP	OV	S.E.	M.E.	In.LwA	Out.LwA
BAE-DW	182	I	100	100	93.50	BD	1371	2248	2.07	2.07	1449	75.89	80.85	82	83
BC-DW	200	I	100	100	92.86	BD	1160	1961	2.30	2.30	1208	68.27	71.38	88	N/A
BC-DW	182	I	100	100	83.83	BD	1338	2149	2.36	2.36	1449	66.69	71.05	89	N/A
BAE-DW	165	I	100	100	72.49	BD	1793	2761	2.47	2.47	1773	63.54	69.76	87	88
BC-DW	165	I	100	100	72.61	BD	1595	2358	2.63	2.63	1773	59.66	65.50	89	N/A
BAE-DW	150	I	100	100	49.49	BD	2298	3232	2.85	2.85	2146	55.15	63.06	90	91
BC-DW	150	I	100	100	60.75	BD	1918	2594	2.90	2.90	2146	54.26	62.05	91	N/A
BAE-DW	135	I	100	100	45.87	BD	2755	3374	3.11	3.11	2646	50.49	61.51	91	93

Reports

Curves

AMCA Stmts

Fan Performance Presentation

33-AFDW-41

Fan Performance Chart: Operating Conditions

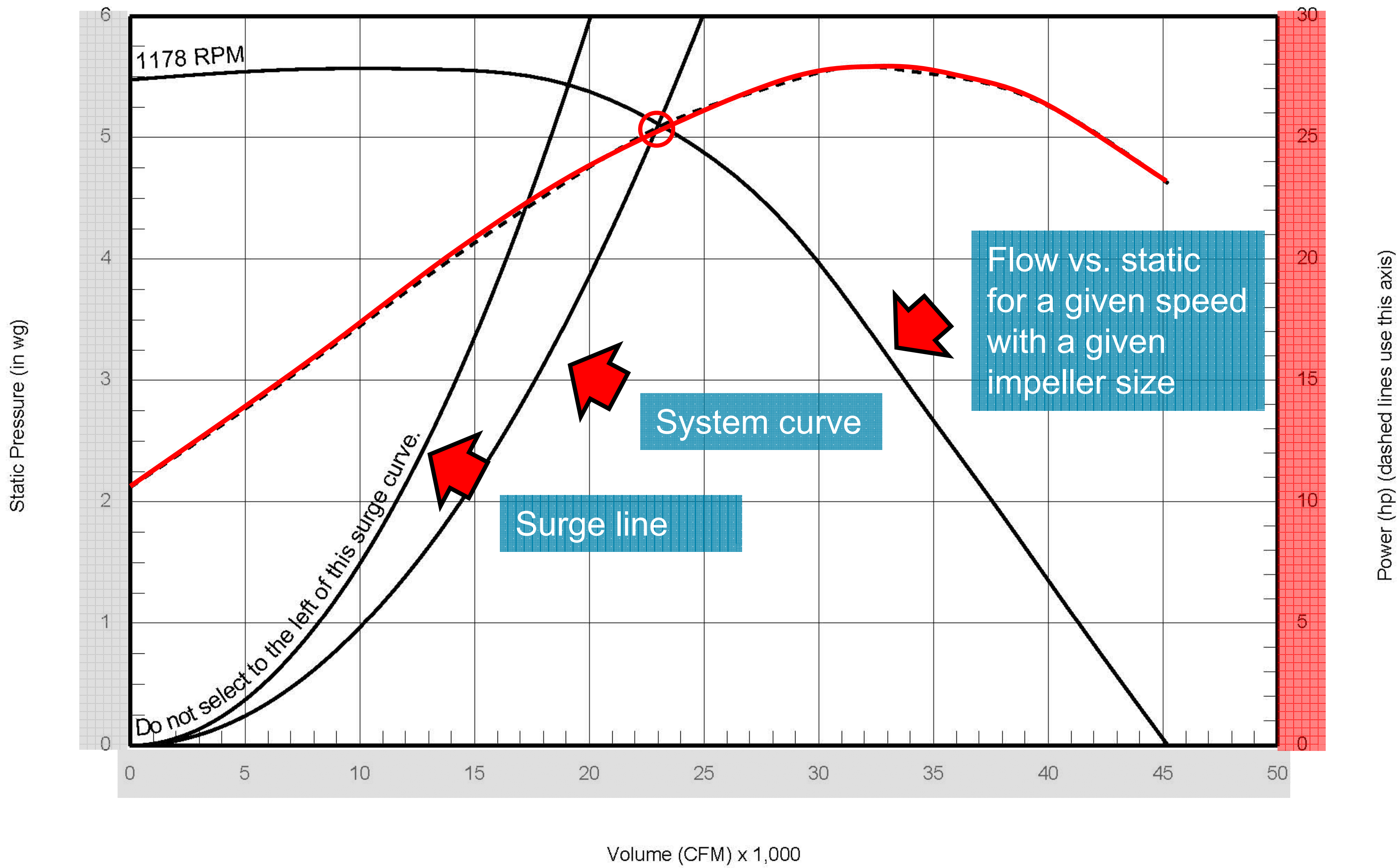
Volume (CFM):	23,000	Air Density (lb/ft3):	0.075
SP (in wg):	5.1	Drive Loss (%):	3
Power (hp):	25.36	Elevation (ft):	0
RPM:	1,178	Air Stream Temp. (F):	70

Inlet Sound Data

62.5	125	250	500	1000	2000	4000	8000	LwA	dBA	Sones
100	97	97	90	88	85	81	73	94	83	42

Outlet Sound Data

62.5	125	250	500	1000	2000	4000	8000	LwA	dBA	Sones
102	98	95	89	87	82	78	76	92	81	39



33-AFDW-41

Fan Performance Chart: RPM Family

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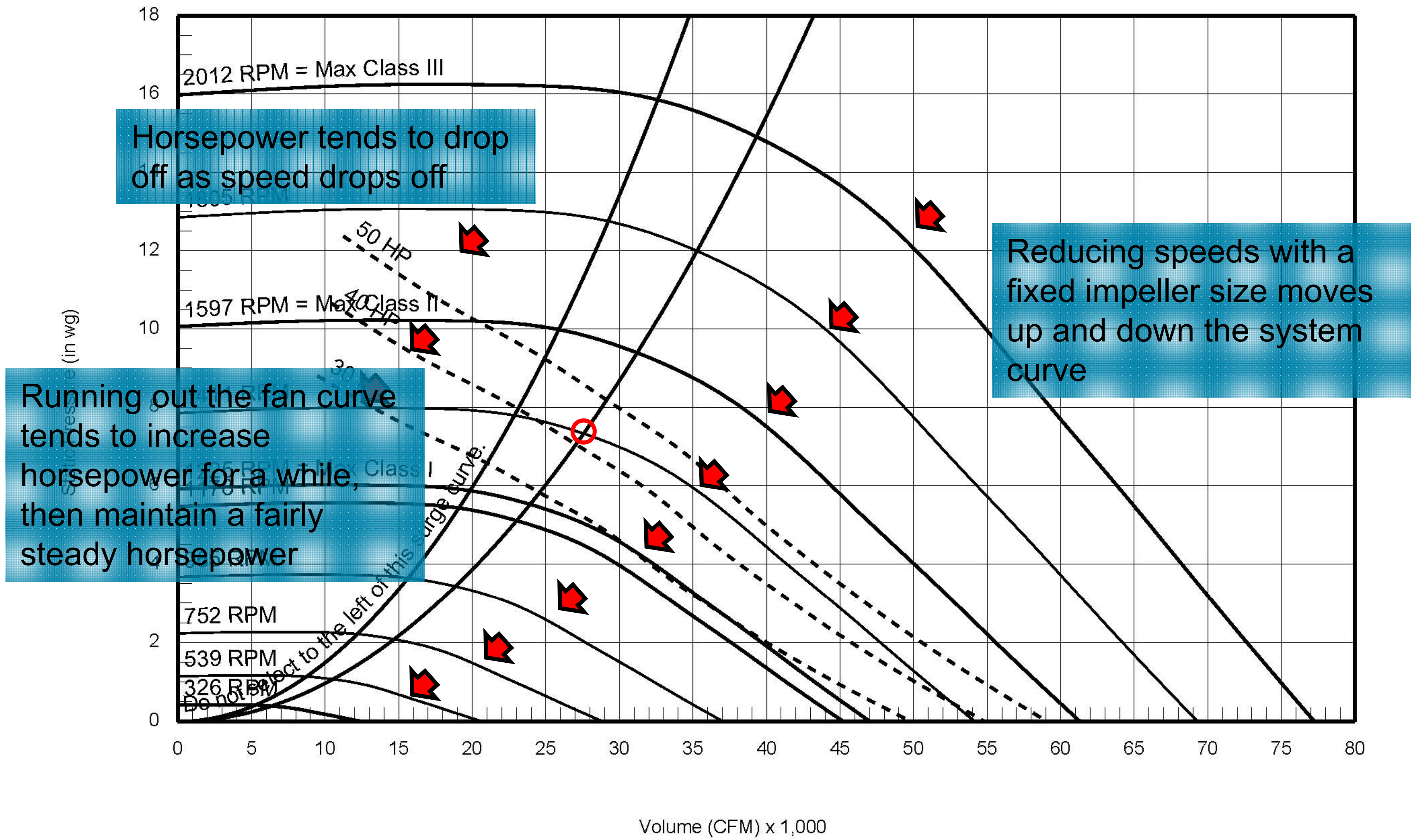
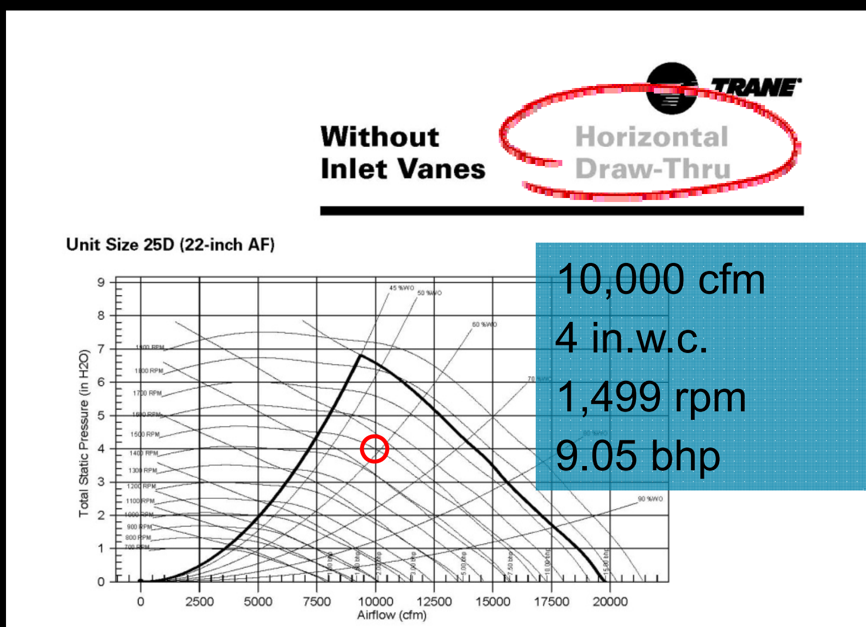
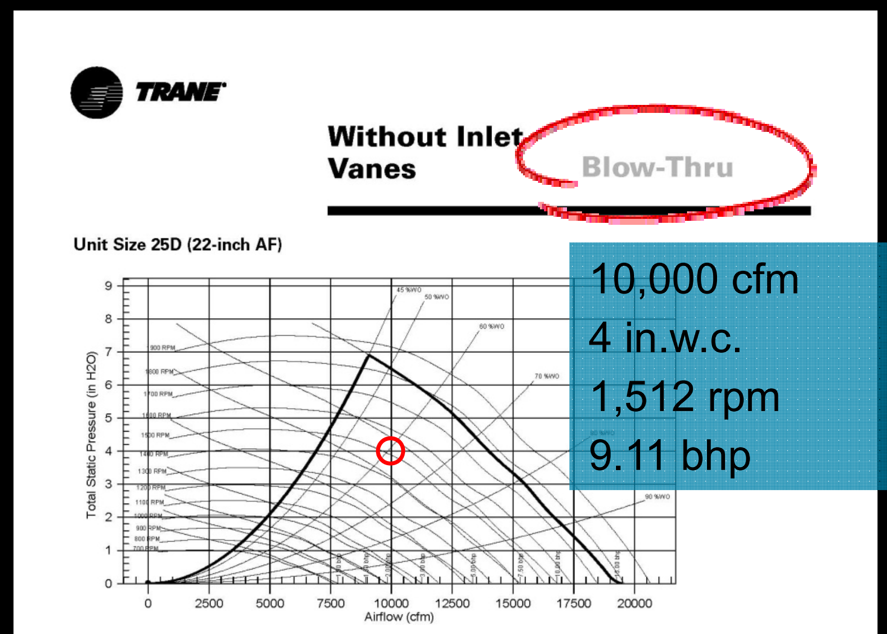


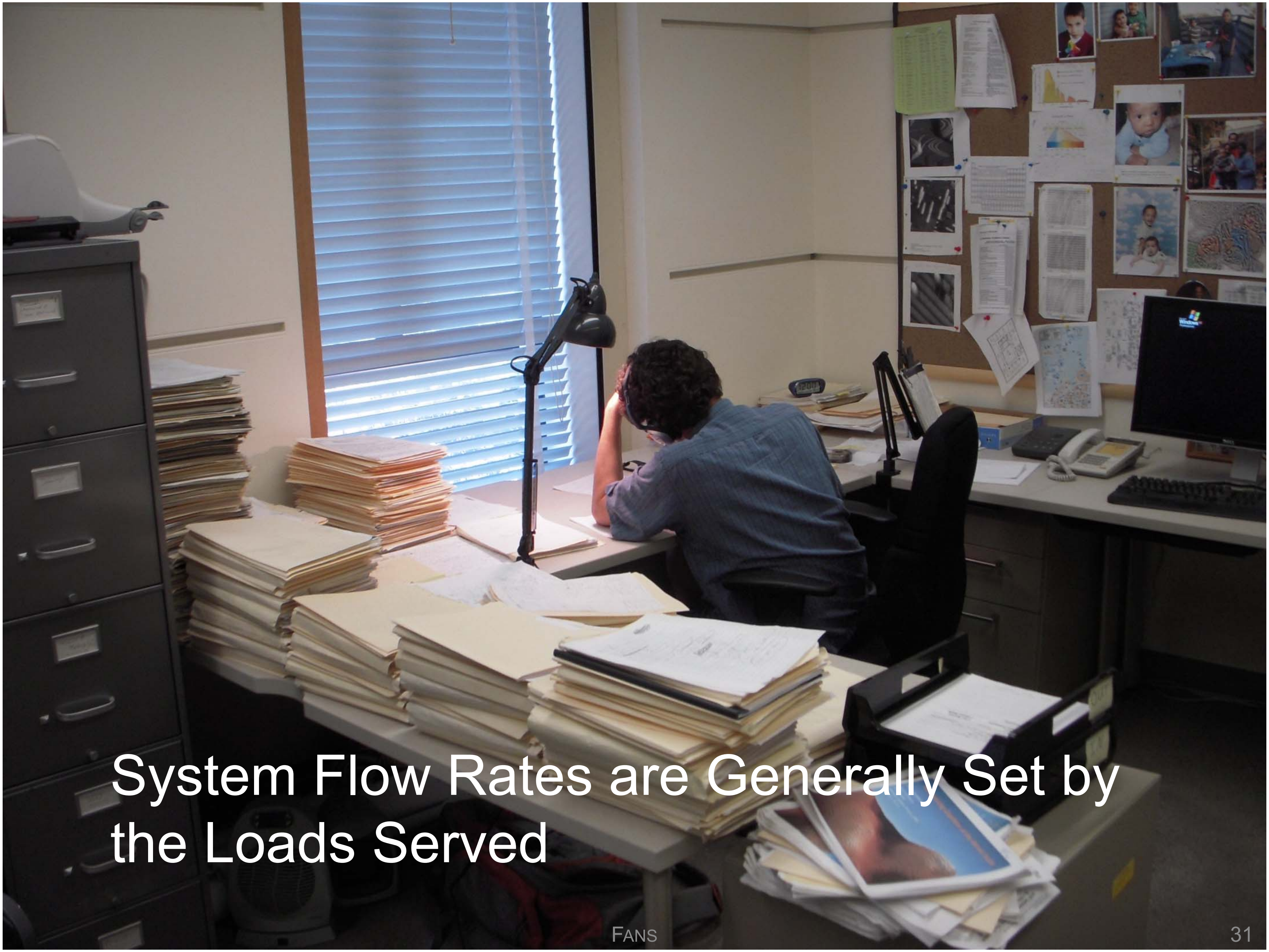
Fan Performance Presentation

There is a difference between the applied fan curve and the fan curve

Some manufacturers document this







System Flow Rates are Generally Set by the Loads Served

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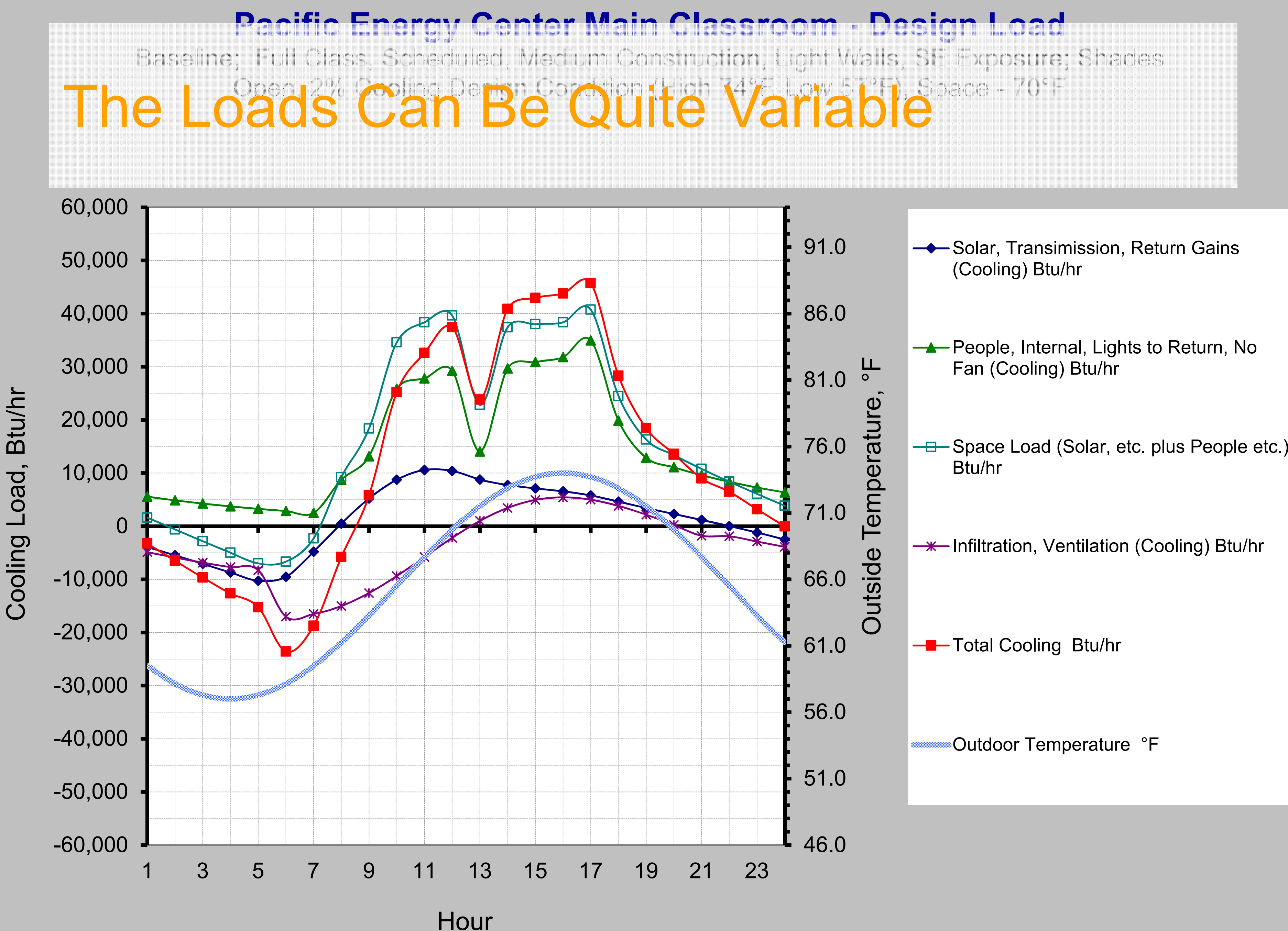
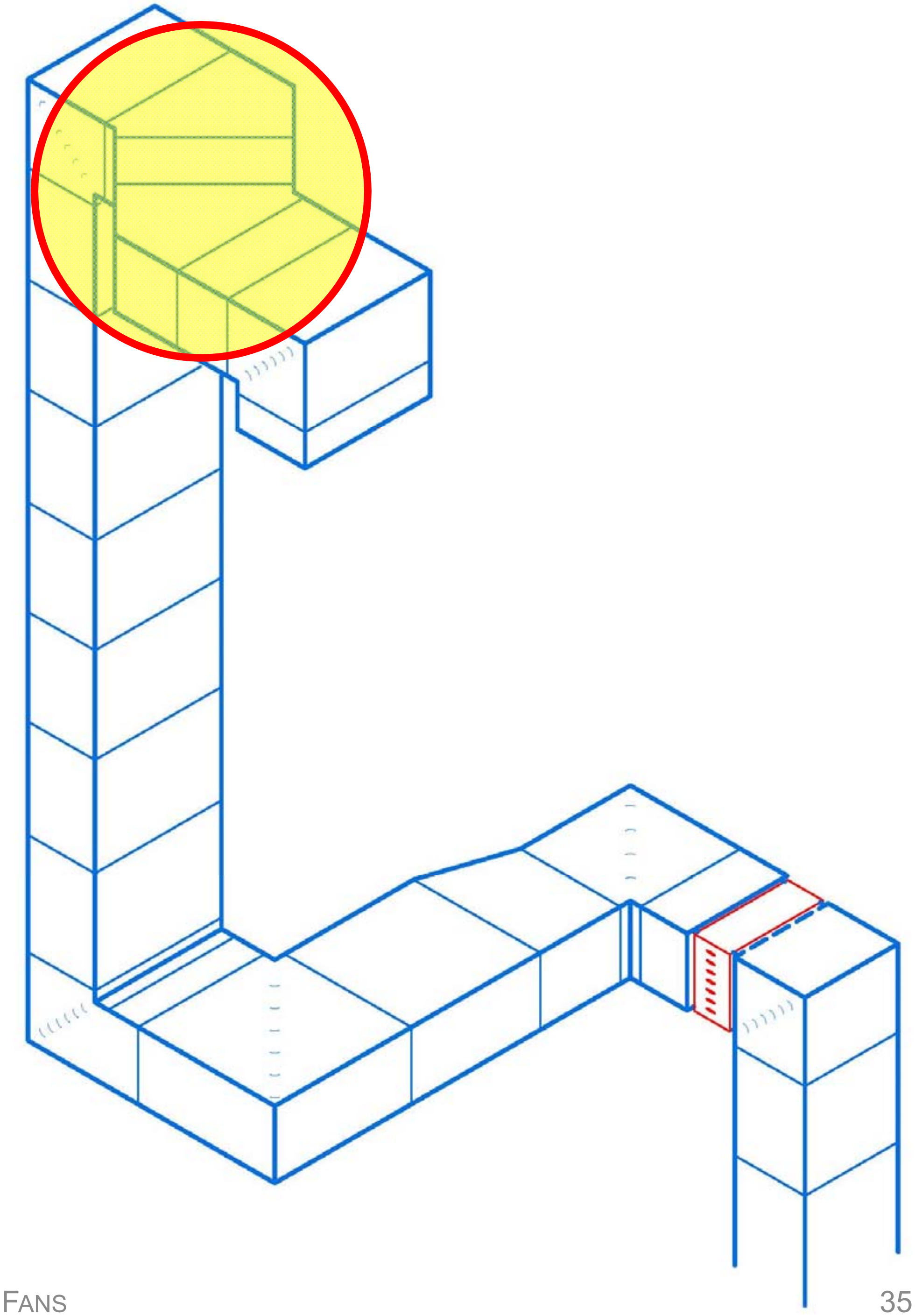
The Loads Can Be Quite Variable



Static Requirements are Set by Geometry

Fabrication details versus as designed details can make a difference

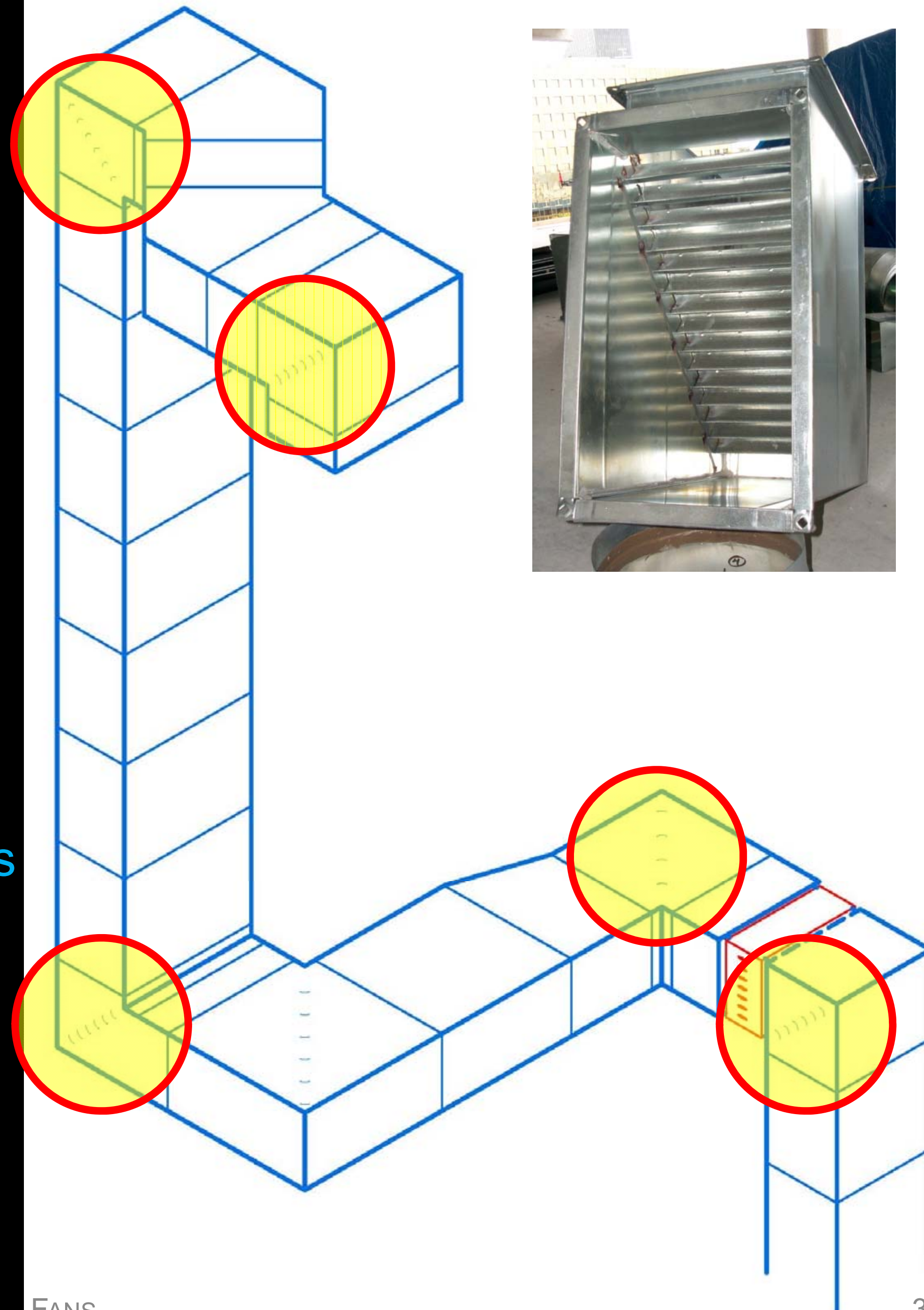
- Design – 25° mitered offset
  - C_0 – 0.11
  - Loss – 0.05 in.w.c.
- Fabrication – 45° mitered offset
  - C_0 – 0.31
  - Loss – 0.14 in.w.c.



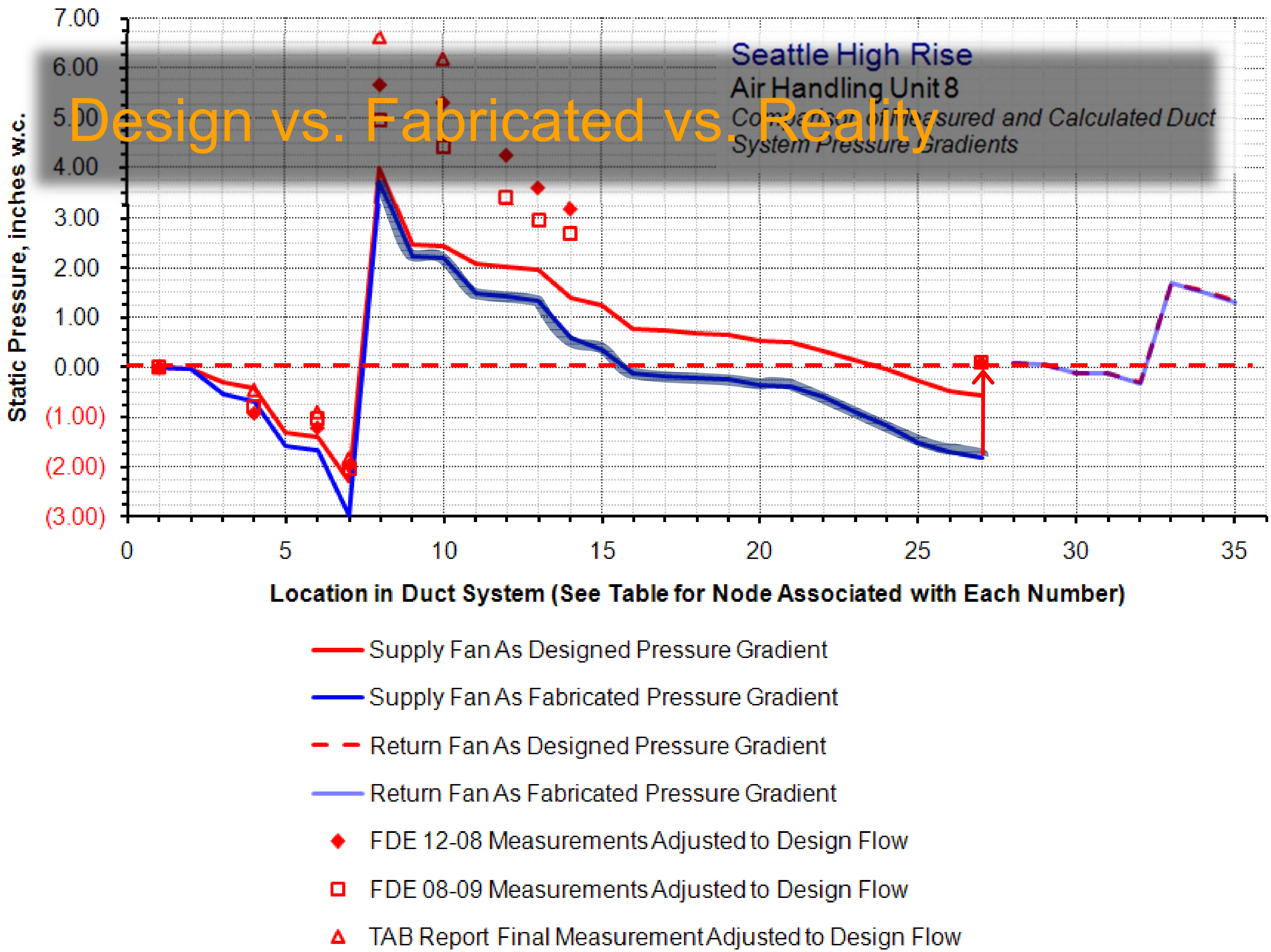
Static Requirements are Set by Geometry

Fabrication details versus as designed details can make a difference

- Design – single thickness turning vanes
  - C_0 – 0.11
  - Loss – 0.05 in.w.c.
- Fabrication – double thickness turning vanes
  - C_0 – 0.25
  - Loss – 0.10 in.w.c.



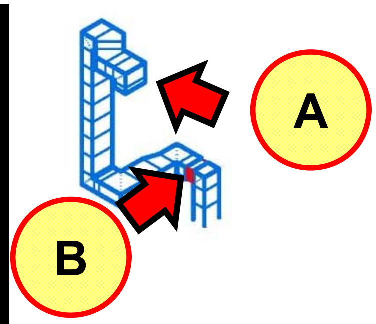
Design vs. Fabricated vs. Reality

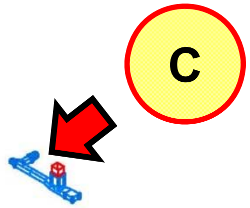


The AHU8 Supply Duct Some Perspective

Plotted to scale from the fan discharge (A) to the terminal unit inlet at the most remote terminal unit (C)

40% of the static pressure is used up between the discharge (A) and the mechanical shaft point of entry (B).





Given:

The fan curve in the next slide

A measured fan speed of 1,411 rpm

A measured flow rate of 30,000 cfm

Determine:

The fan static pressure

The fan class

The fan brake horsepower

The system curve

The speed required to produce 28,000 cfm and the operating conditions at that speed

What would happen if you throttled to 28,000 cfm instead of reducing fan speed?

Could you speed the fan up and obtain 35,000 cfm?

33-AFDW-41

Fan Performance Chart: RPM Family

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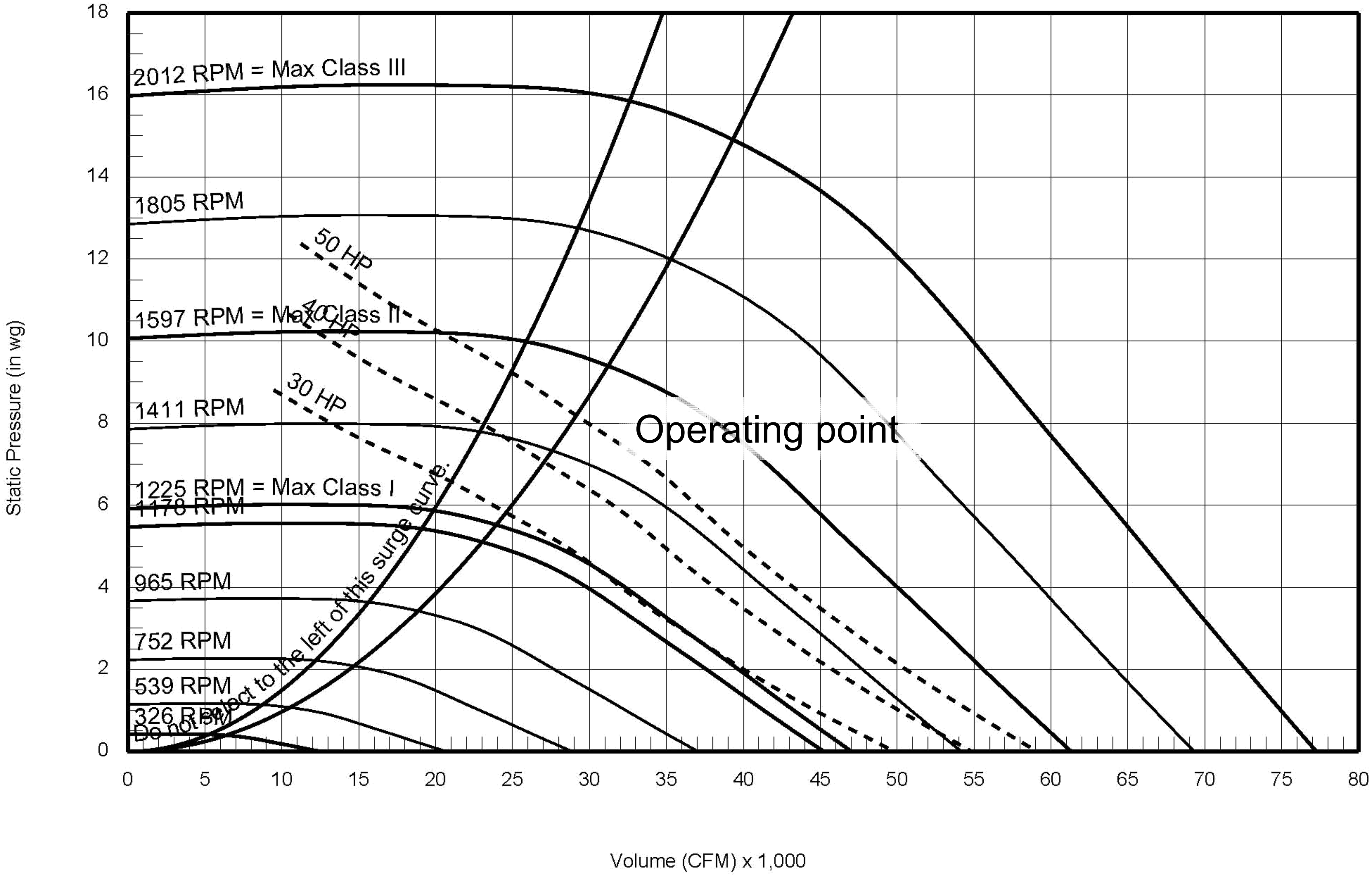

CAPS 3.1.2.3

33-AFDW-41

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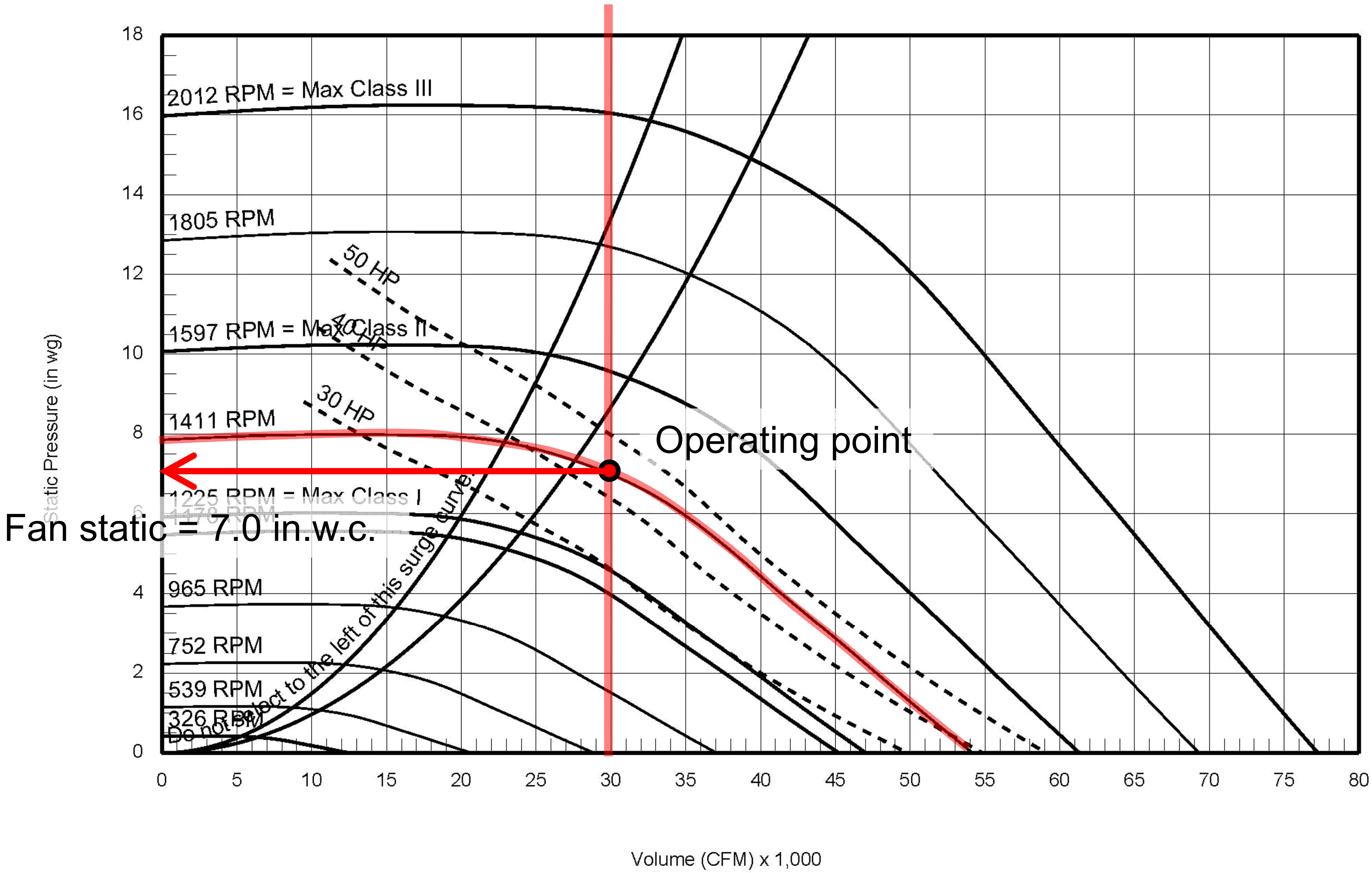

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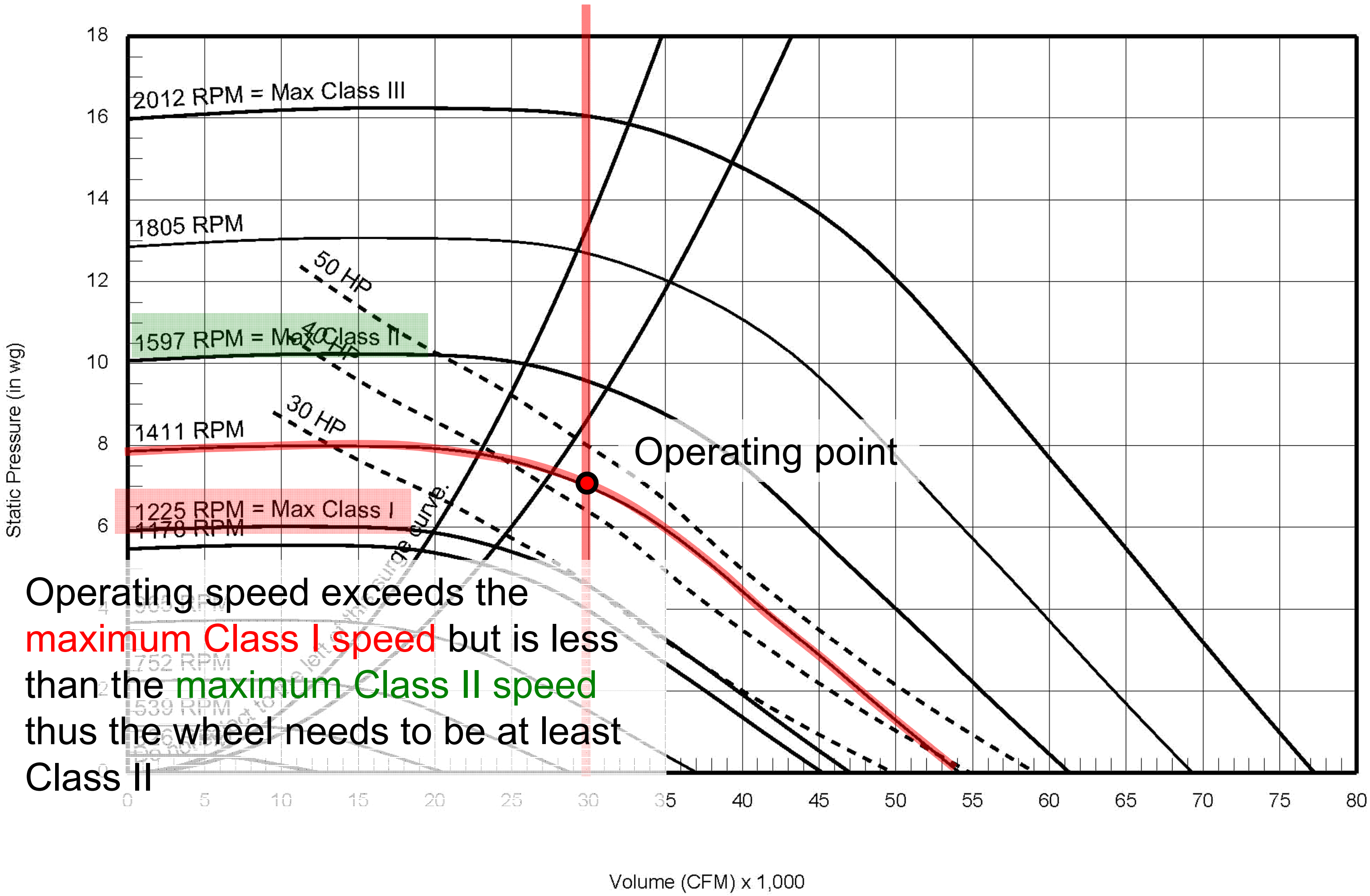

Operating speed exceeds the maximum Class I speed but is less than the maximum Class II speed thus the wheel needs to be at least Class II

33-AFDW-41

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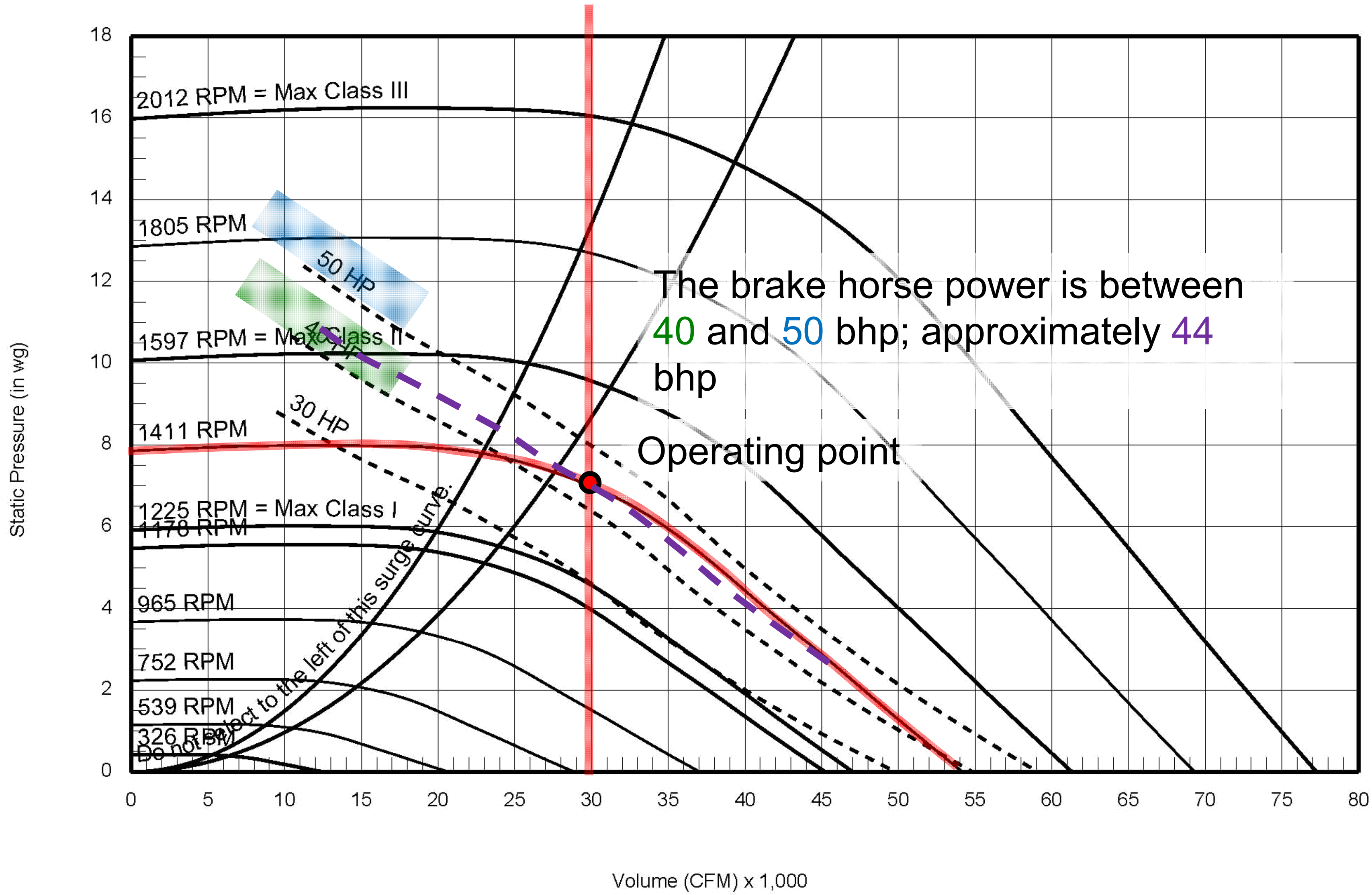

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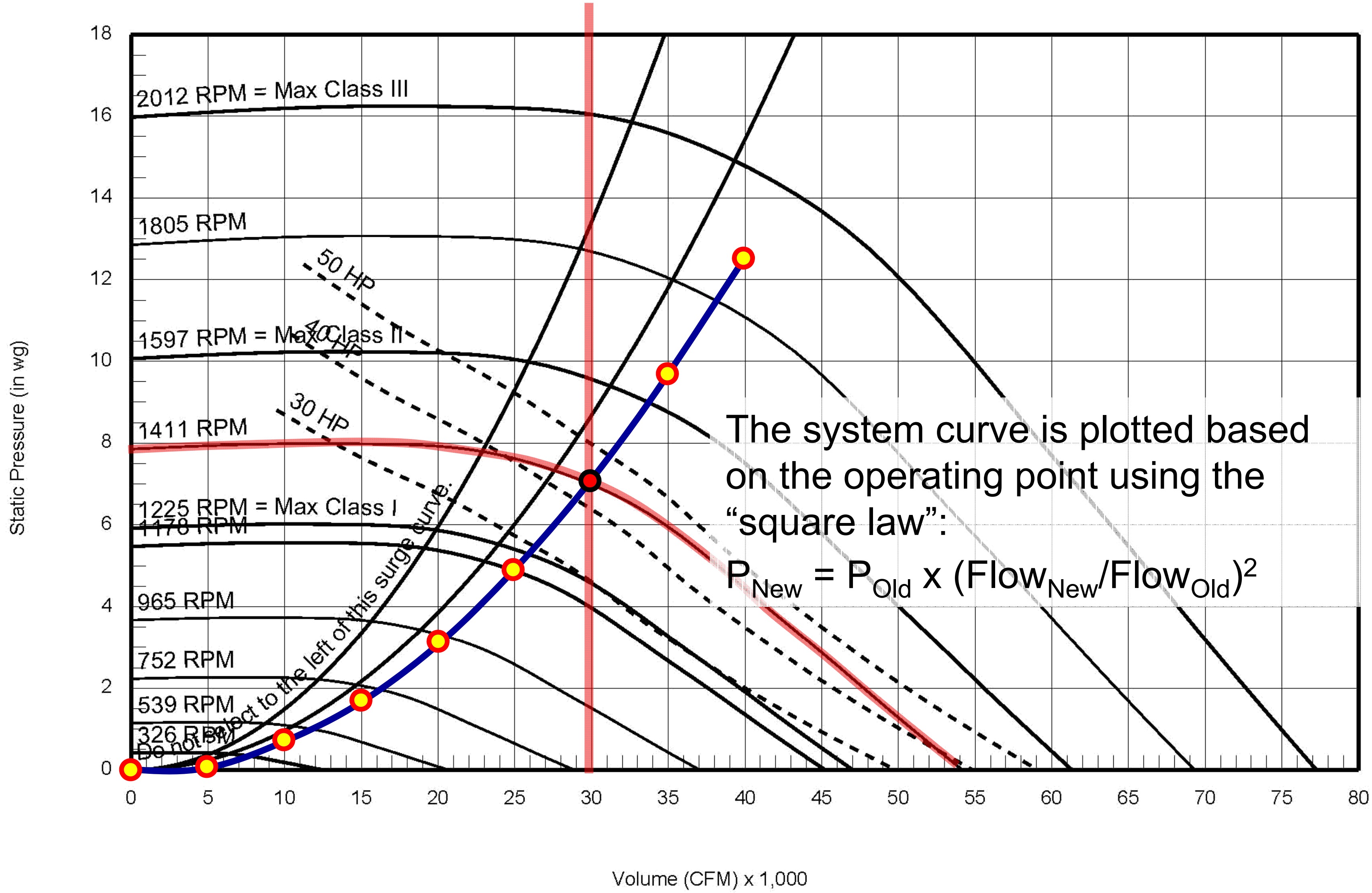


The system curve is plotted based on the operating point using the "square law":

$$P_{New} = P_{Old} \times (Flow_{New}/Flow_{Old})^2$$

Discussion Point

- *Do VAV systems operating on a single fan curve?*
- *Where is the origin of the fan curve for a VAV system.*

33-AFDW-41

Fan Performance Chart: RPM Family

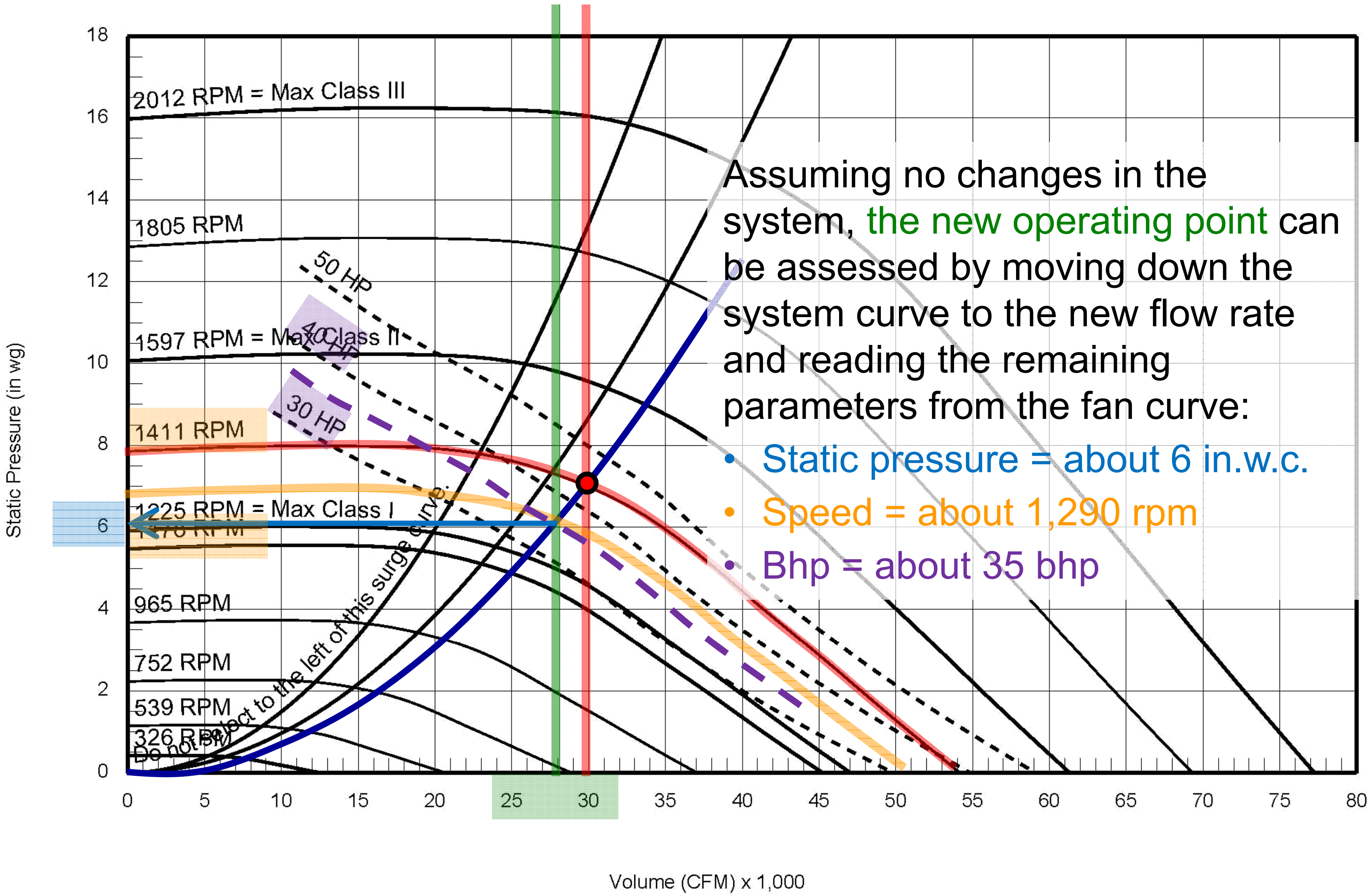
Volume (CFM):	23,000	Air Density (lb/ft3):	0.075
SP (in wg):	5.1	Drive Loss (%):	3
Power (hp):	25.36	Elevation (ft):	0
FRPM:	1,178	Air Stream Temp. (F):	70

Inlet Sound Data

62.5	125	250	500	1000	2000	4000	8000	LwA	dBA	Sones
100	97	97	90	88	85	81	78	94	83	42

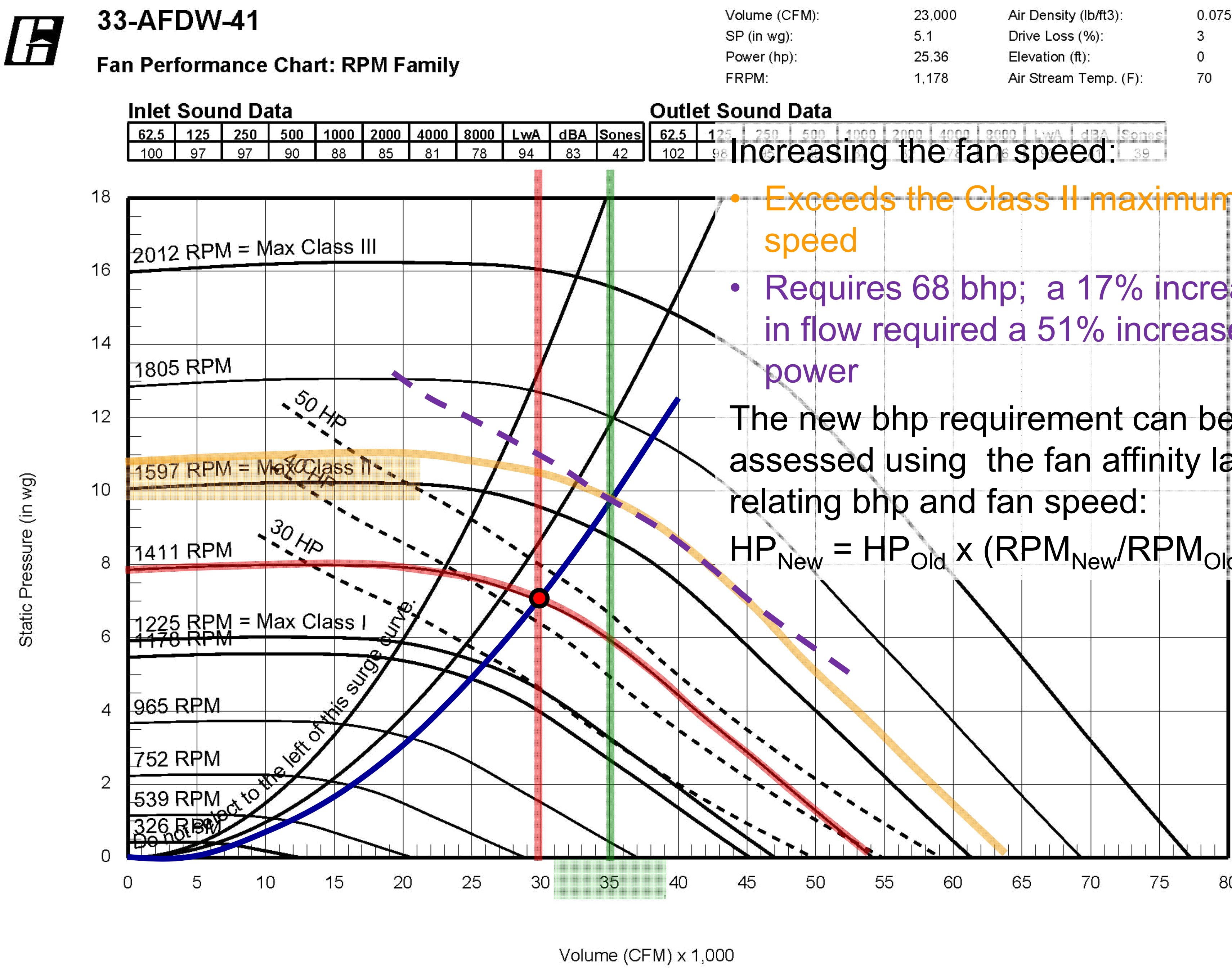
Outlet Sound Data

62.5	125	250	500	1000	2000	4000	8000	LwA	dBA	Sones
102	98	95	89	87	82	78	76	92	81	39



Assuming no changes in the system, the new operating point can be assessed by moving down the system curve to the new flow rate and reading the remaining parameters from the fan curve:

- Static pressure = about 6 in.w.c.
- Speed = about 1,290 rpm
- Bhp = about 35 bhp



Increasing the fan speed:

- Exceeds the Class II maximum speed
- Requires 68 bhp; a 17% increase in flow required a 51% increase in power

The new bhp requirement can be assessed using the fan affinity law relating bhp and fan speed:

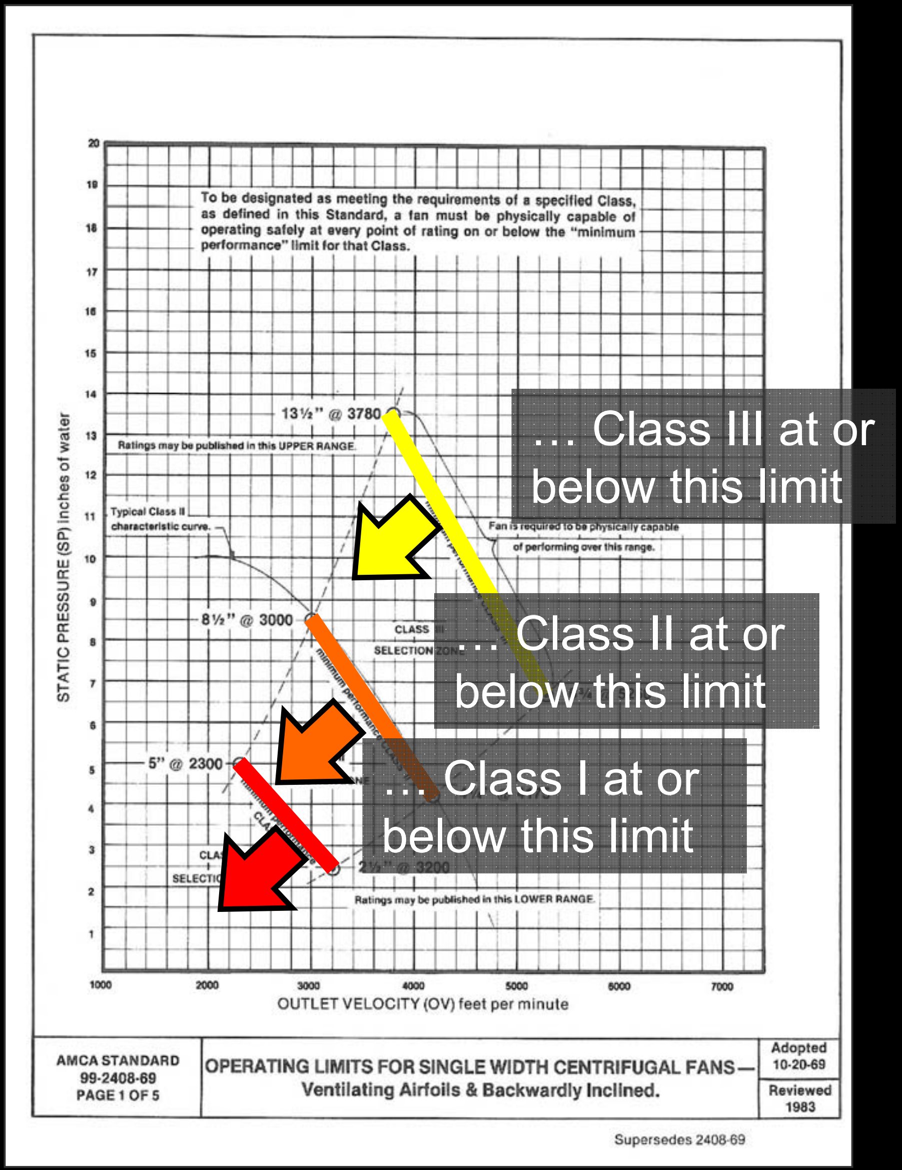
$HP_{New} = HP_{Old} \times (RPM_{New}/RPM_{Old})^3$

Fan Operating Limits

Fan wheels have structural limits

“.. must be physically capable of operating safely at every point of rating on or below the minimum performance limit …”

- Class I – Class IV (minimum to maximum rating)
- Result in a maximum speed rating for each class



This Is What Can Happen If You Over-speed A Fan

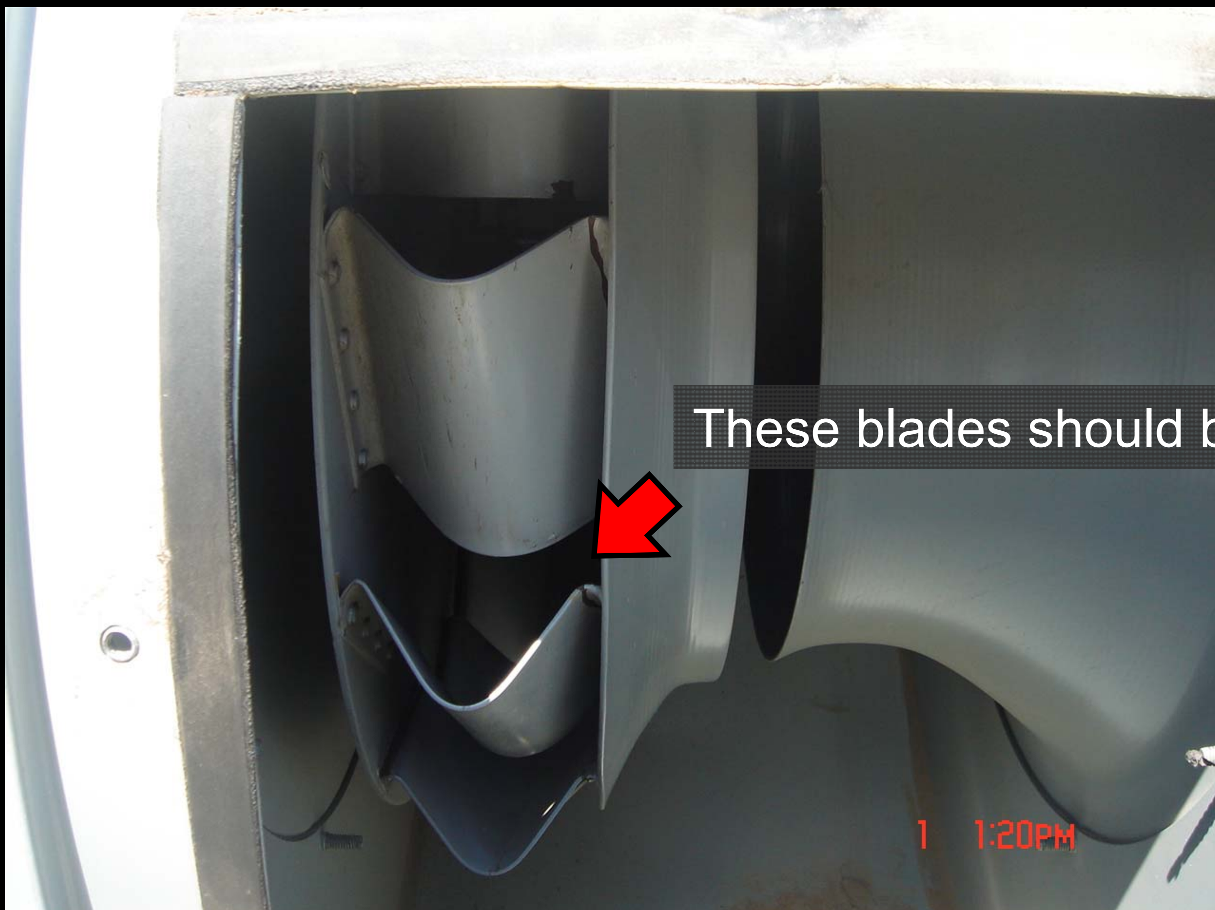
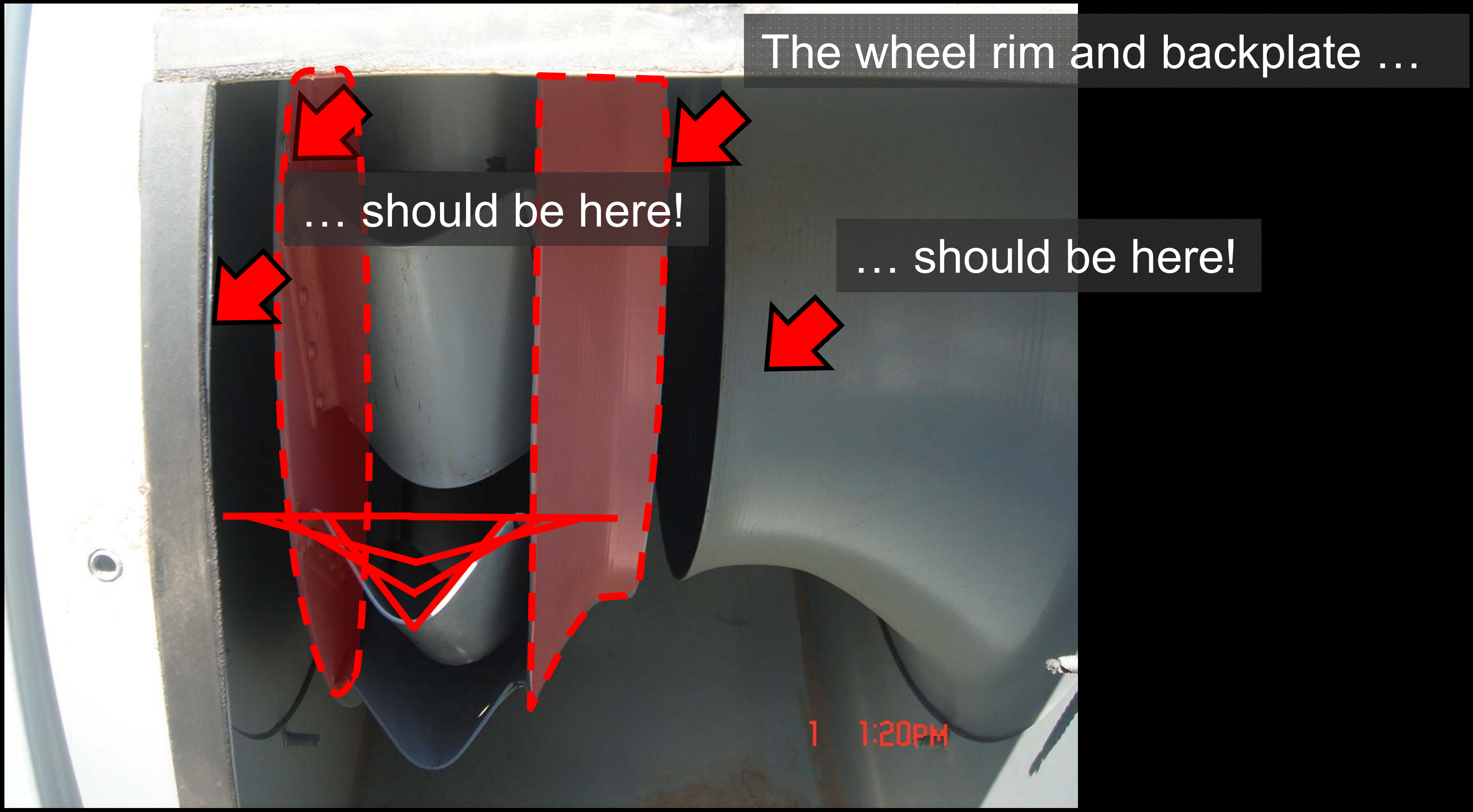


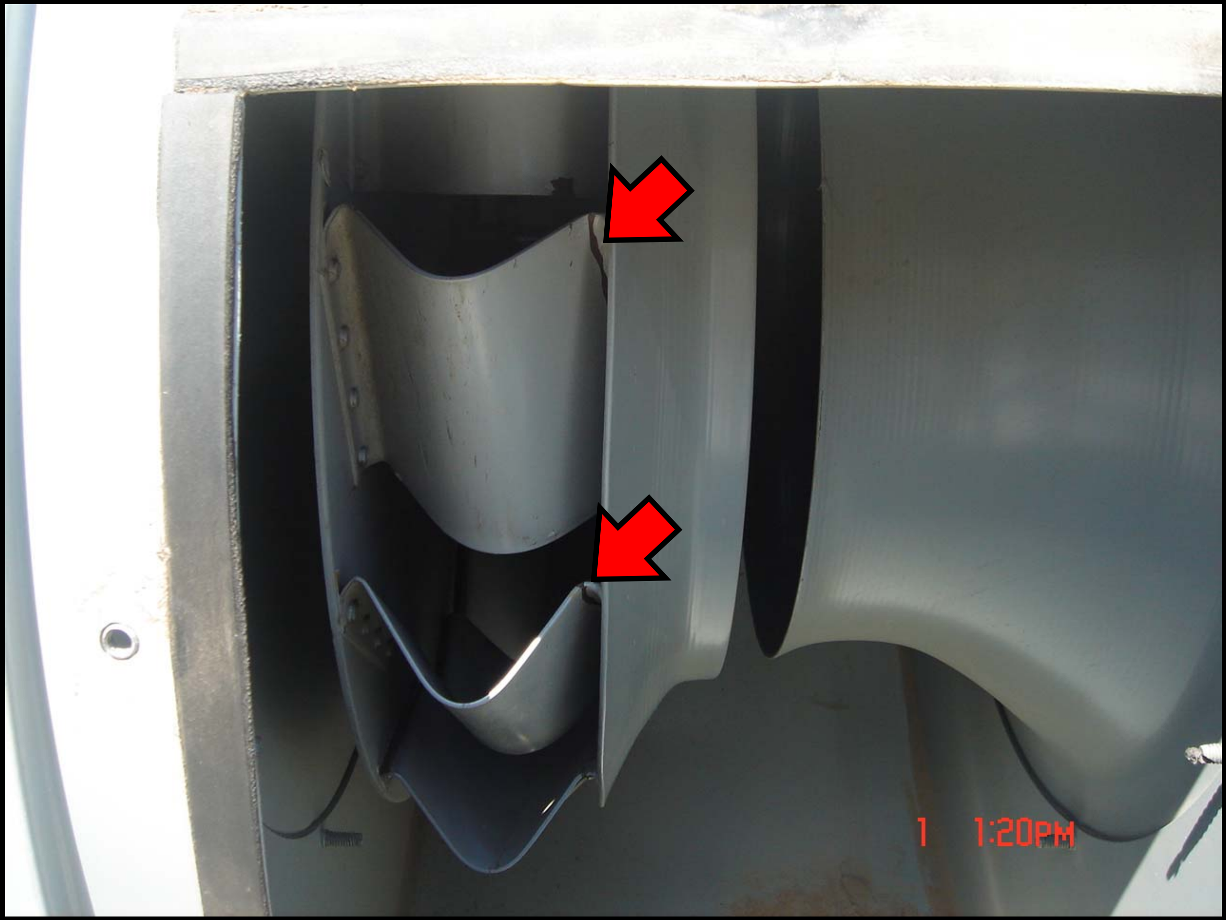
Image courtesy of Jim Bochat of Pro Services

The fan had been running about 1,000 rpm over the maximum speed limit for its fan class.

This Is What Can Happen If You Over-speed A Fan



This Project Was Lucky

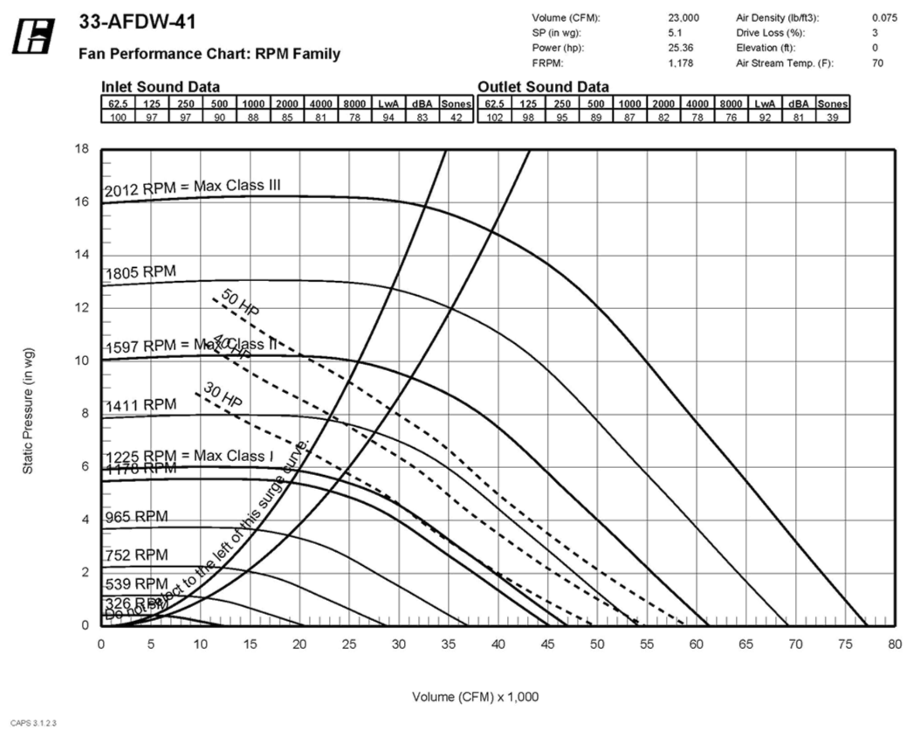


- The wheel did not disintegrate
- The collapse was so uniform the wheel remained in balance
- The problem was discovered before stress cracks cause the wheel to fail

Given the Following Information

- Flow - 25,000 cfm
- Inlet static pressure – negative 1.9 in.w.c.
- Discharge static pressure - 4.1 in.w.c.
- Fan speed – 1,411 rpm
- Volts – 463
- Amps – 42

Where do you think the fan is operating and why?



33-AFDW-41

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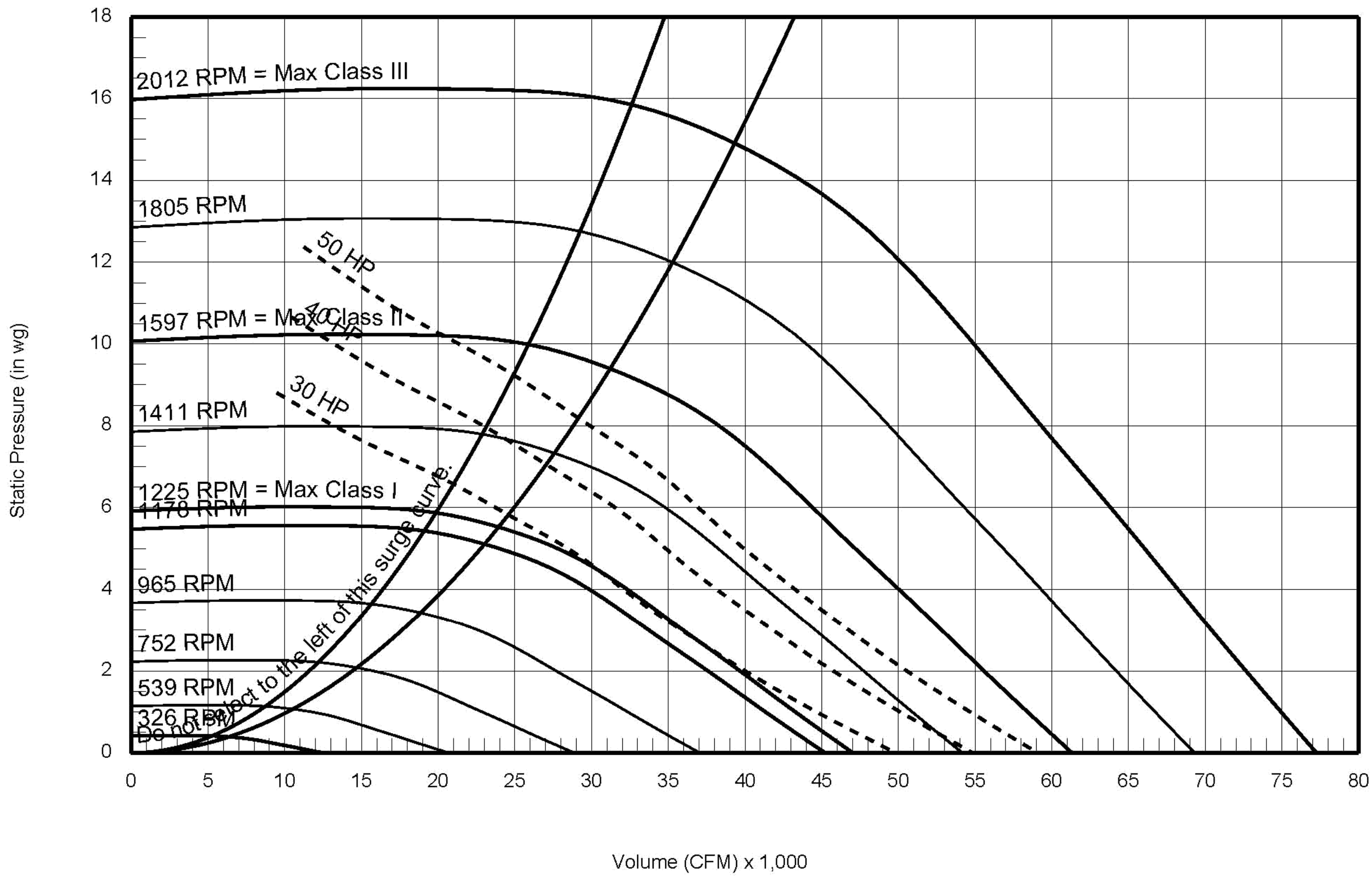

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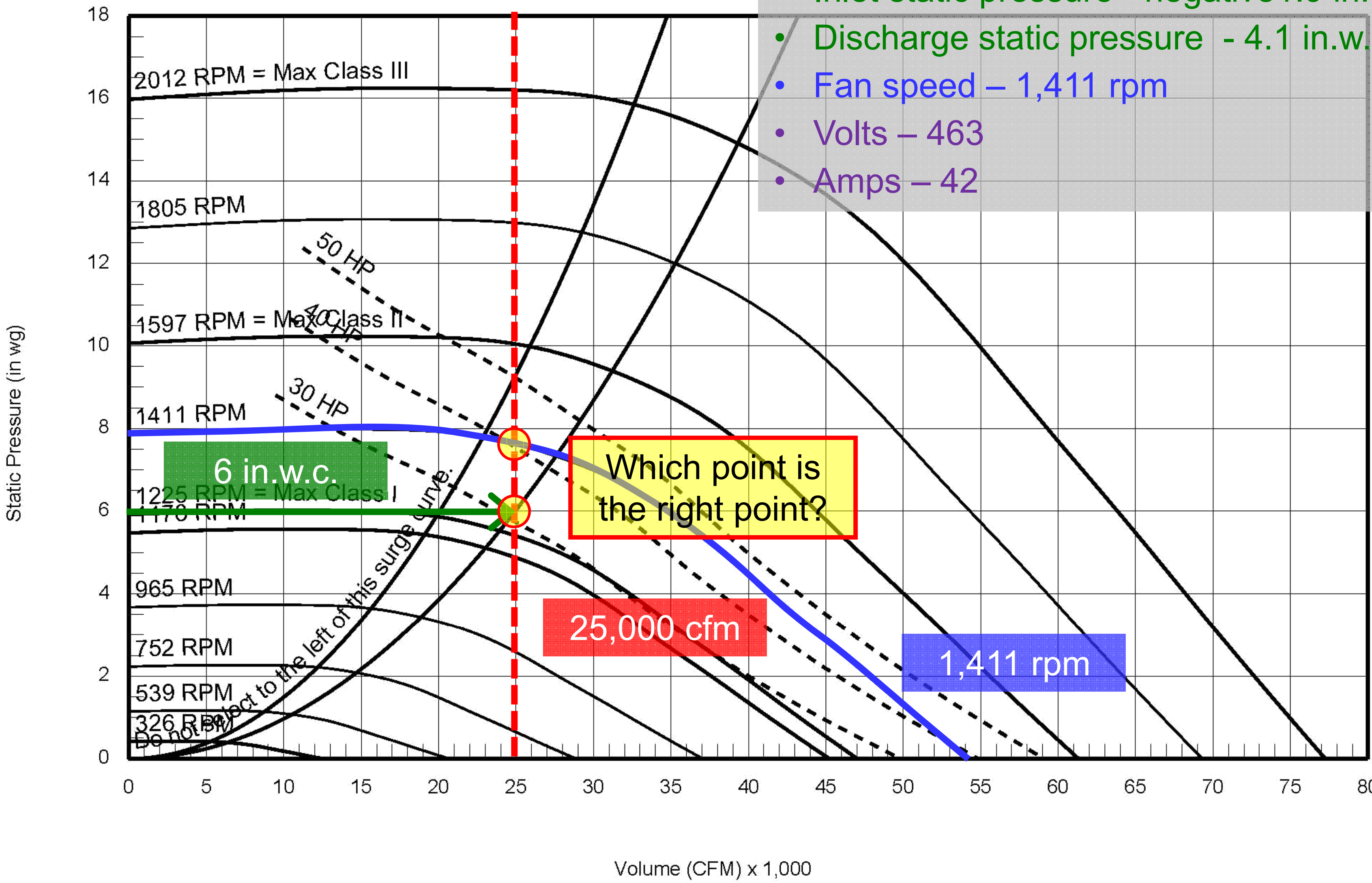

CAPS 3.1.2.3

33-AFDW-41

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- Fan speed – 1,411 rpm
- Volts – 463
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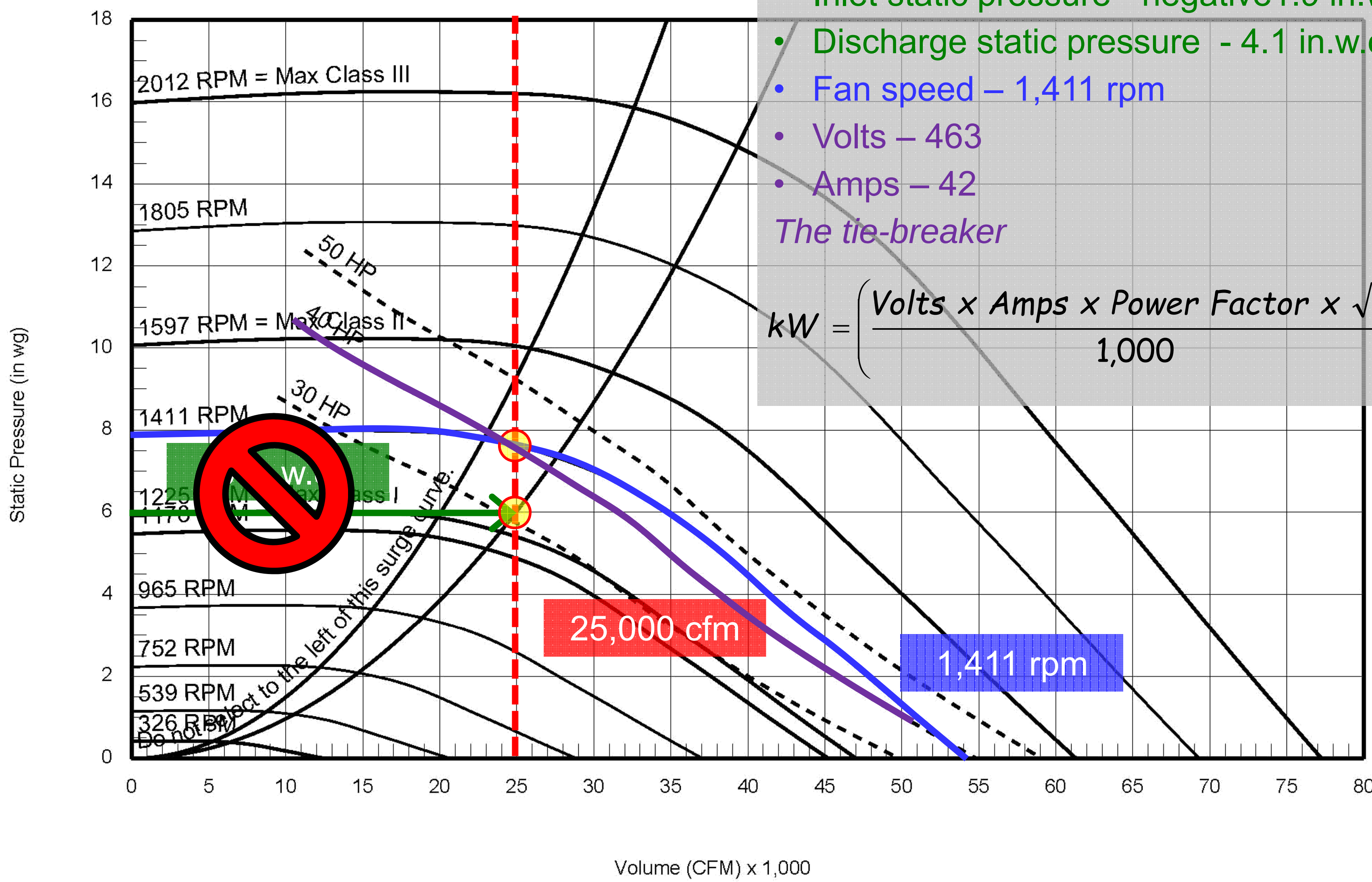
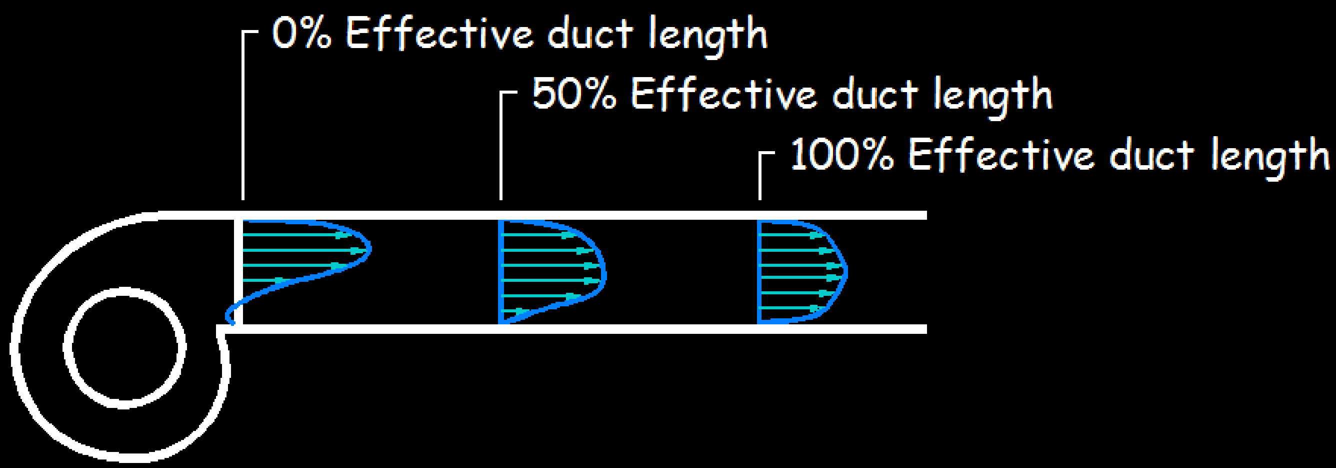
The tie-breaker

$$kW = \left(\frac{Volts \times Amps \times Power\ Factor \times \sqrt{3}}{1{,}000} \right)$$



Fan Static Pressure



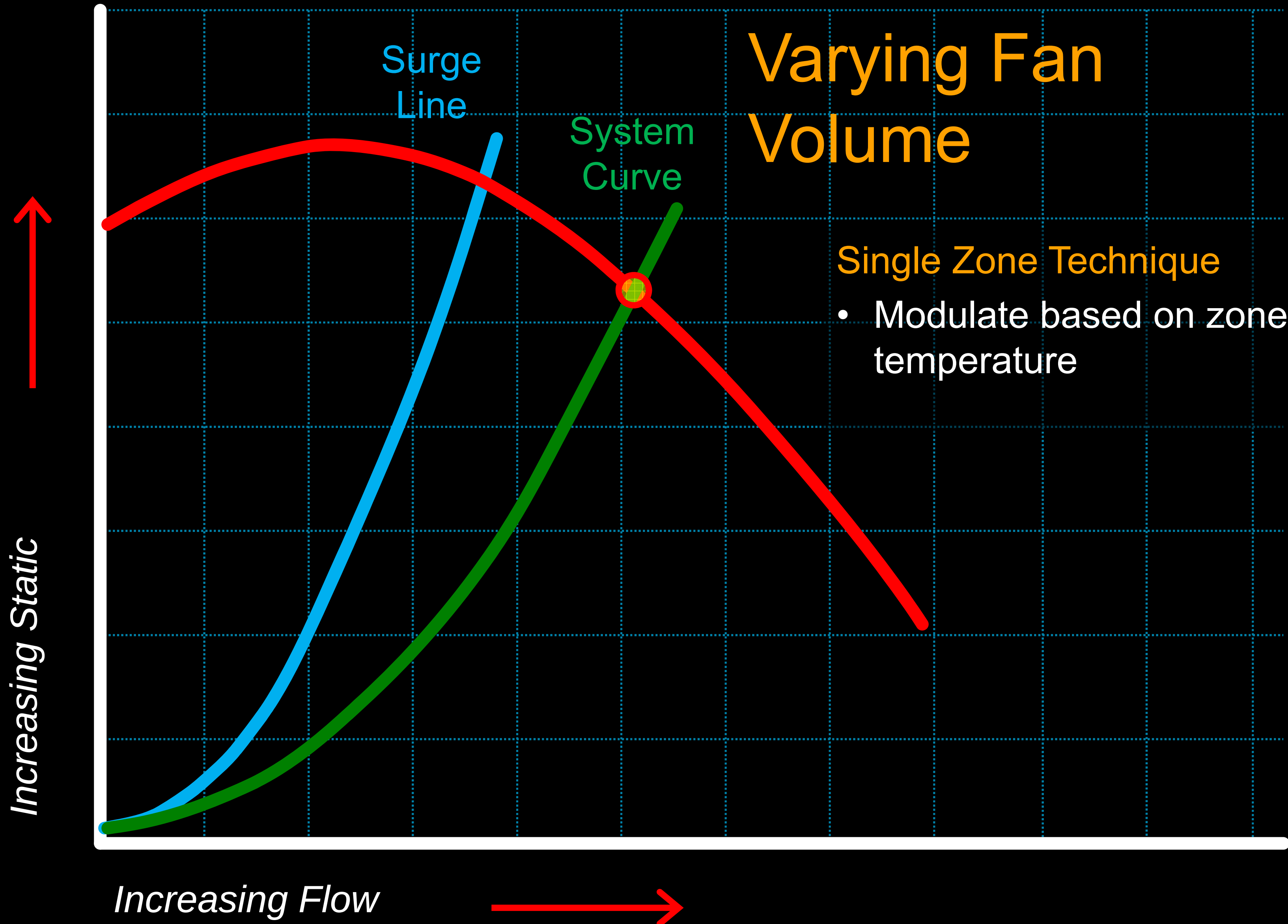
$P_{total} = P_{total\ out} - P_{total\ in}$

$P_{static} = P_{total} - P_{velocity\ in}$

- Derived from the AMCA test method
  - Gauge static at 100% effective duct length corrected to discharge
  - Fan draws air from surroundings through a well shaped inlet

$P_{static} = P_{static\ out} - P_{total\ in}$

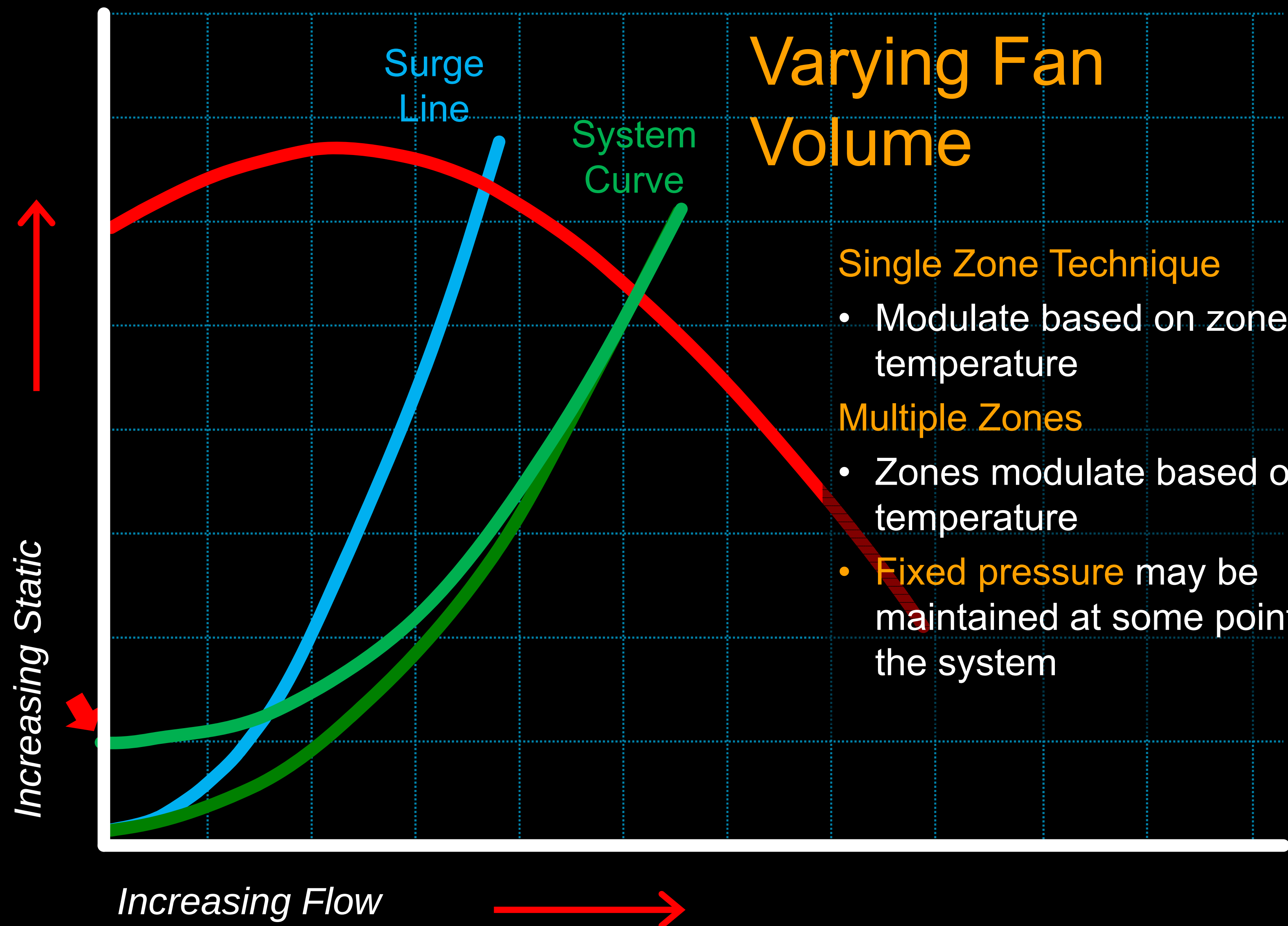
Varying Fan Volume



Single Zone Technique

- Modulate based on zone temperature

Varying Fan Volume



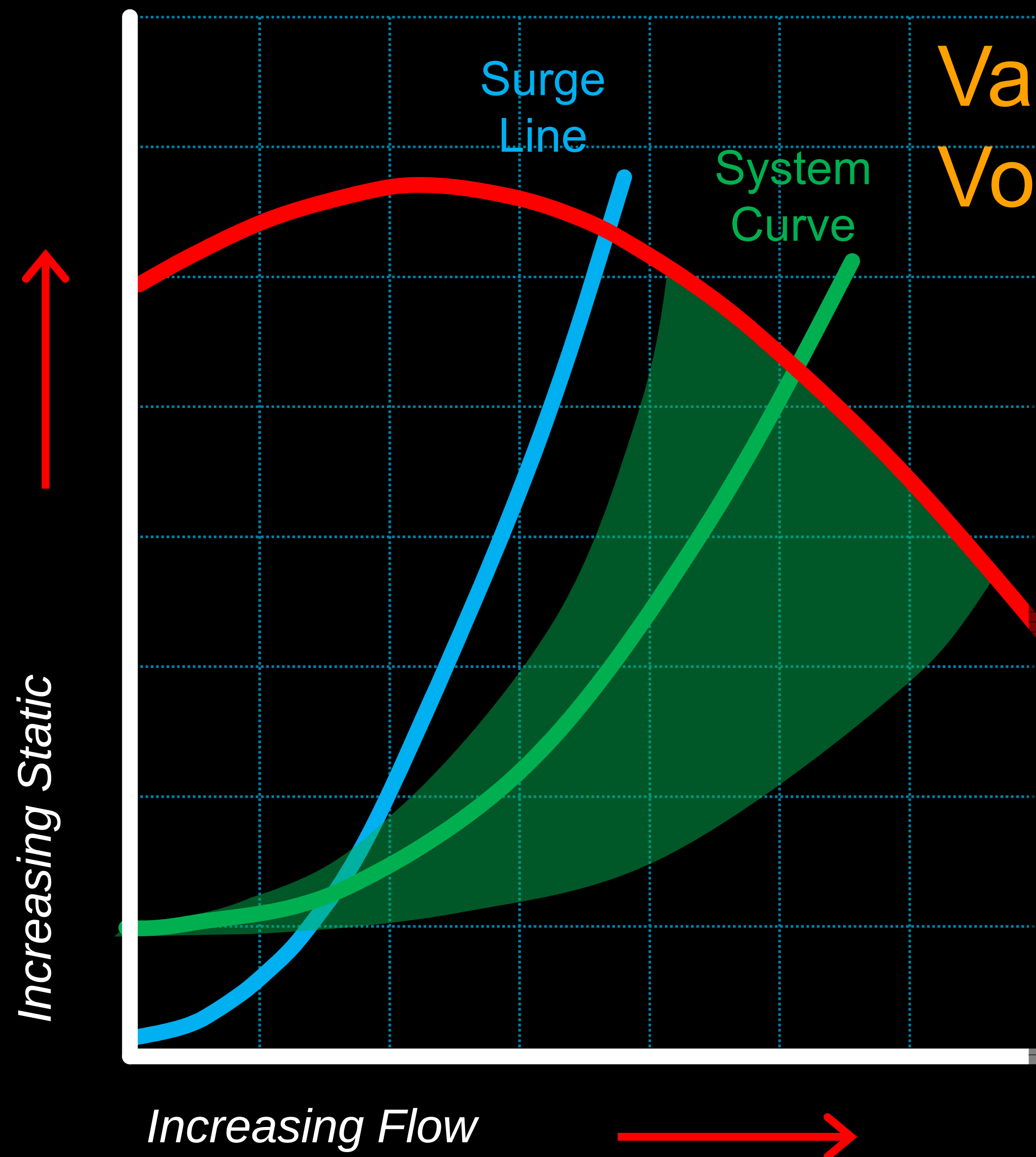
Single Zone Technique

- Modulate based on zone temperature

Multiple Zones

- Zones modulate based on temperature
- Fixed pressure may be maintained at some point in the system

Varying Fan Volume

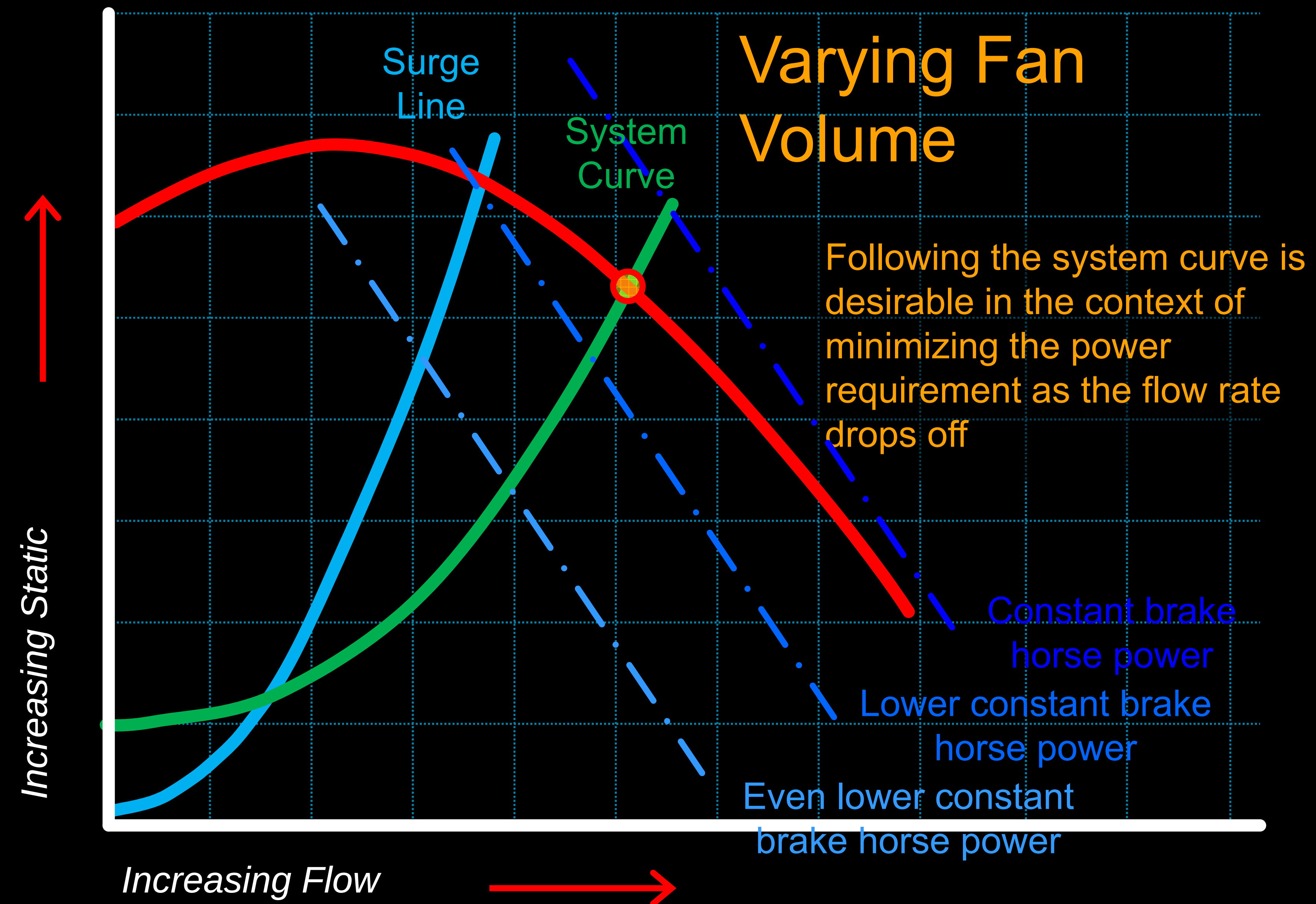


Single Zone Technique

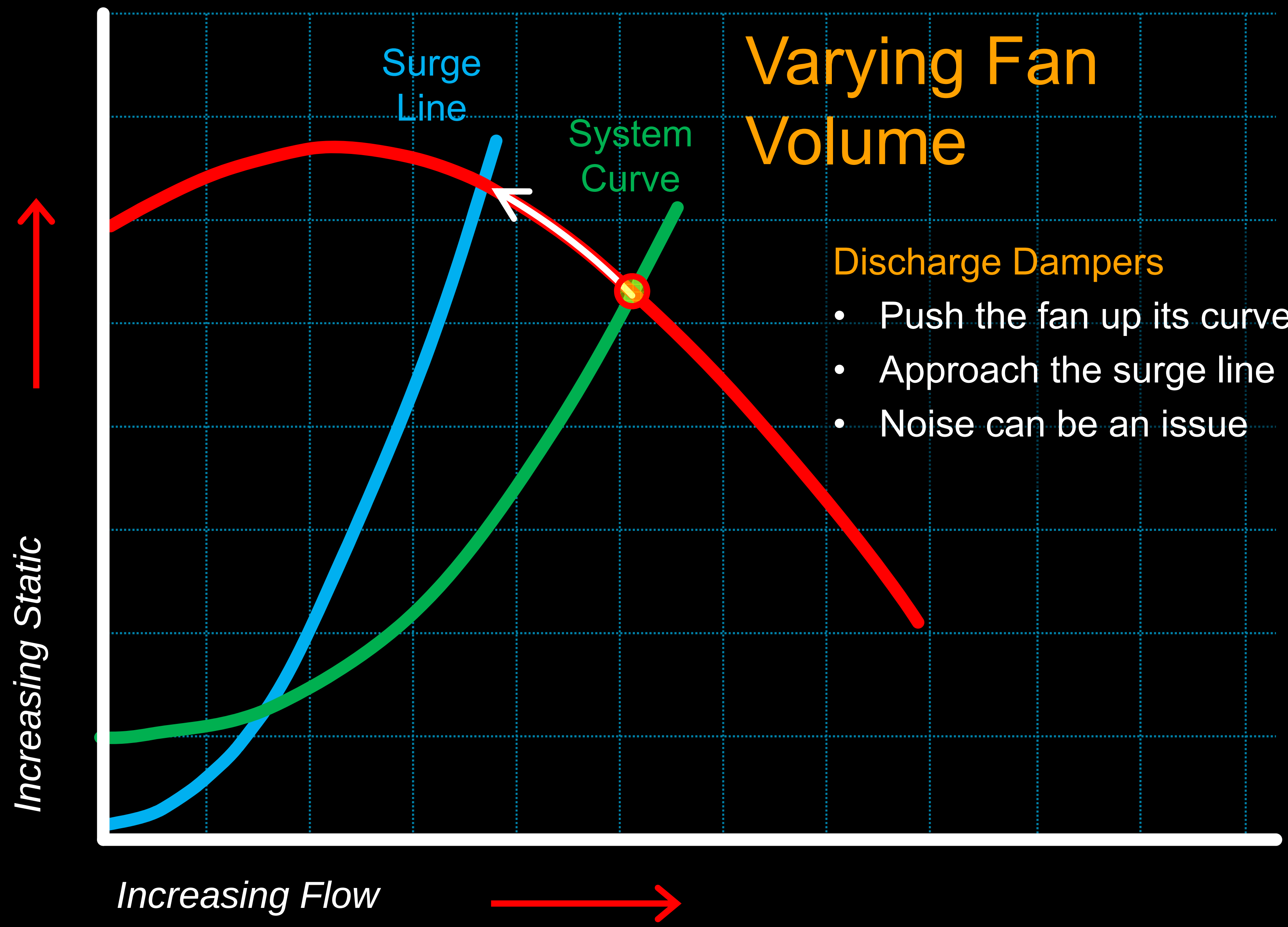
- Modulate based on zone temperature

Multiple Zones

- Zones modulate based on temperature
- Fixed pressure may be maintained at some point in the system
- Fan follows the total zone flow requirement
- Work on a family of system curves


Varying Fan Volume
Surge Line
System Curve
Following the system curve is desirable in the context of minimizing the power requirement as the flow rate drops off
Constant brake horse power
Lower constant brake horse power
Even lower constant brake horse power
Increasing Static
Increasing Flow

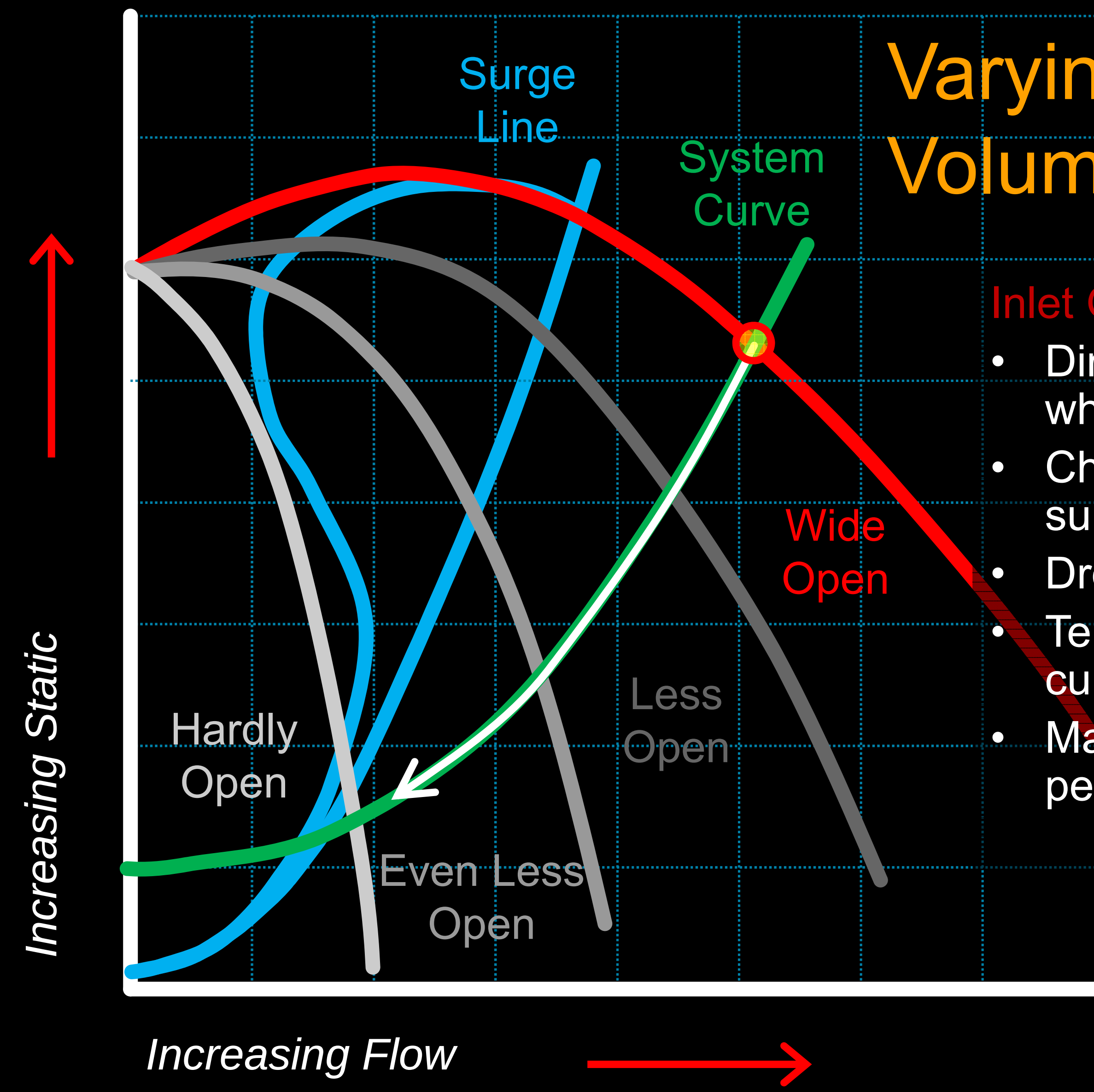
Varying Fan Volume



Discharge Dampers

- Push the fan up its curve
- Approach the surge line
- Noise can be an issue

Varying Fan Volume



Inlet Guide Vanes

- Direct the flow into the fan wheel imparting “swirl”
- Changes the shape of the surge line
- Droops the fan curve
- Tend to follow the system curve
- May be integral to the fan’s peak efficiency point

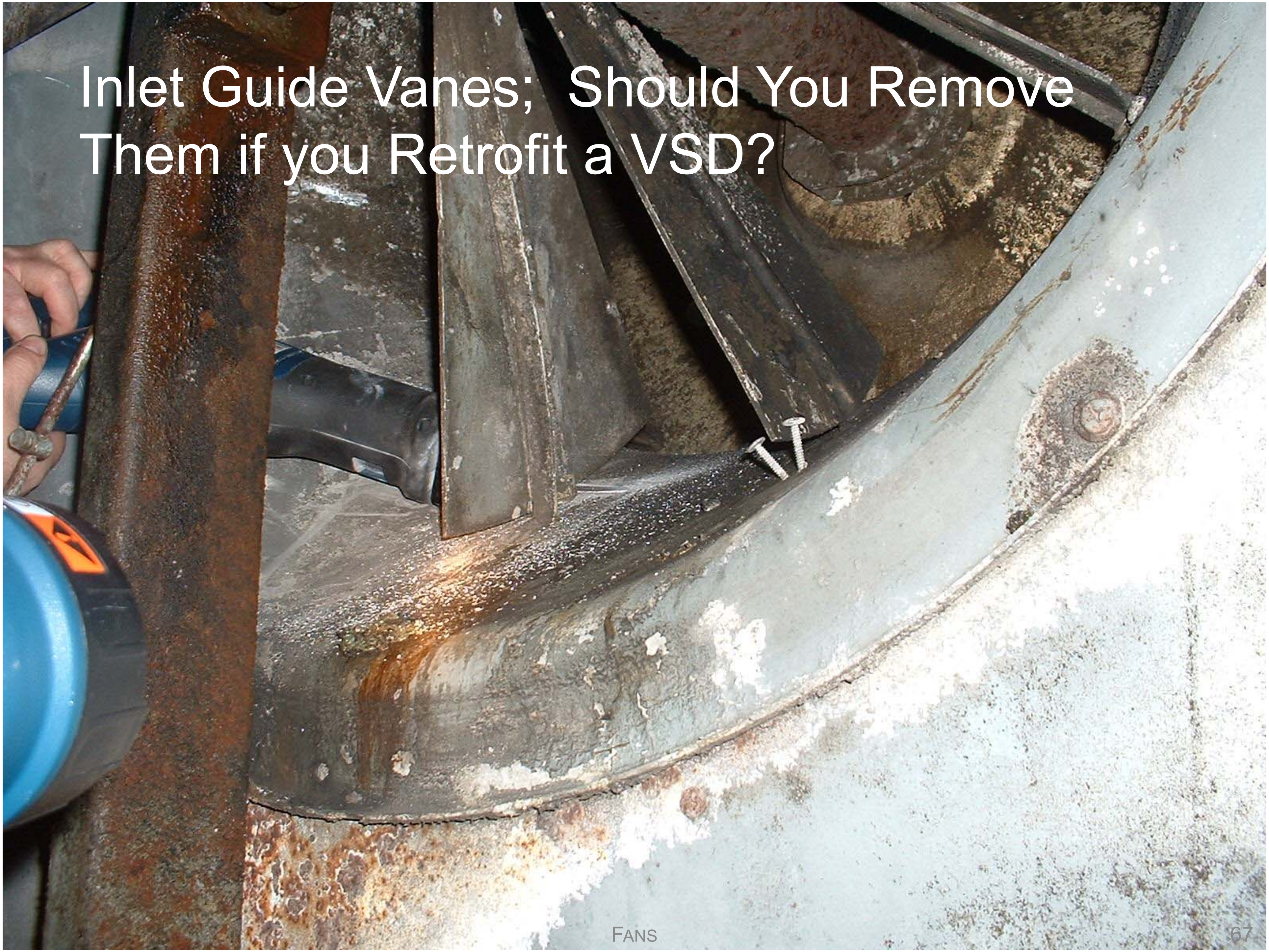
Inlet Guide Vanes; Directing Airflow into the Fan Wheel

Inlet Guide Vanes; Directing Airflow into the Fan Wheel

Inlet Guide Vanes; Directing Airflow into the Fan Wheel

Inlet Guide Vanes; Directing Airflow into the Fan Wheel

Inlet Guide Vanes; Should You Remove Them if you Retrofit a VSD?



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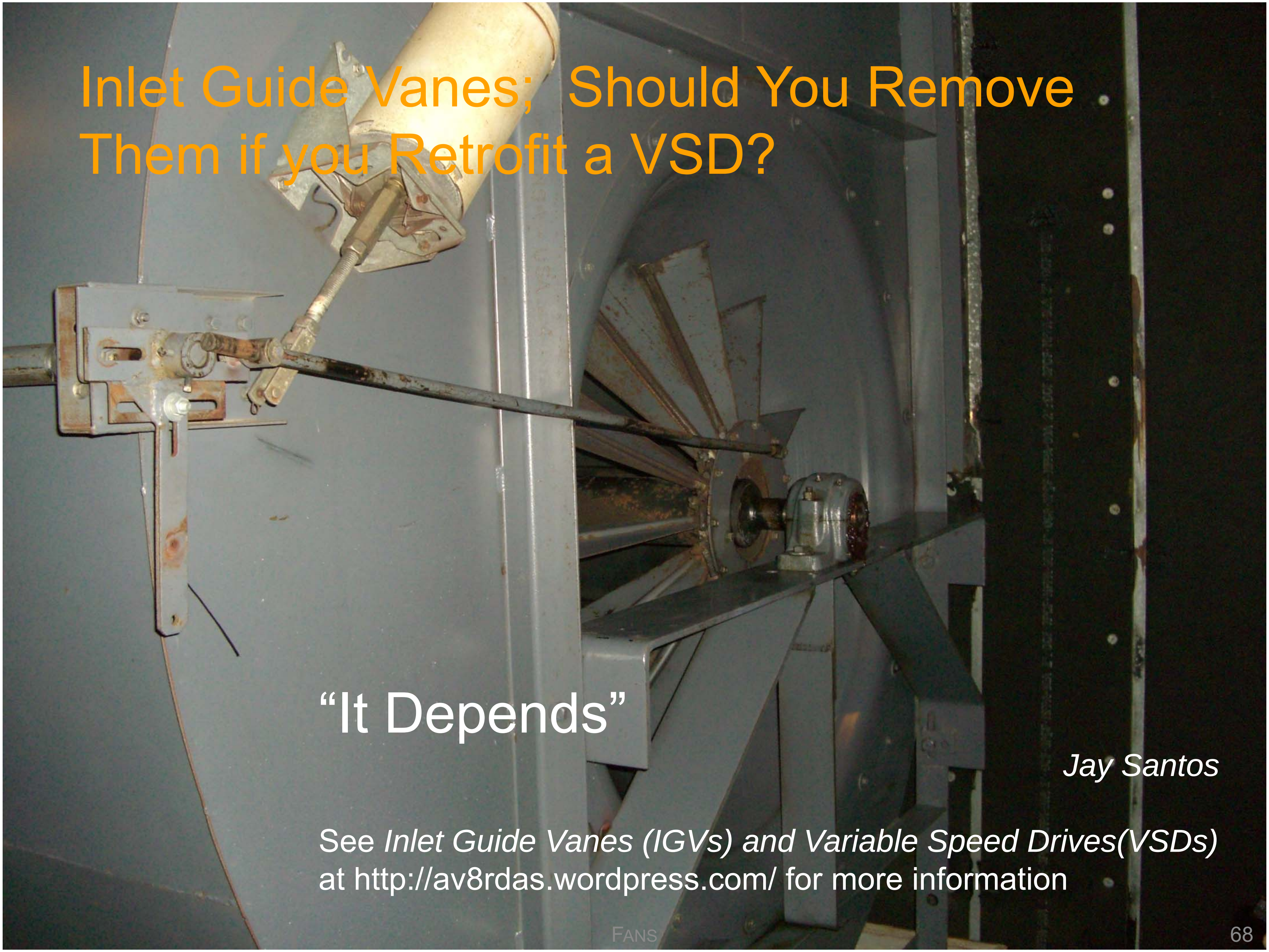


“It Depends”

Jay Santos

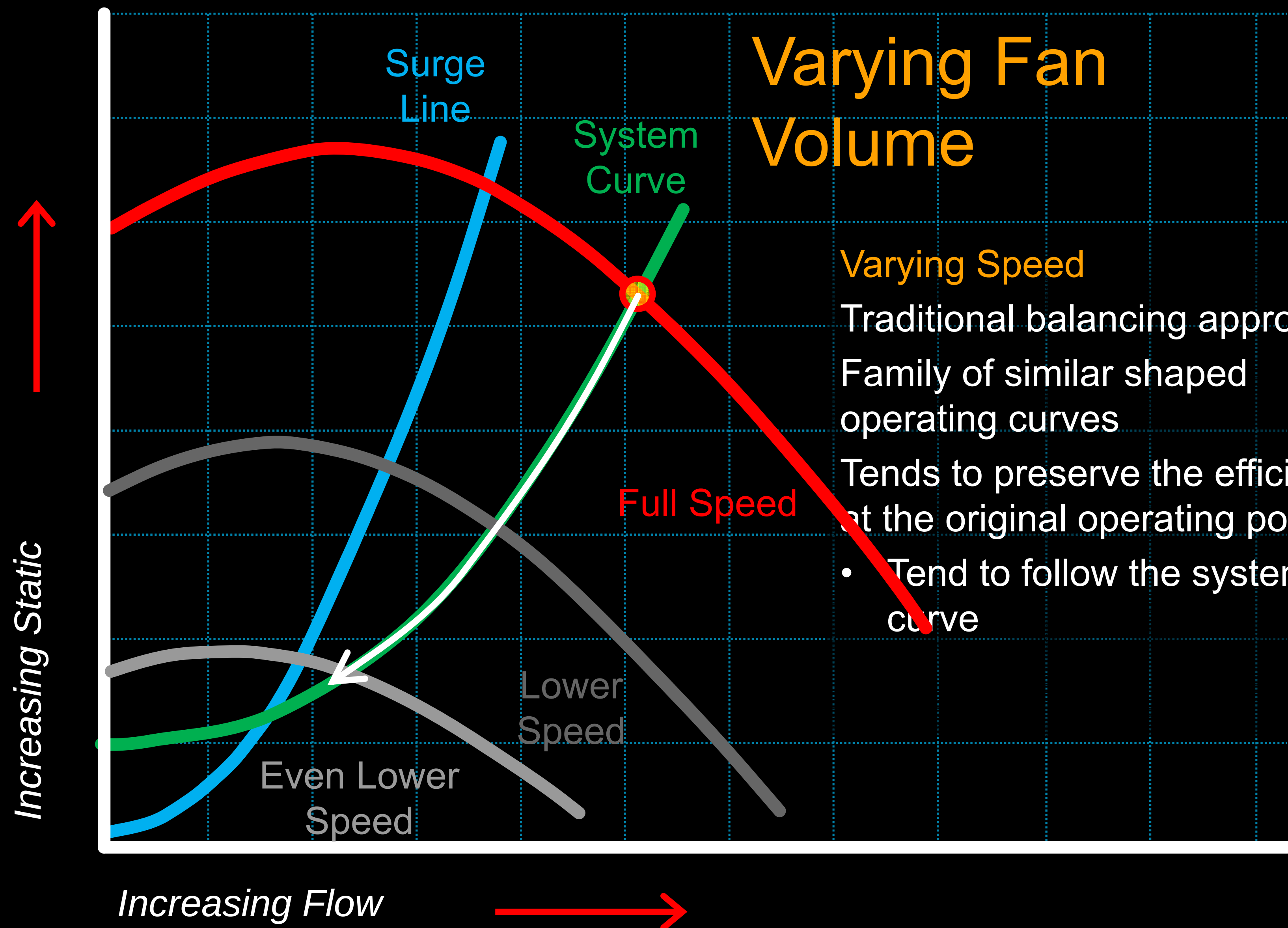
See *Inlet Guide Vanes (IGVs) and Variable Speed Drives(VSDs)* at http://av8rdas.wordpress.com/ for more information

Image courtesy Bill Michell – DOE – NY Marriott Marque

Adding VFDs?

Remove the Vanes (Maybe), Leave the Inlet Cone (For Sure)

Varying Fan Volume



Varying Speed

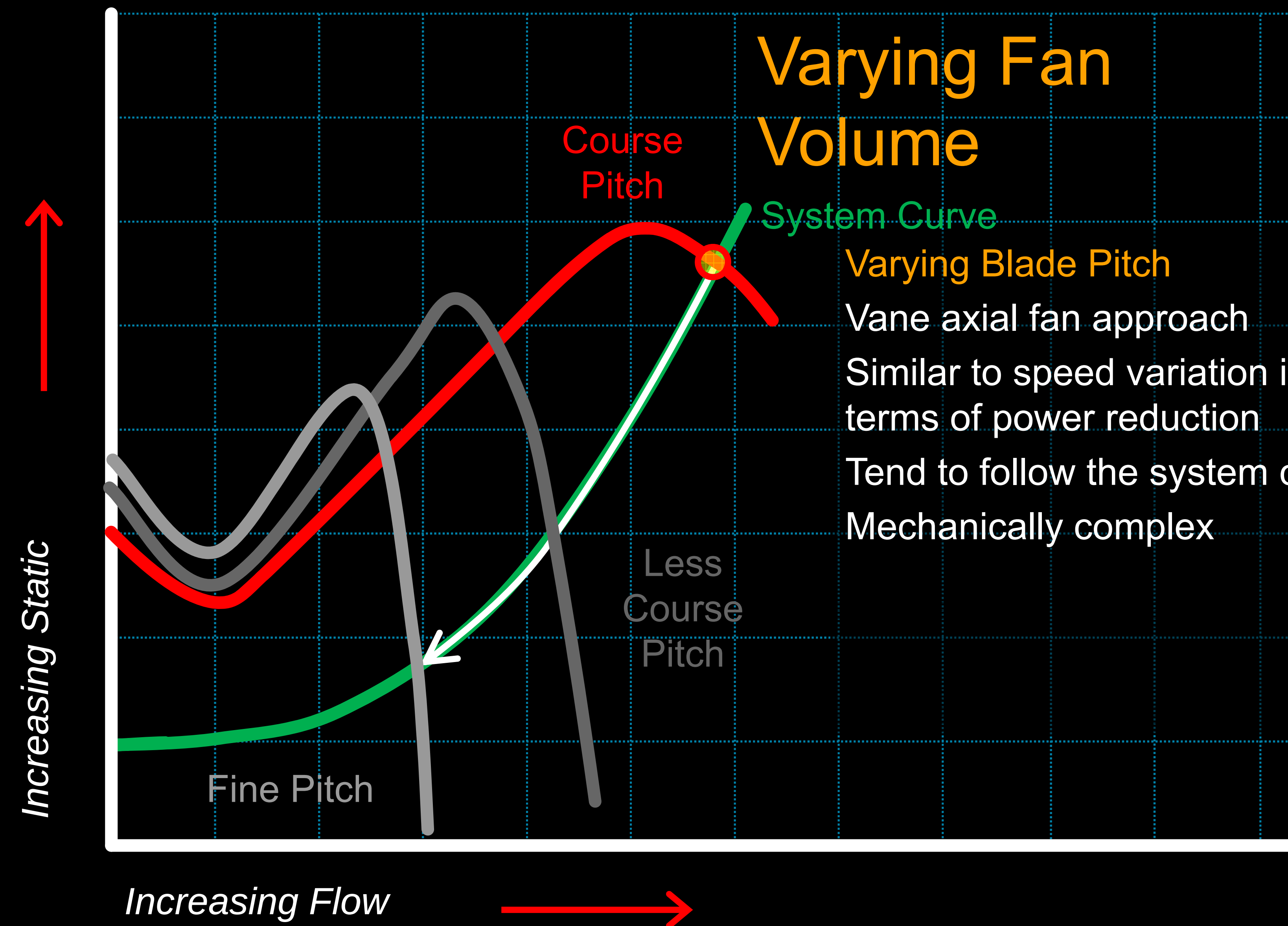
Traditional balancing approach

Family of similar shaped operating curves

Tends to preserve the efficiency at the original operating point

- Tend to follow the system curve

Varying Fan Volume

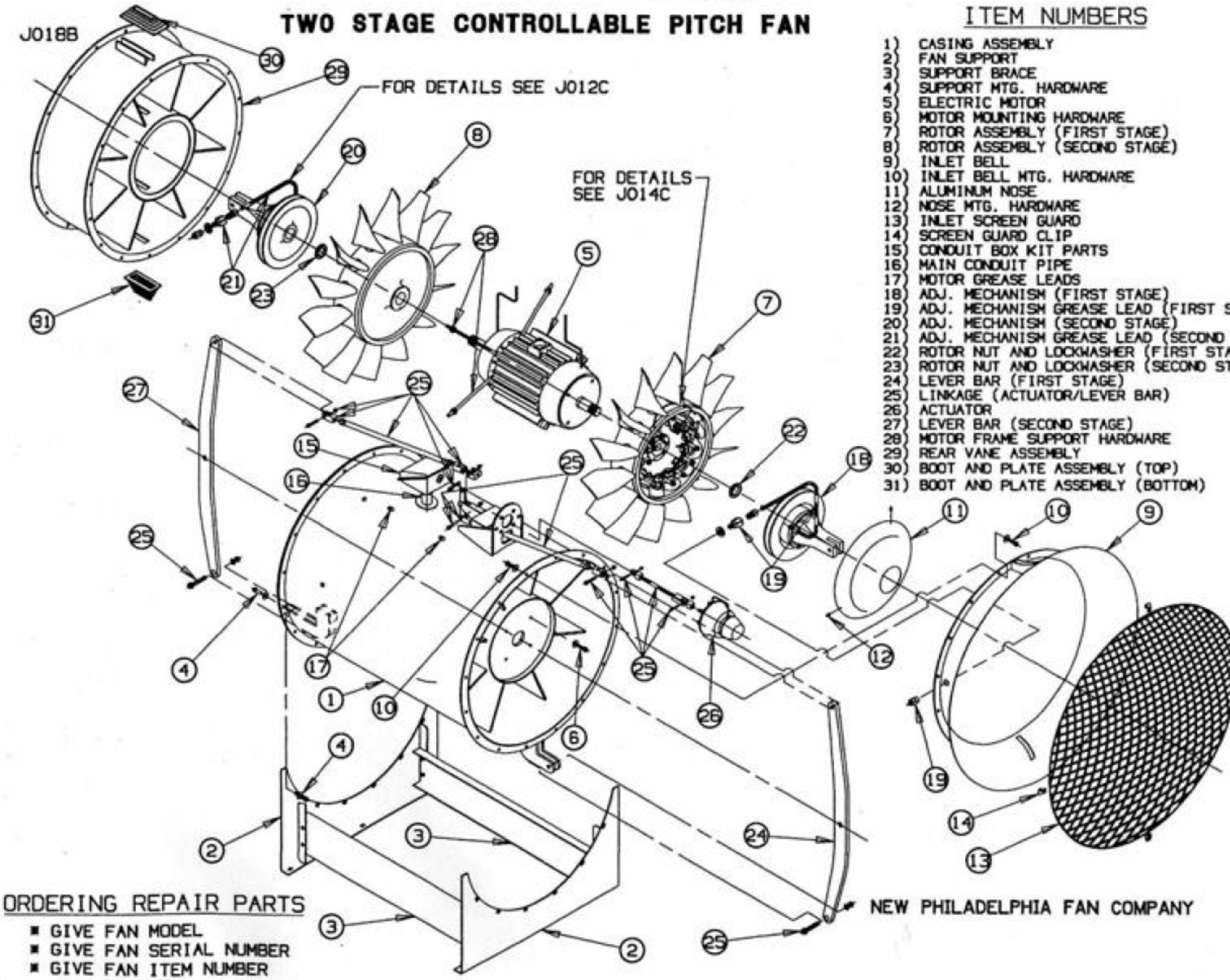


Varying Blade Pitch

- Vane axial fan approach
- Similar to speed variation in terms of power reduction
- Tend to follow the system curve
- Mechanically complex

Uncontrolled Drawing

TWO STAGE CONTROLLABLE PITCH FAN



ITEM NUMBERS

1) CASING ASSEMBLY
2) FAN SUPPORT
3) SUPPORT BRACE
4) SUPPORT MTG. HARDWARE
5) ELECTRIC MOTOR
6) MOTOR MOUNTING HARDWARE
7) ROTOR ASSEMBLY (FIRST STAGE)
8) ROTOR ASSEMBLY (SECOND STAGE)
9) INLET BELL
10) INLET BELL MTG. HARDWARE
11) ALUMINUM NOSE
12) NOSE MTG. HARDWARE
13) INLET SCREEN GUARD
14) SCREEN GUARD CLIP
15) CONDUIT BOX KIT PARTS
16) MAIN CONDUIT PIPE
17) MOTOR GREASE LEADS
18) ADJ. MECHANISM (FIRST STAGE)
19) ADJ. MECHANISM GREASE LEAD (FIRST STAGE)
20) ADJ. MECHANISM (SECOND STAGE)
21) ADJ. MECHANISM GREASE LEAD (SECOND STAGE
22) ROTOR NUT AND LOCKWASHER (FIRST STAGE)
23) ROTOR NUT AND LOCKWASHER (SECOND STAGE)
24) LEVER BAR (FIRST STAGE)
25) LINKAGE (ACTUATOR/LEVER BAR)
26) ACTUATOR
27) LEVER BAR (SECOND STAGE)
28) MOTOR FRAME SUPPORT HARDWARE
29) REAR VANE ASSEMBLY
30) BOOT AND PLATE ASSEMBLY (TOP)
31) BOOT AND PLATE ASSEMBLY (BOTTOM)

ORDERING REPAIR PARTS

* GIVE FAN MODEL
* GIVE FAN SERIAL NUMBER
* GIVE FAN ITEM NUMBER

Image courtesy AVA HVAC Products
http://avahvacproducts.com/Joy_Fan_Service___Parts.html

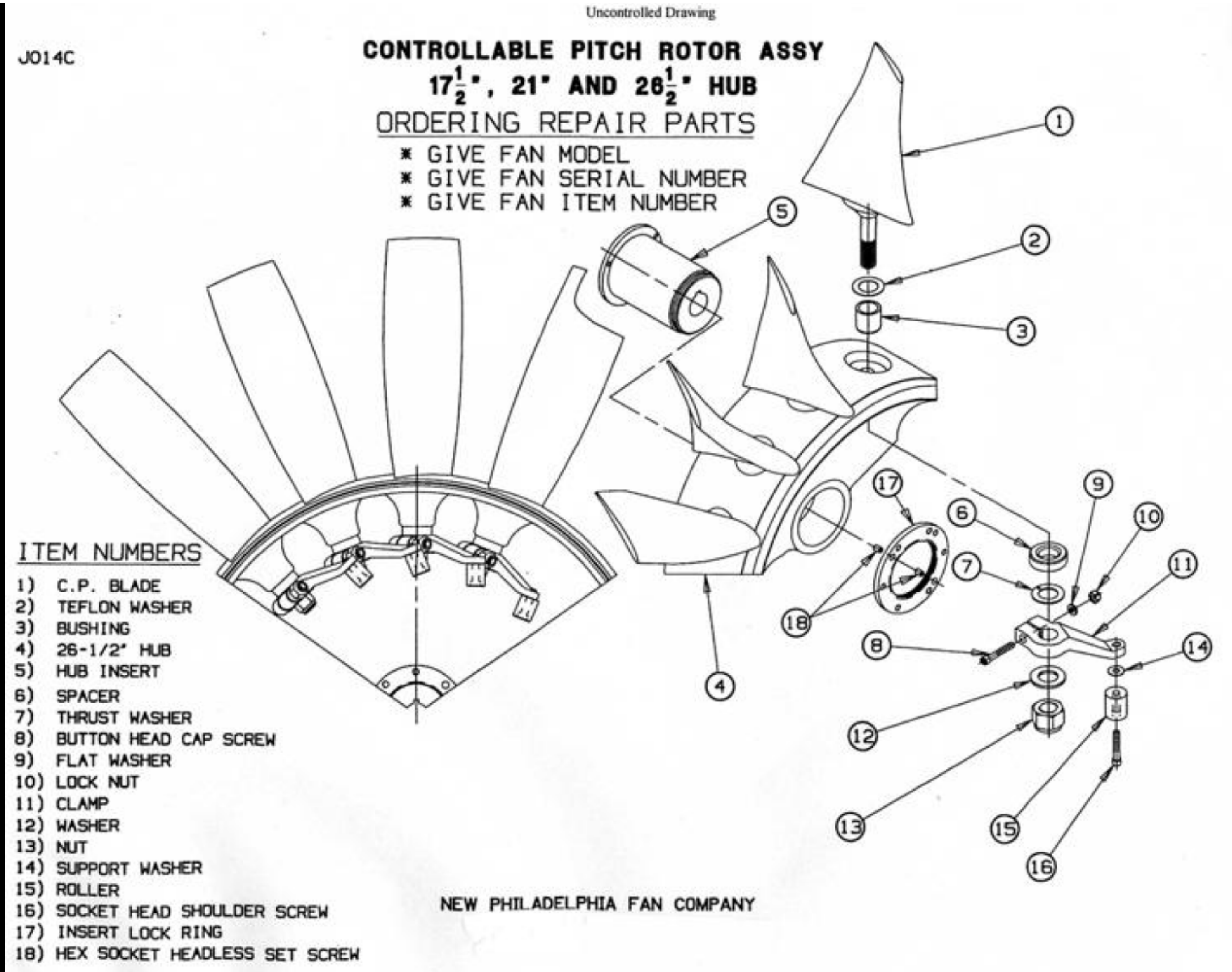
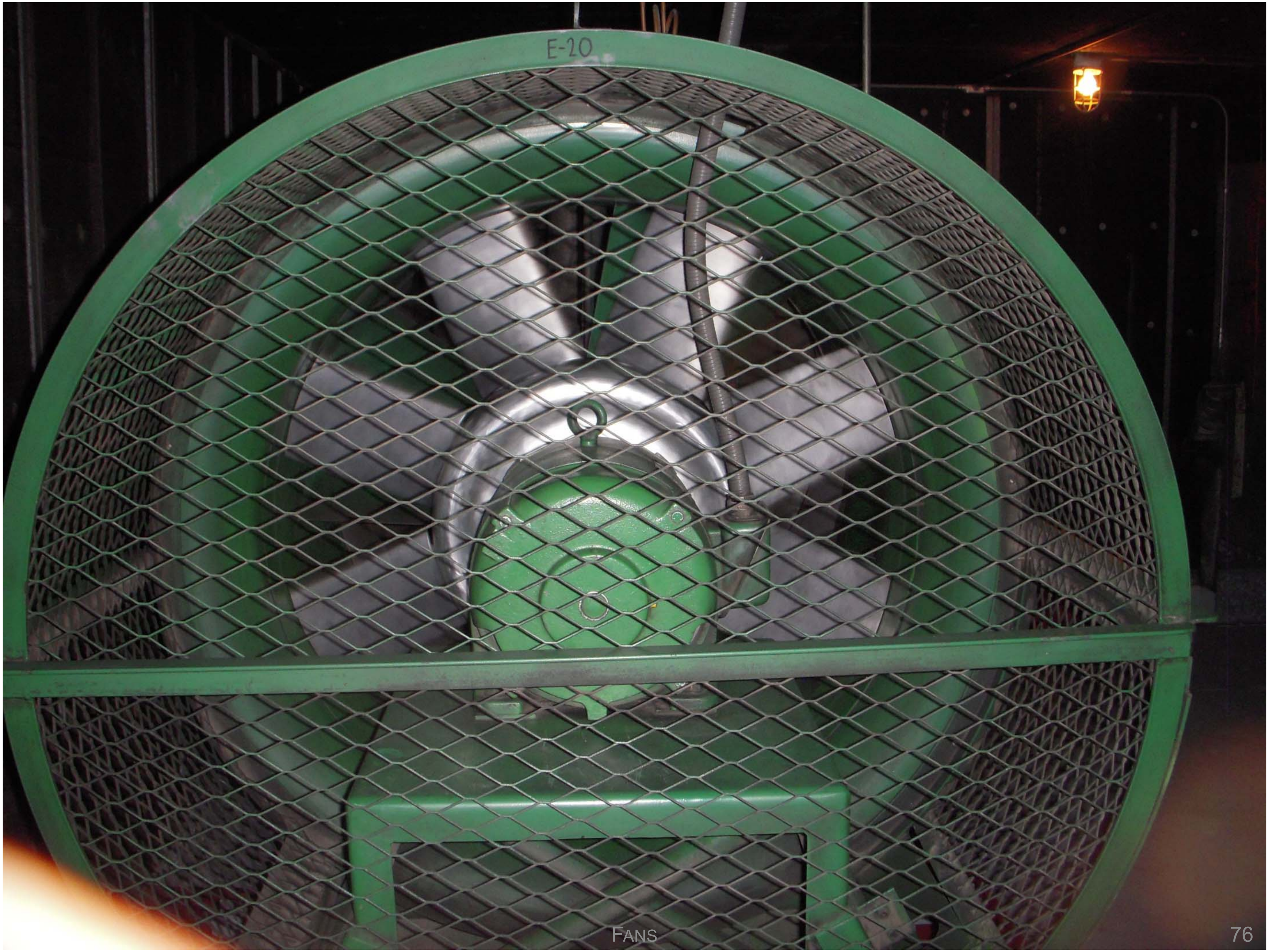
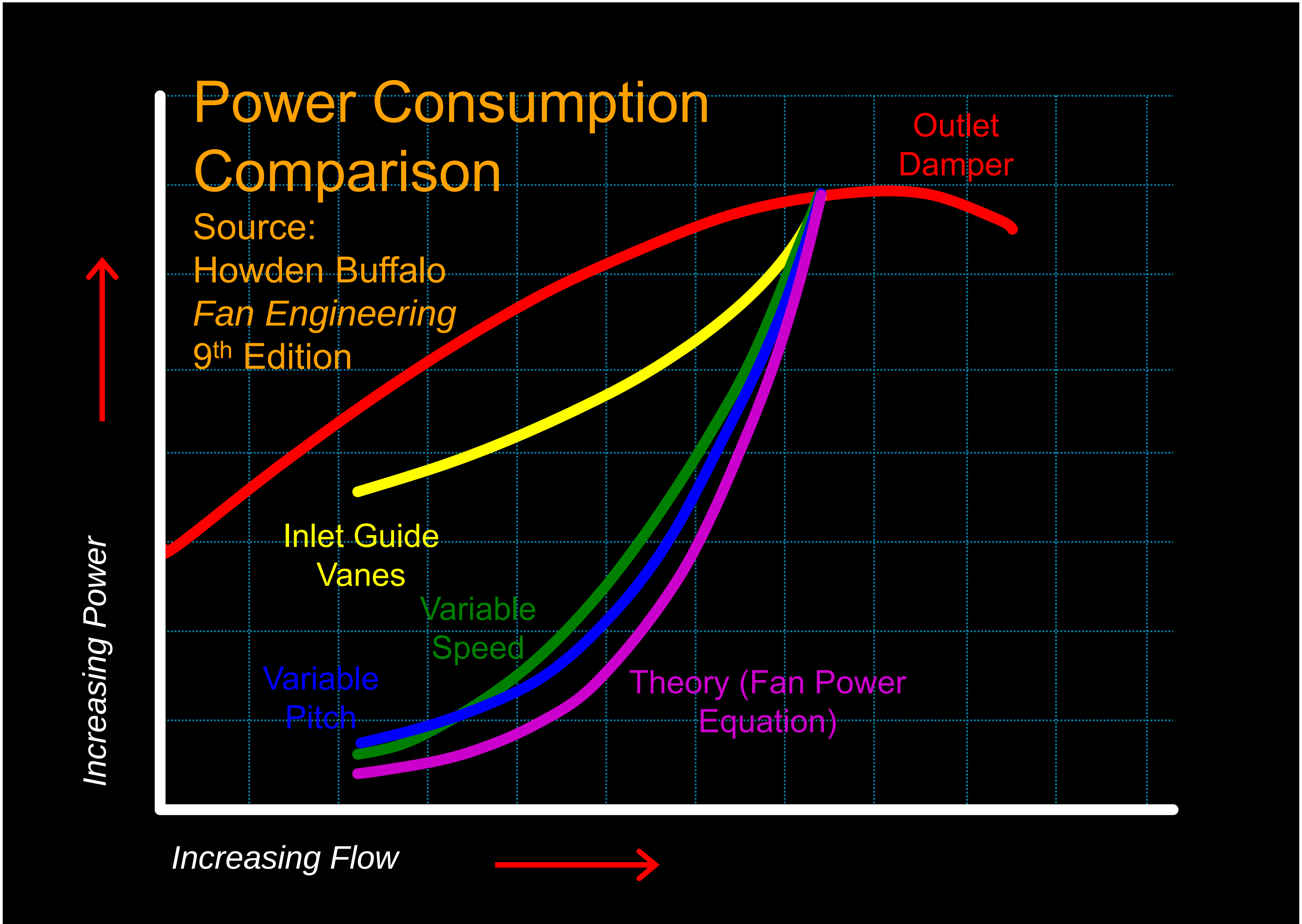


Image courtesy AVA HVAC Products
http://avahvacproducts.com/Joy_Fan_Service___Parts.html

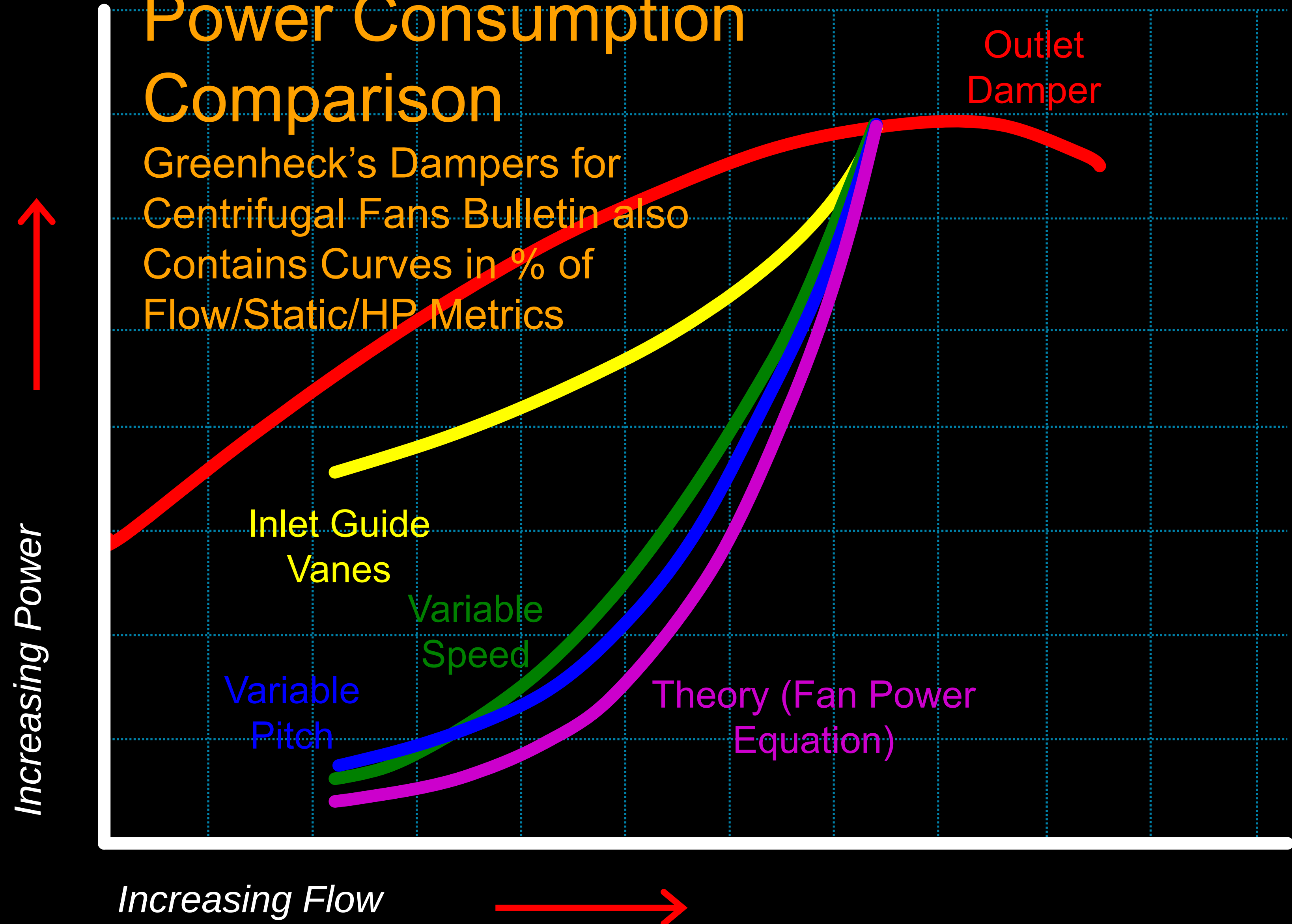

ACCESS SECTION
UP


E-20

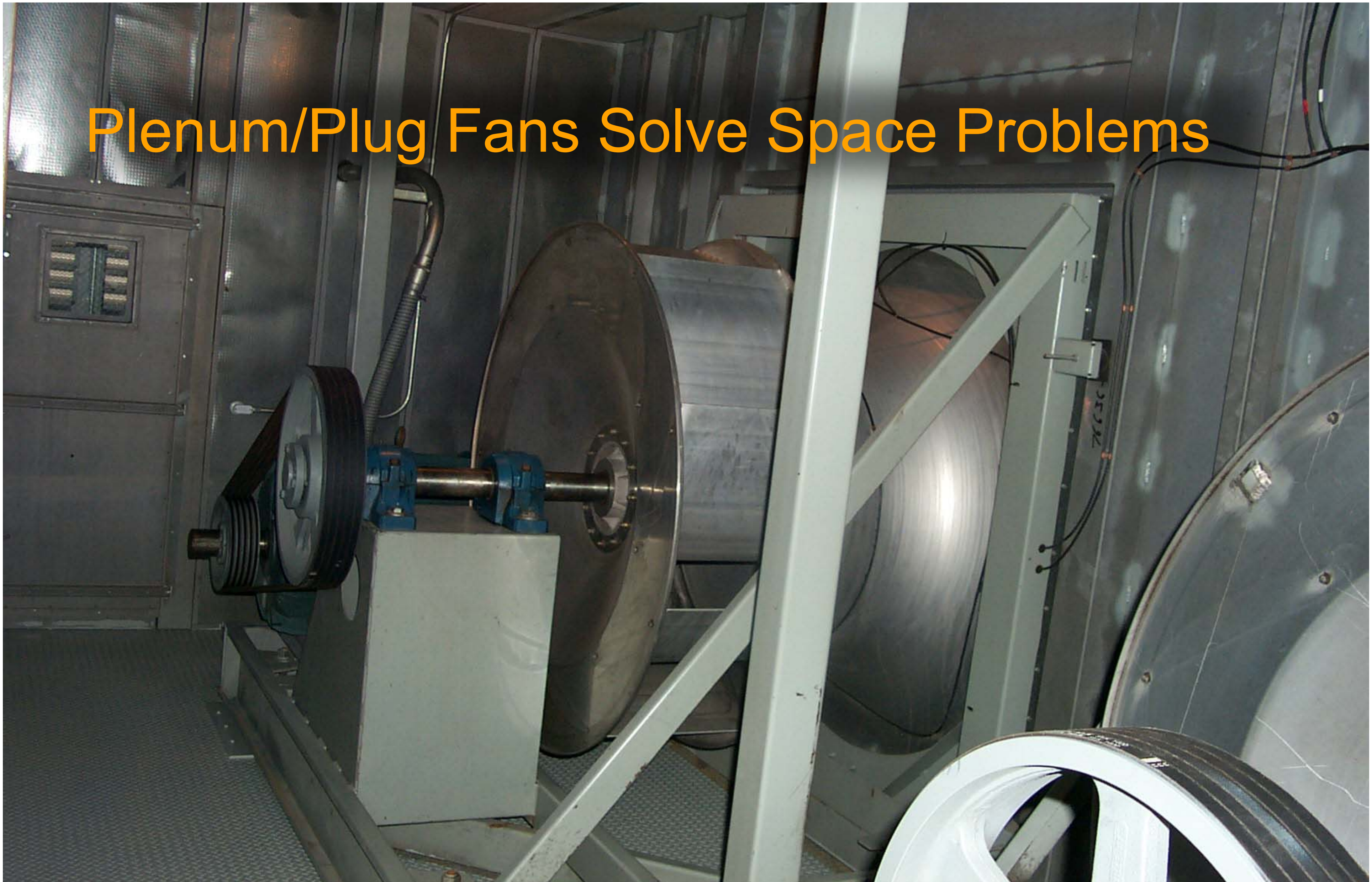

Power Consumption Comparison
Source:
Howden Buffalo
Fan Engineering
9th Edition
Outlet Damper
Inlet Guide Vanes
Variable Speed
Variable Pitch
Theory (Fan Power Equation)
Increasing Power
Increasing Flow

Power Consumption Comparison

Greenheck's Dampers for Centrifugal Fans Bulletin also Contains Curves in % of Flow/Static/HP Metrics



Plenum/Plug Fans Solve Space Problems



Plenum/Plug Fans Don't Have the Scroll

SWSI Fans Do

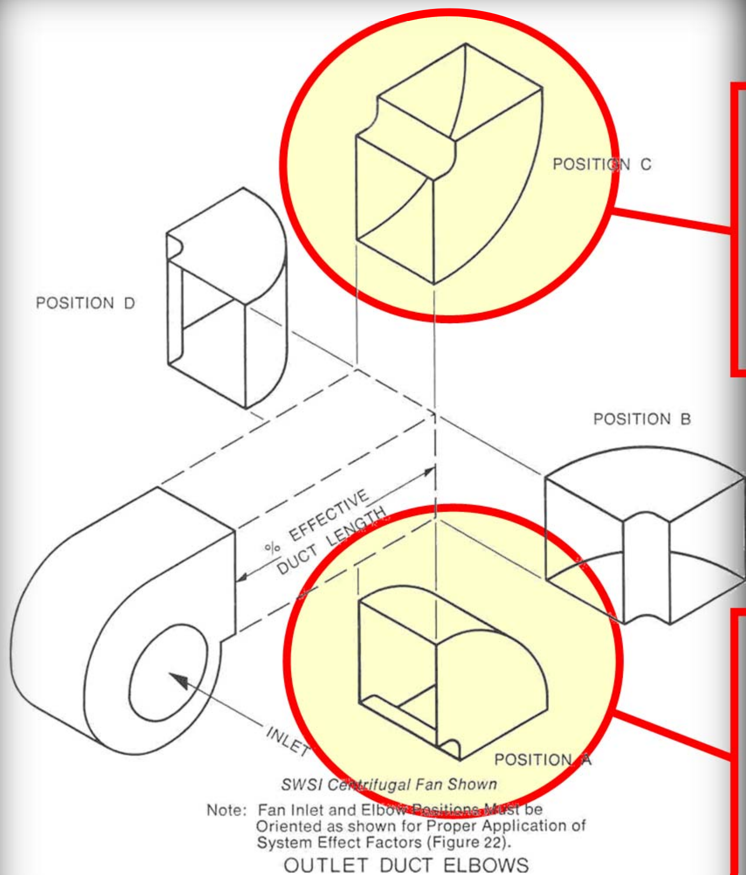
(SWSI = Single Width Single Inlet)

So Do DWDI Fans

(DWDI = Double Width Double Inlet)

Integration of the Fan with the Duct System Also Impacts Efficiency

Fitting placement and/or lack of a discharge duct has the same effect as adding static pressure



- .55 in.w.c. at 0% effective duct length
- .18 in.w.c. at 50% effective duct length

- .20 in.w.c. at 0% effective duct length
- .05 in.w.c. at 50% effective duct length

System effect assessed at 2,500 fpm and an outlet area to blast area ratio of 70%

Past Experience with Fan Selections

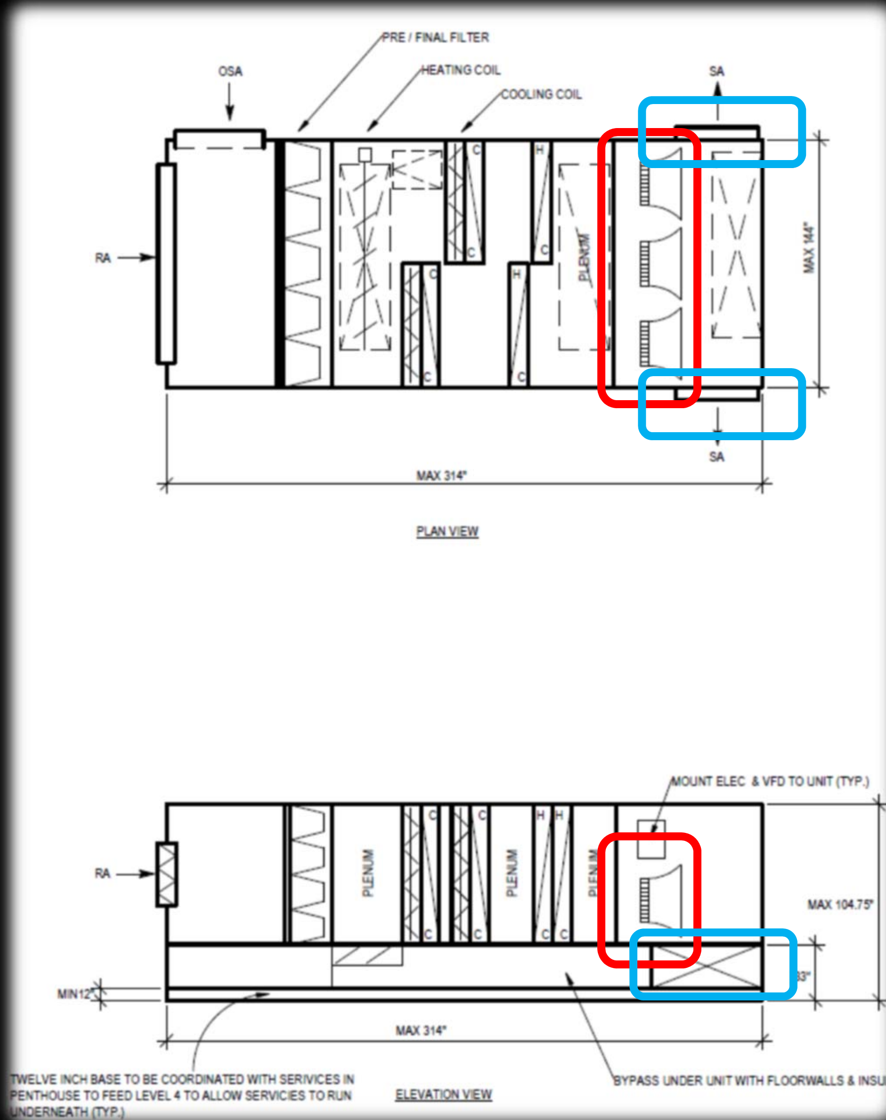
All other things being equal a SWDI or DWDI fan will be 5-10% more efficient than a plenum fan for the same operating conditions

The improved efficiency gained by a SWDI or DWDI fan can be squandered in losses at the inlet and discharge if system effect is not considered

DD Phase Air Handling Equipment

Air handling units incorporate multiple plenum fans

Ducts leave the unit in multiple directions

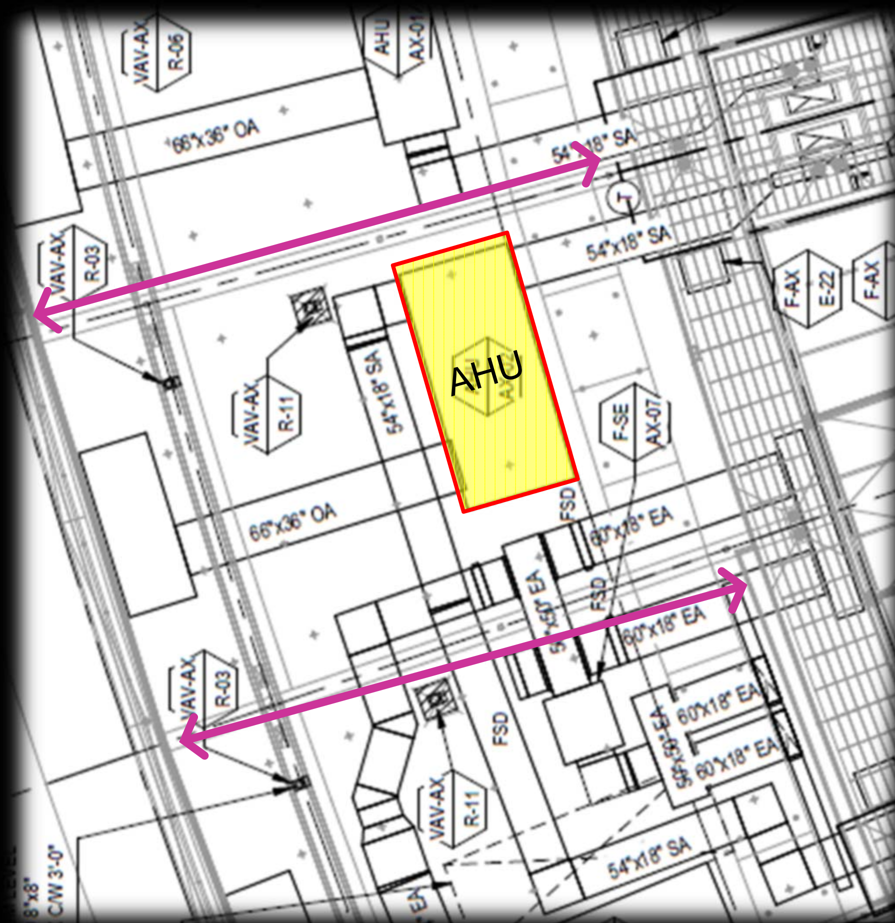


DD Phase Air Handling Equipment

Air handling units incorporate multiple plenum fans

Ducts leave the unit in multiple directions

Mechanical spaces are constrained vertically but not so much horizontally



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Brake horse power requirements imply fan efficiencies in the range of 68-71%

TYPE	EQUIPMENT LOCATION	AREA SERVED	SUP					
			CFM	TOTAL S.P. IN W.C.	EXT S.P. IN W.C.	Motor RPM	FAN QTY	BHP PER FAN
AHU-AX-01	PENTHOUSE	POD/OFFICE	11,000	6.03	4.0	1,800	2	7.66
AHU-AX-02	PENTHOUSE	POD/OFFICE	22,000	6.01	4.0	1,800	3	9.81
AHU-AX-03	PENTHOUSE	ENTRANCES	20,000	6.31	4.0	1,800	3	9.49
AHU-AX-04	PENTHOUSE	ENTRANCES	20,000	6.31	4.0	1,800	3	9.49
AHU-AX-05	PENTHOUSE	ENTRANCES	12,500	5.15	3.5	1,800	2	7.45
AHU-AX-06	PENTHOUSE	ENTRANCES	10,000	5.17	3.5	1,800	2	6.00
AHU-AX-09	PENTHOUSE	MINI ENTRANCE	4,000	3.52	2.0	1,800	1	3.25
AHU-AX-10	PENTHOUSE	MINI ENTRANCE	7,000	5.87	4.0	1,800	2	5.00
AHU-AX-11	PENTHOUSE	BATHROOMS	5,500	3.49	2.0	1,800	1	4.30
AHU-AX-12	PENTHOUSE	BATHROOMS	4,500	3.59	2.0	1,800	1	3.72

$$\eta_{Fan} = \left(\frac{\boxed{Flow} \times \boxed{Static}}{6{,}356 \times \boxed{bhp}} \right)$$

Where :

bhp = Brake horse power into the fan drive shaft

$Flow$ = Flow rate in cubic feet per minute

$Static$ = Fan static in inches water column

$6{,}356$ = A units conversion constant

η_{Fan} = Fan efficiency

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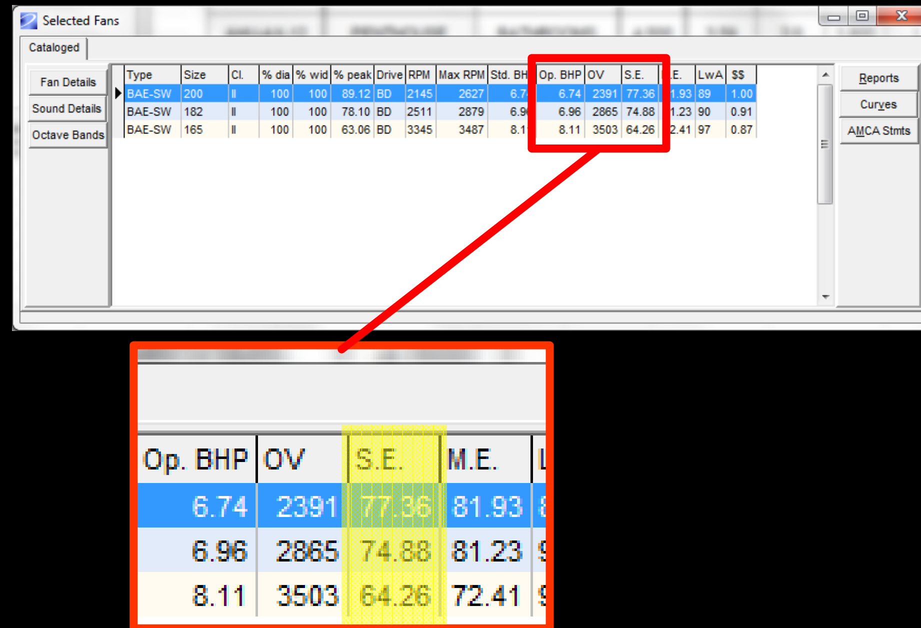
Twin City Blower SWSI fan selections indicate a 8-11% potential efficiency improvement

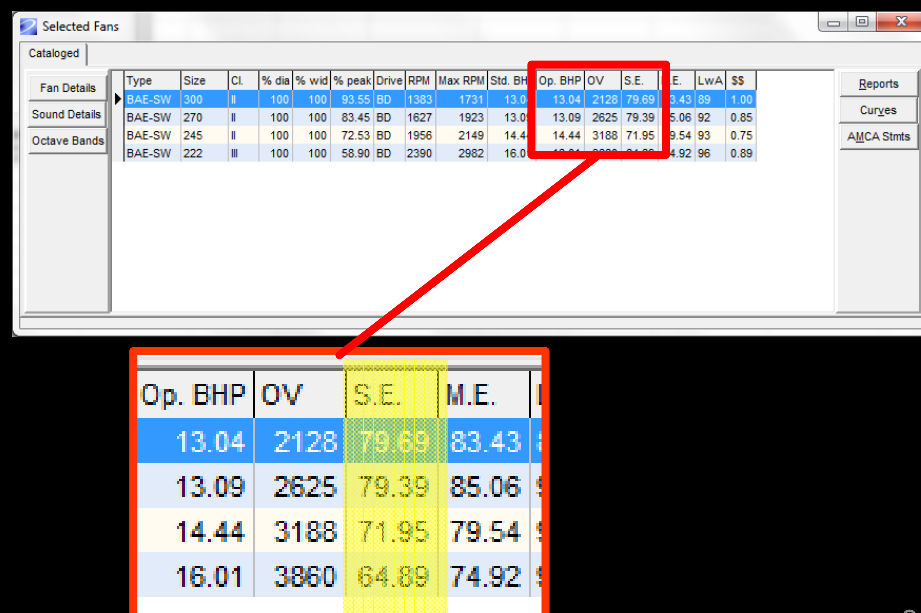


Selected Fans

Cataloged

Type	Size	Cl.	% dia	% wid	% peak	Drive	RPM	Max RPM	Std. BH	Op. BHP	OV	S.E.	.E.	LwA	$$
BAE-SW	200	II	100	100	89.12	BD	2145	2627	6.7	6.74	2391	77.36	1.93	89	1.00
BAE-SW	182	II	100	100	78.10	BD	2511	2879	6.9	6.96	2865	74.88	1.23	90	0.91
BAE-SW	165	II	100	100	63.06	BD	3345	3487	8.1	8.11	3503	64.26	2.41	97	0.87

Op. BHP	OV	S.E.	M.E.
6.74	2391	77.36	81.93
6.96	2865	74.88	81.23
8.11	3503	64.26	72.41



Selected Fans

Cataloged

Type	Size	Cl.	% dia	% wid	% peak	Drive	RPM	Max RPM	Std. BH	Op. BHP	OV	S.E.	.E.	LwA	$$
BAE-SW	300	II	100	100	93.55	BD	1383	1731	13.0	13.04	2128	79.69	3.43	89	1.00
BAE-SW	270	II	100	100	83.45	BD	1627	1923	13.0	13.09	2625	79.39	5.06	92	0.85
BAE-SW	245	II	100	100	72.53	BD	1956	2149	14.4	14.44	3188	71.95	9.54	93	0.75
BAE-SW	222	III	100	100	58.90	BD	2390	2982	16.0	[illegible]	[illegible]	[illegible]	4.92	96	0.89

Op. BHP	OV	S.E.	M.E.
13.04	2128	79.69	83.43
13.09	2625	79.39	85.06
14.44	3188	71.95	79.54
16.01	3860	64.89	74.92

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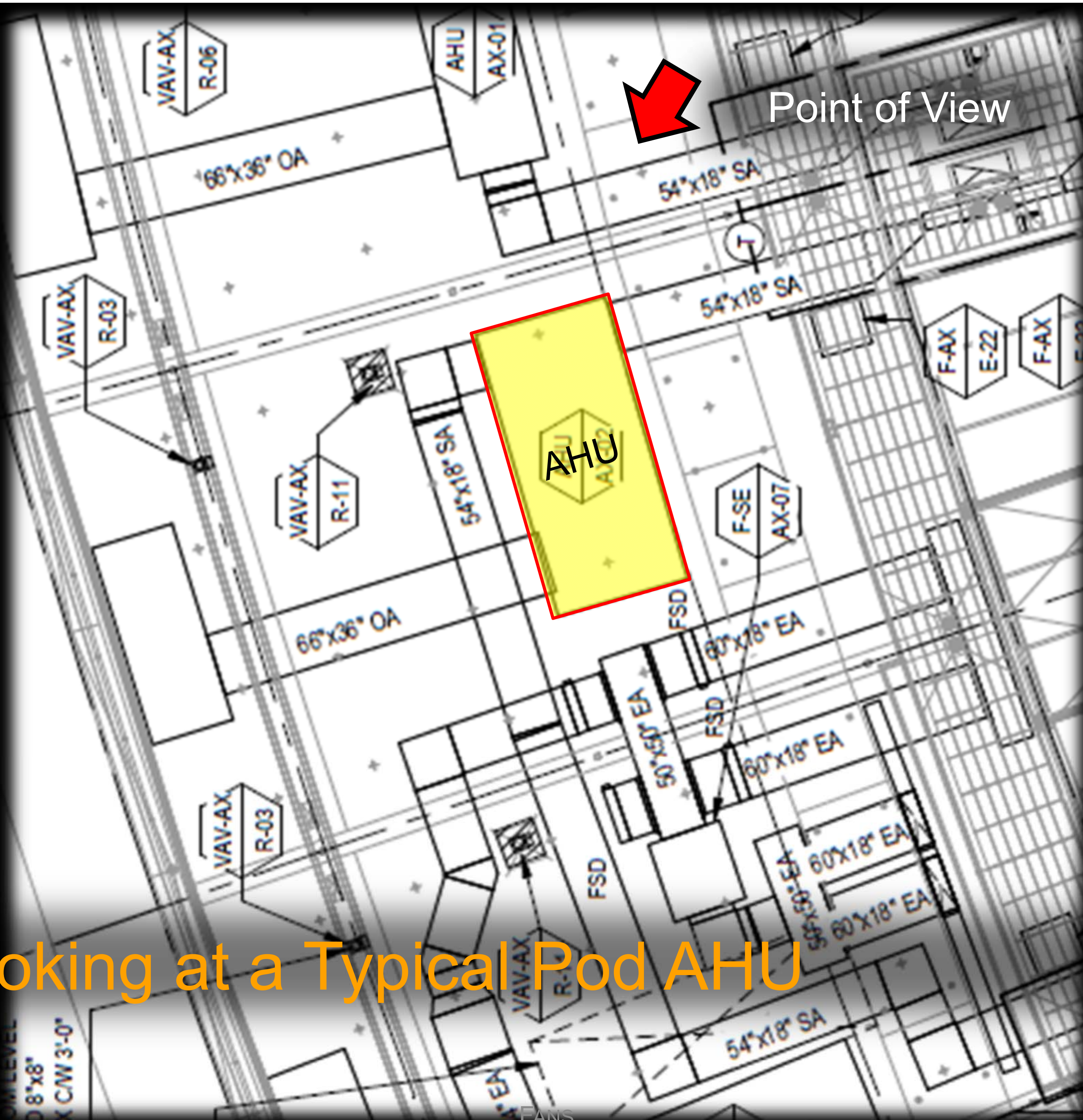
Twin City Blower SWSI fan selections indicate a 8-11% potential efficiency improvement

The potential benefits

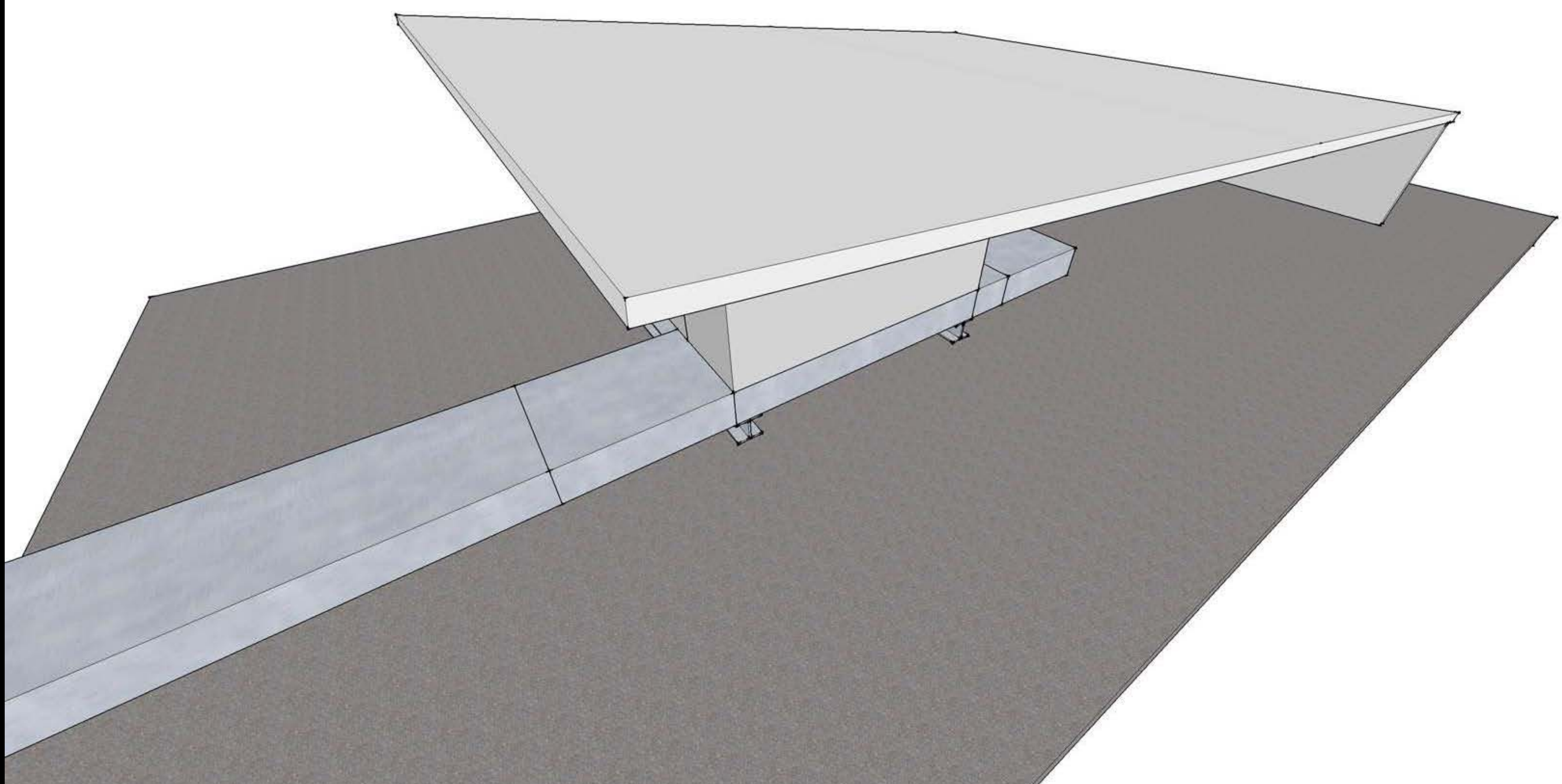
- 8-11% lower fan energy
- 8-11% lower operating cost
- Potential first cost improvements
  - Smaller motors
  - Smaller variable speed drives
  - Smaller electrical distribution equipment

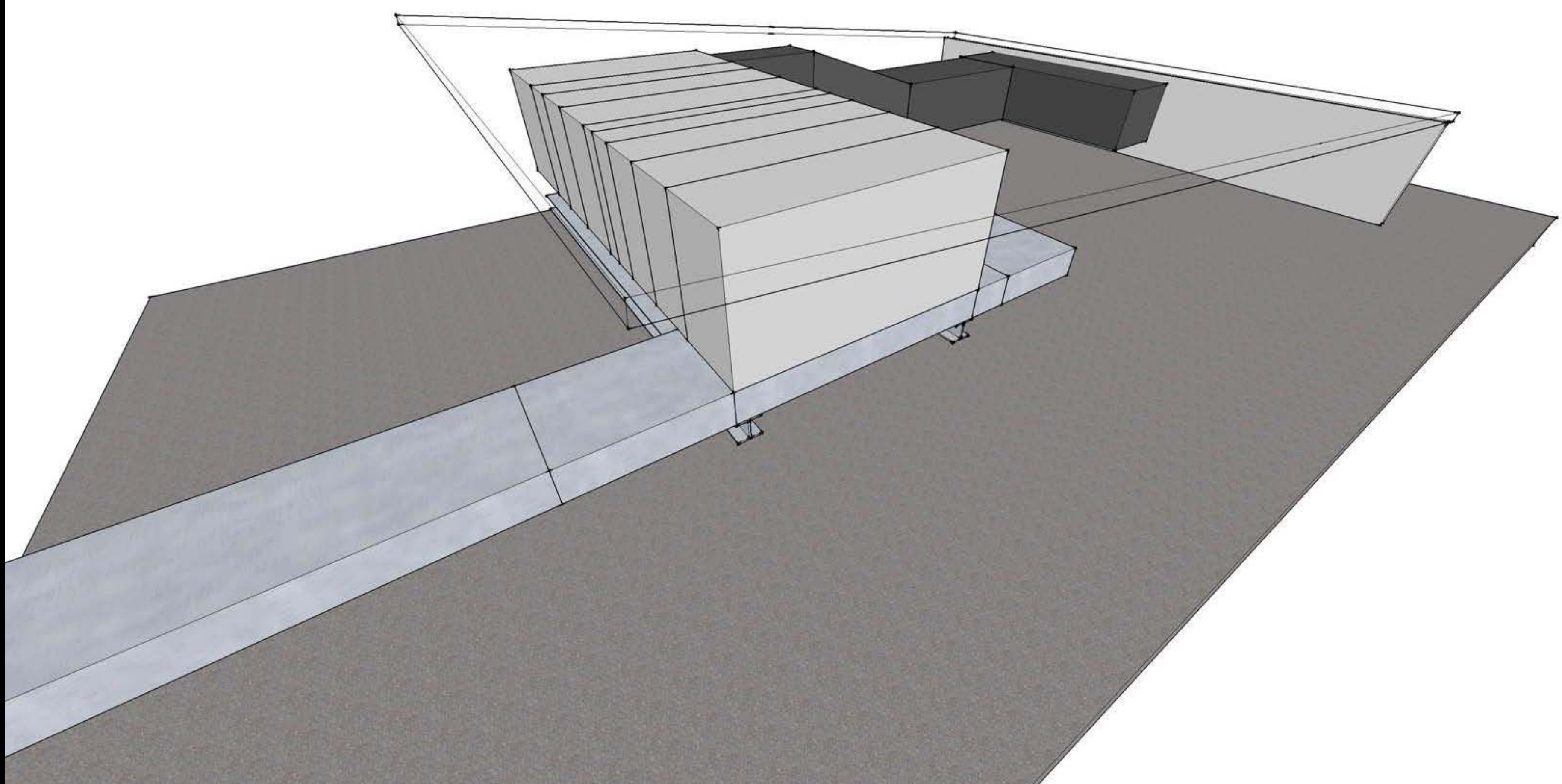
The question

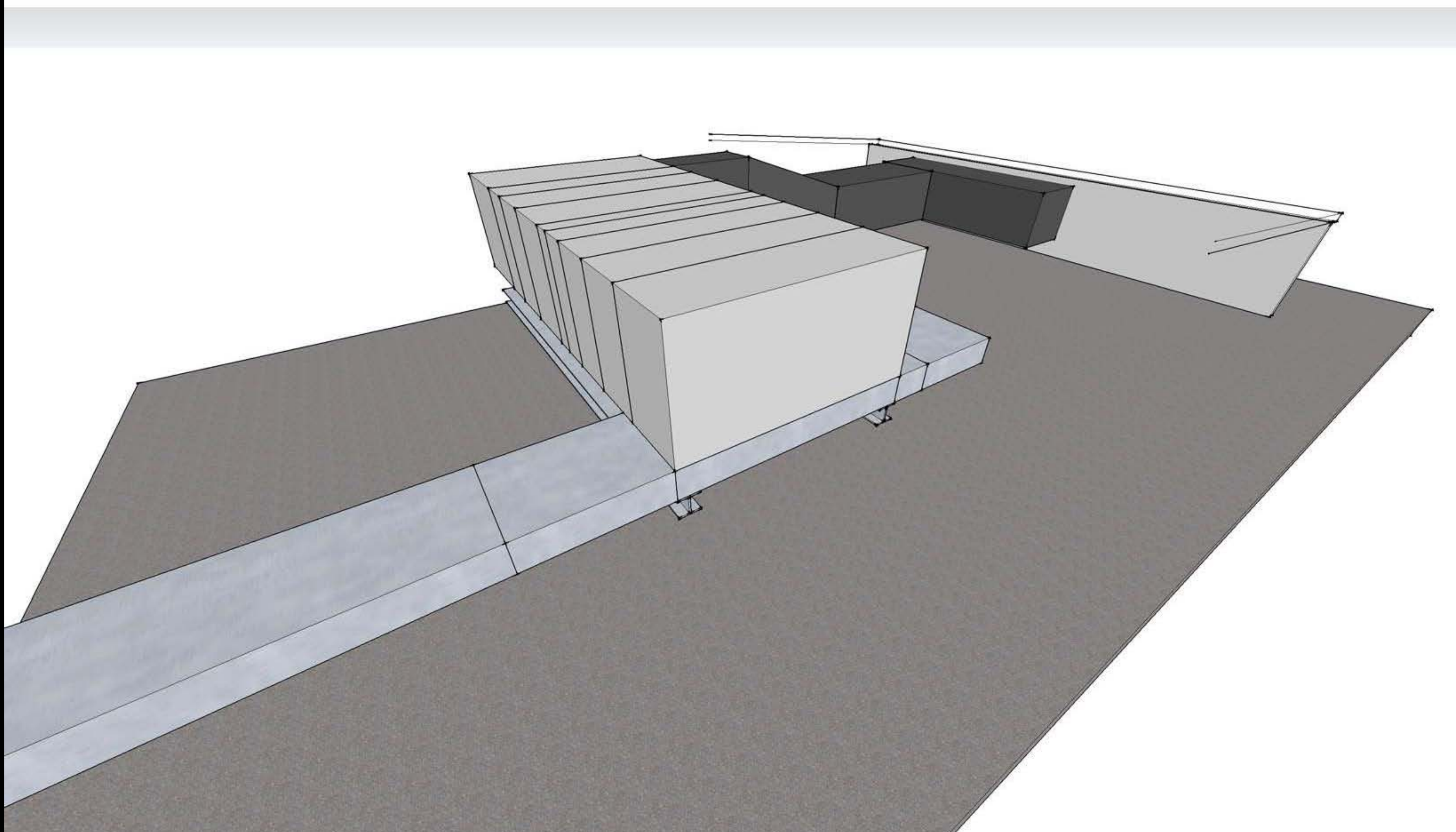
Can SWSI fans be applied in a way that allows them to fit with out compromising their discharge conditions?

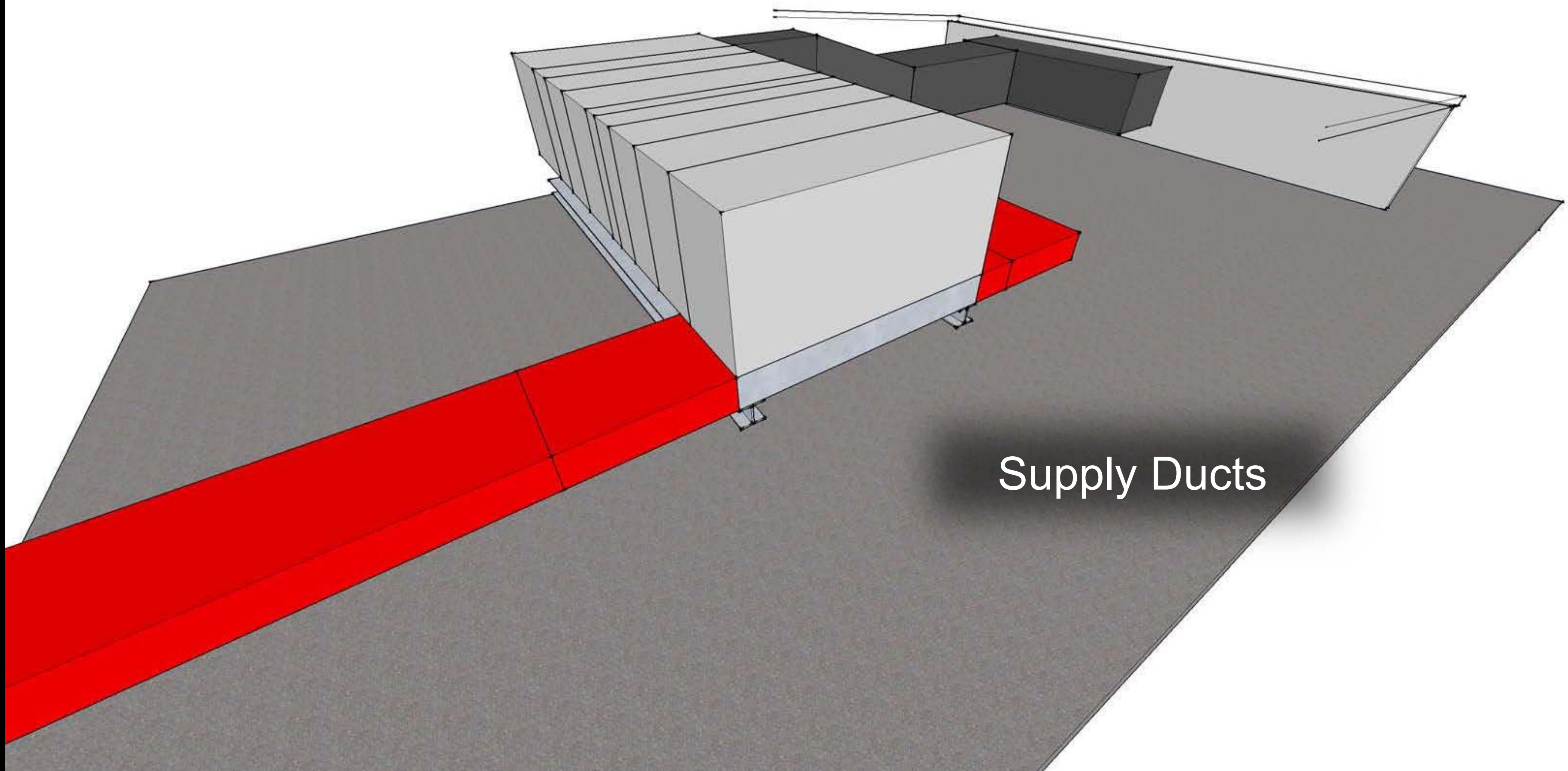


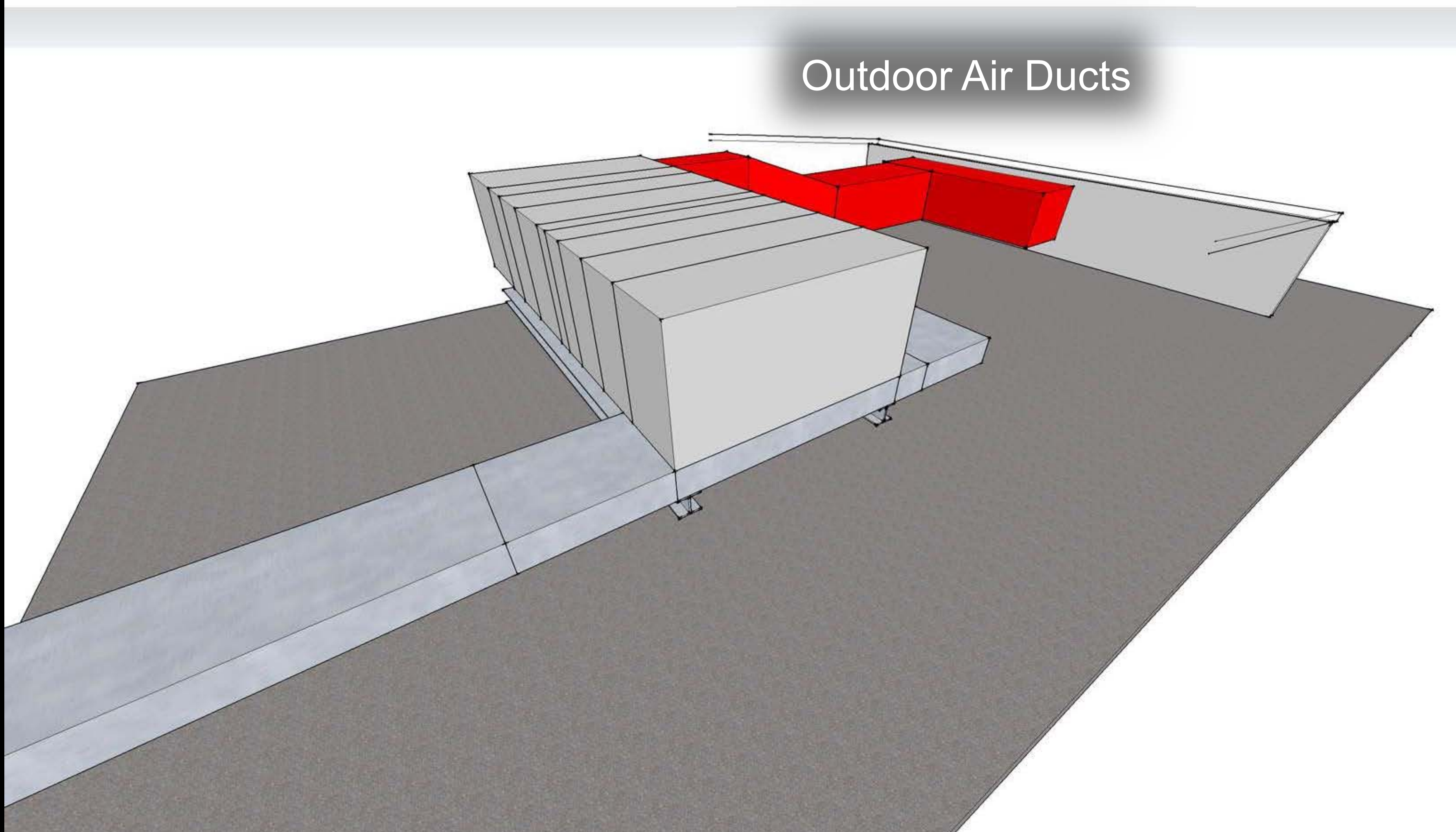
Looking at a Typical Pod AHU



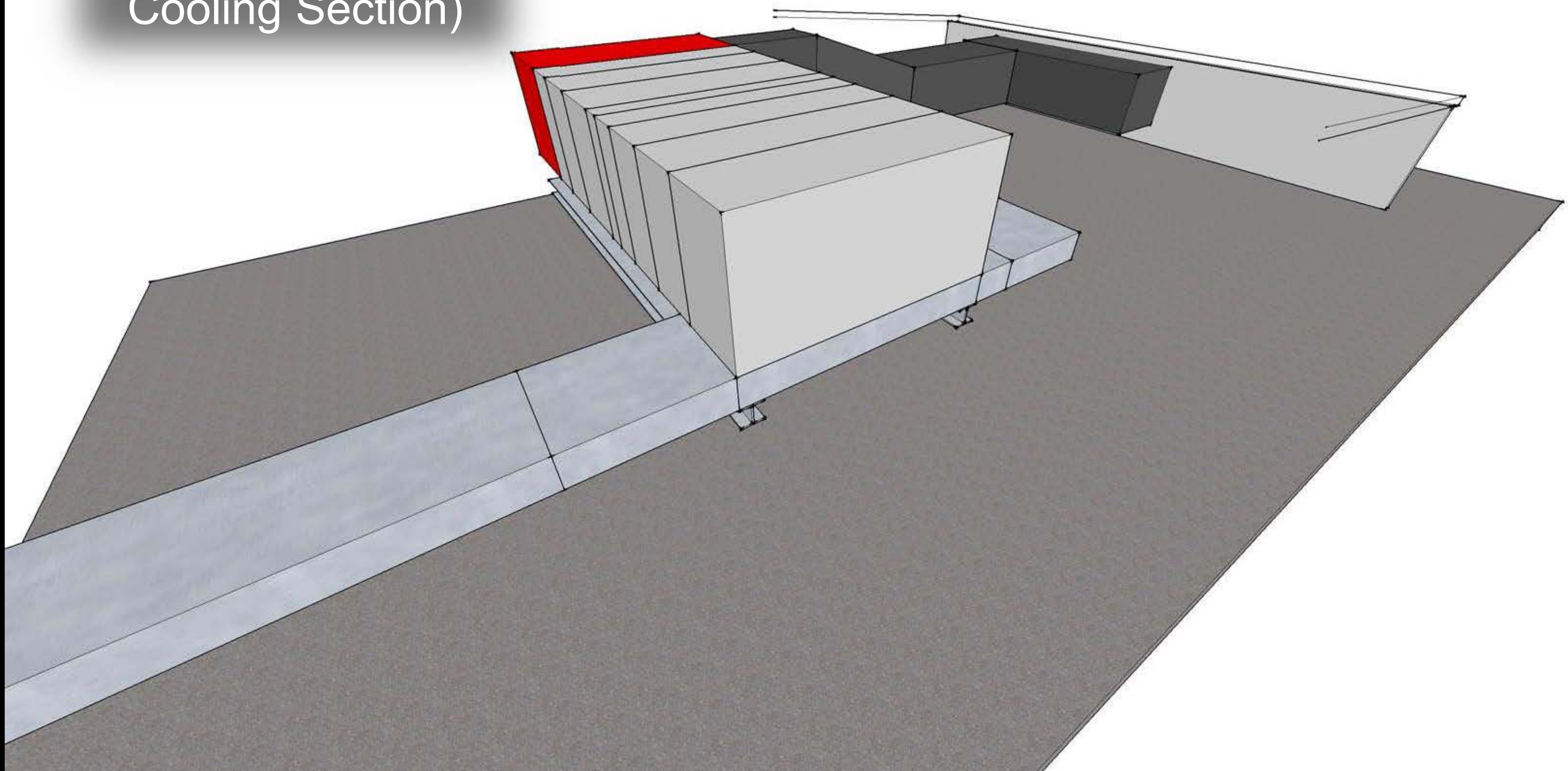


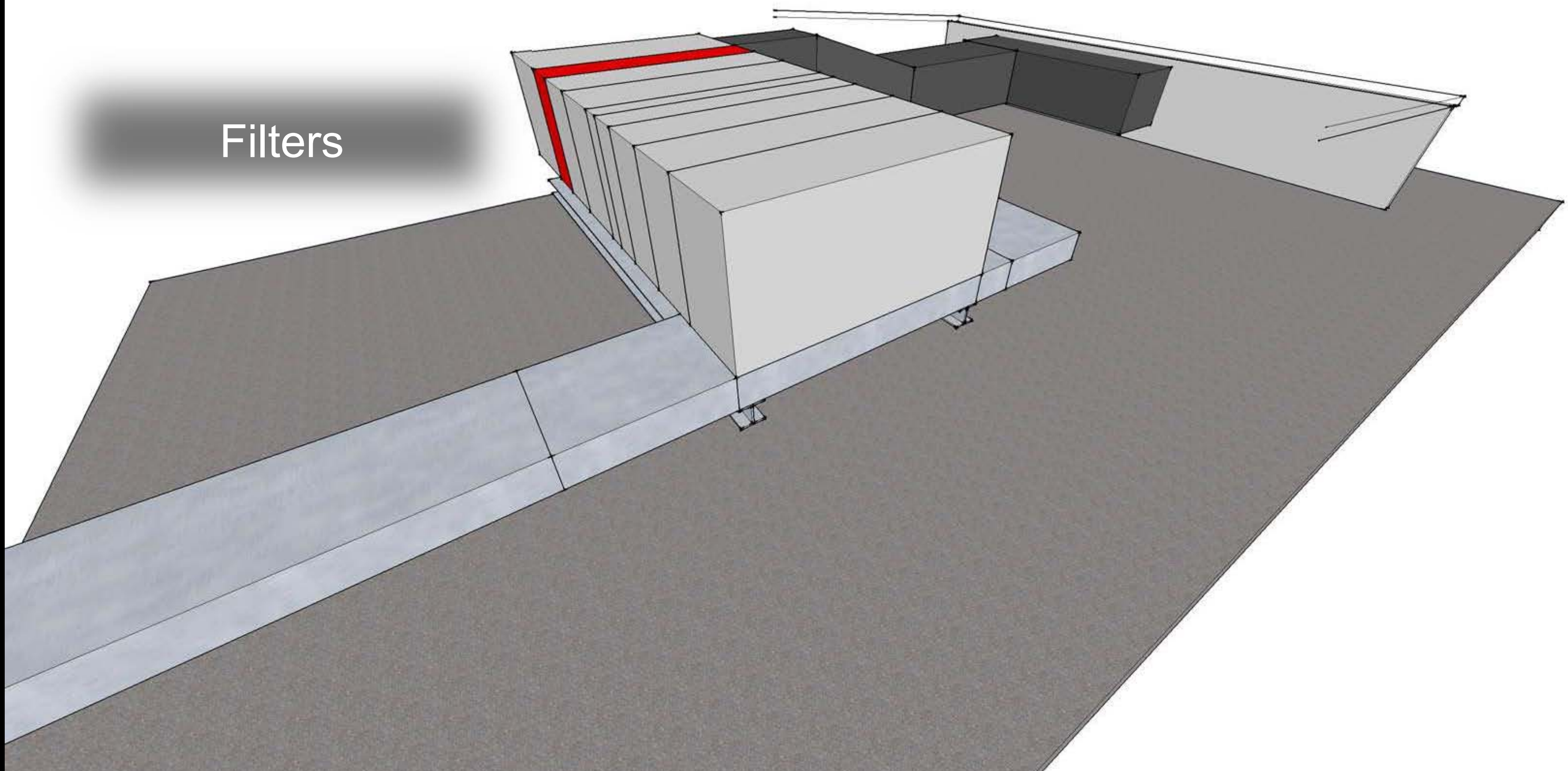


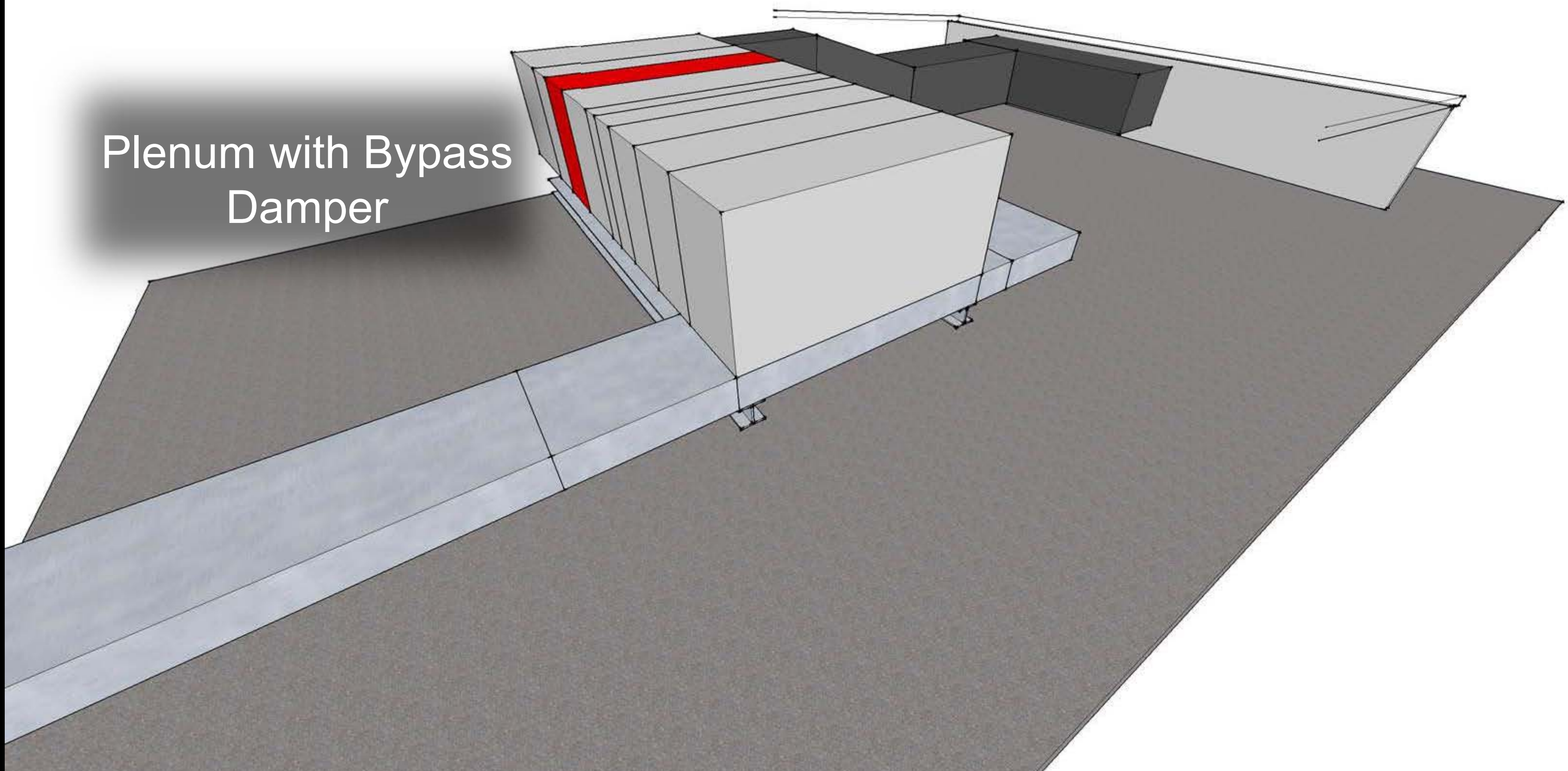

Supply Ducts

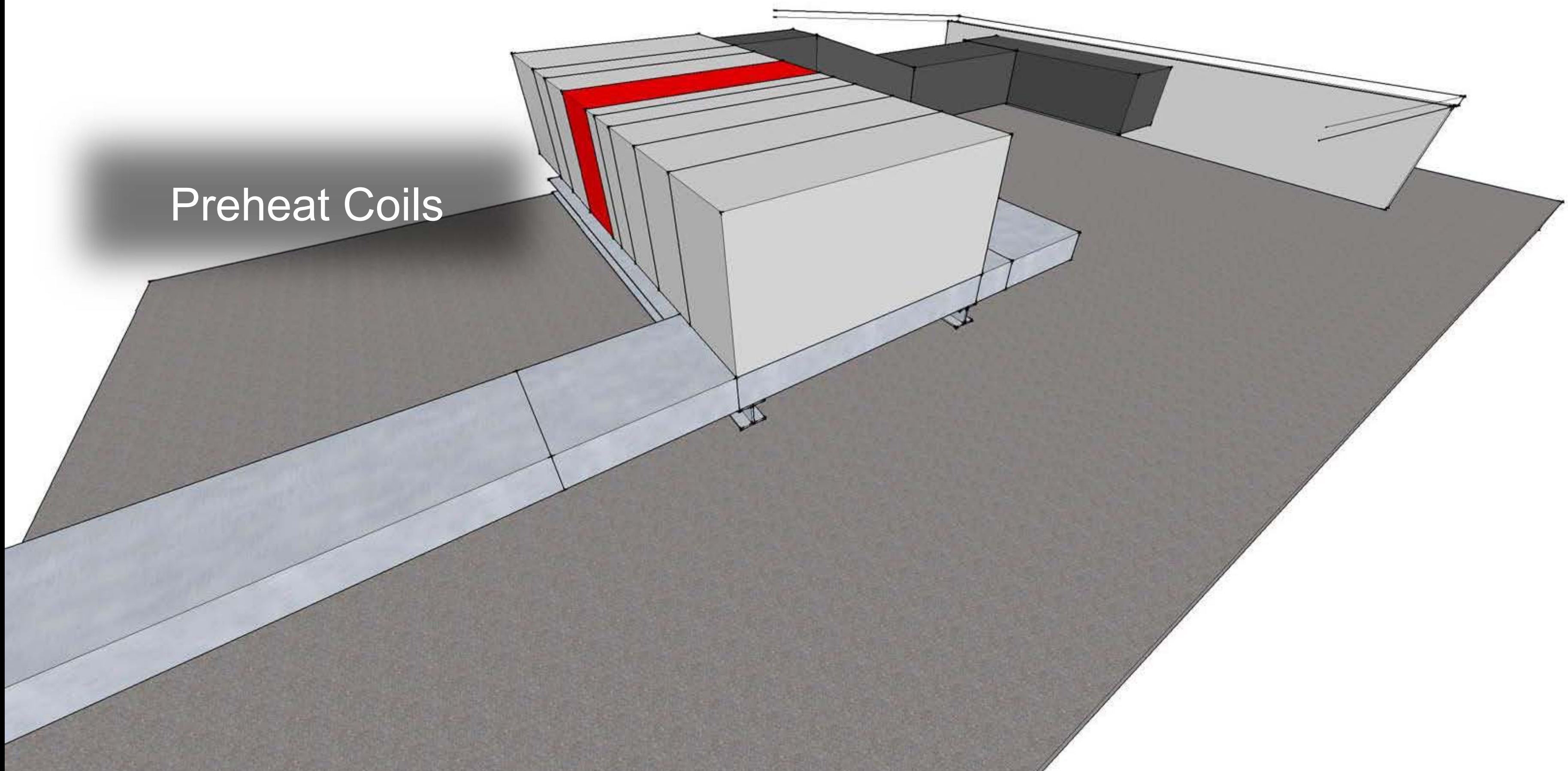

Outdoor Air Ducts

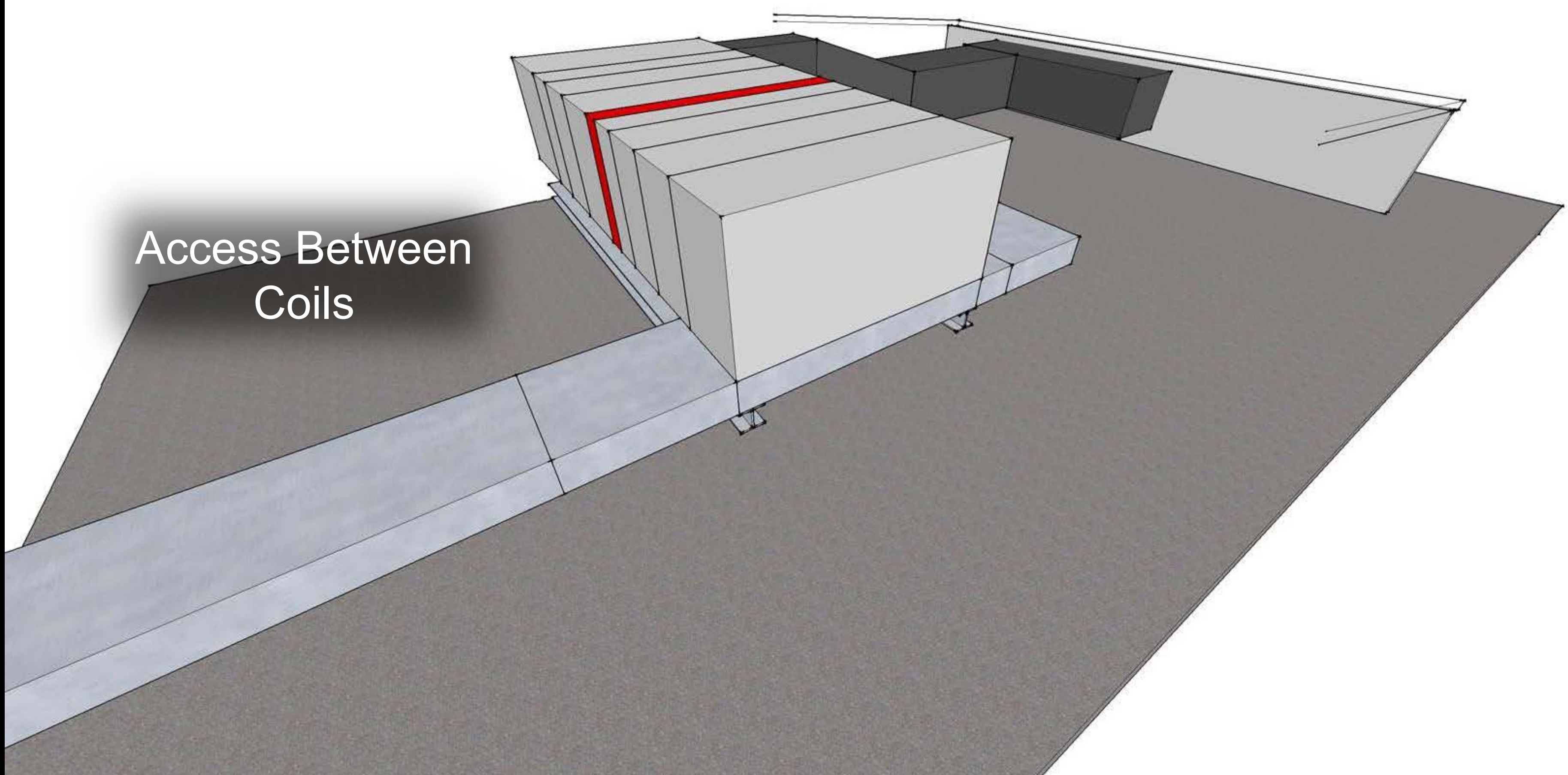
Mixing Box (Economizer/Free Cooling Section)



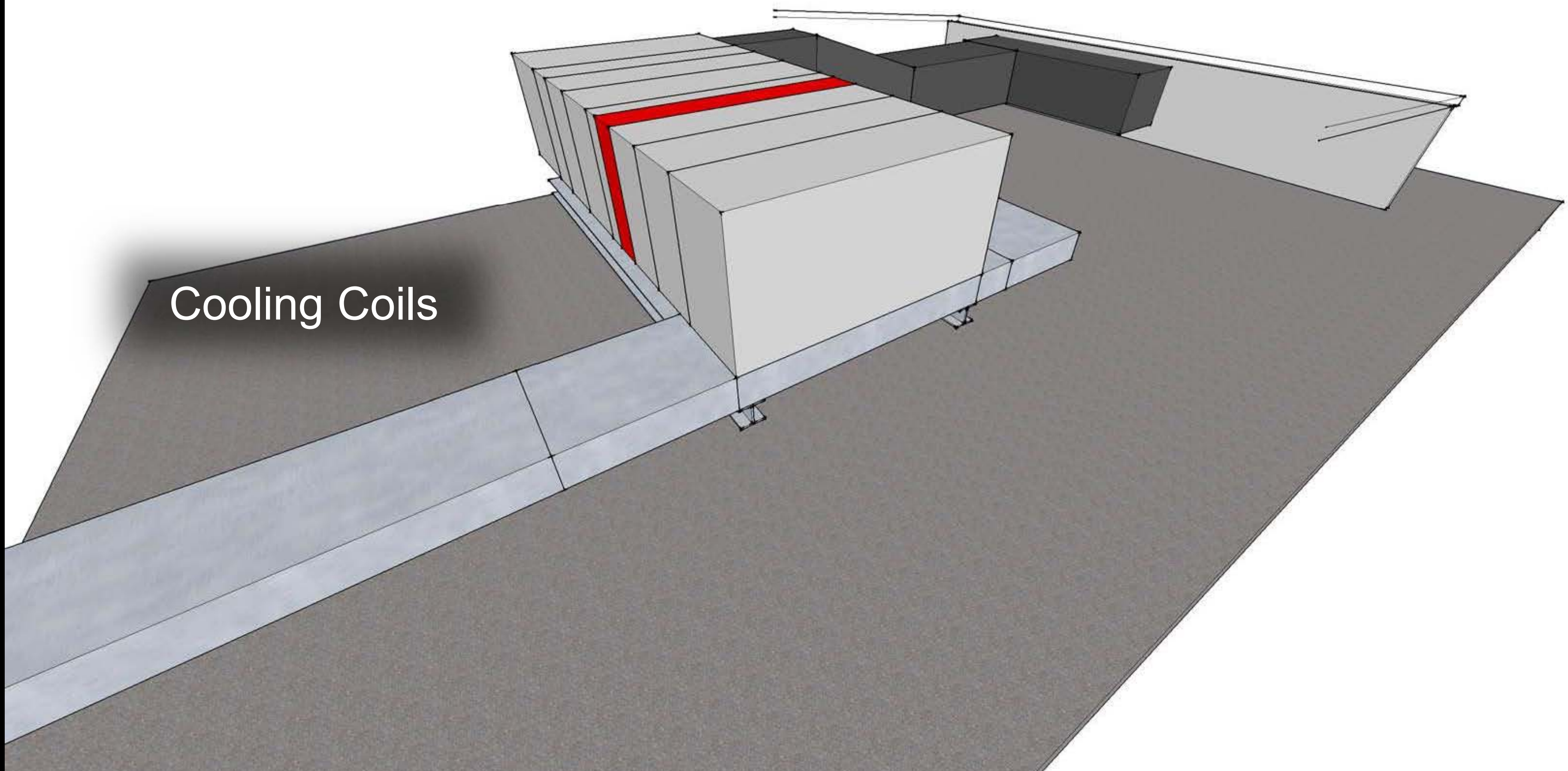

Filters

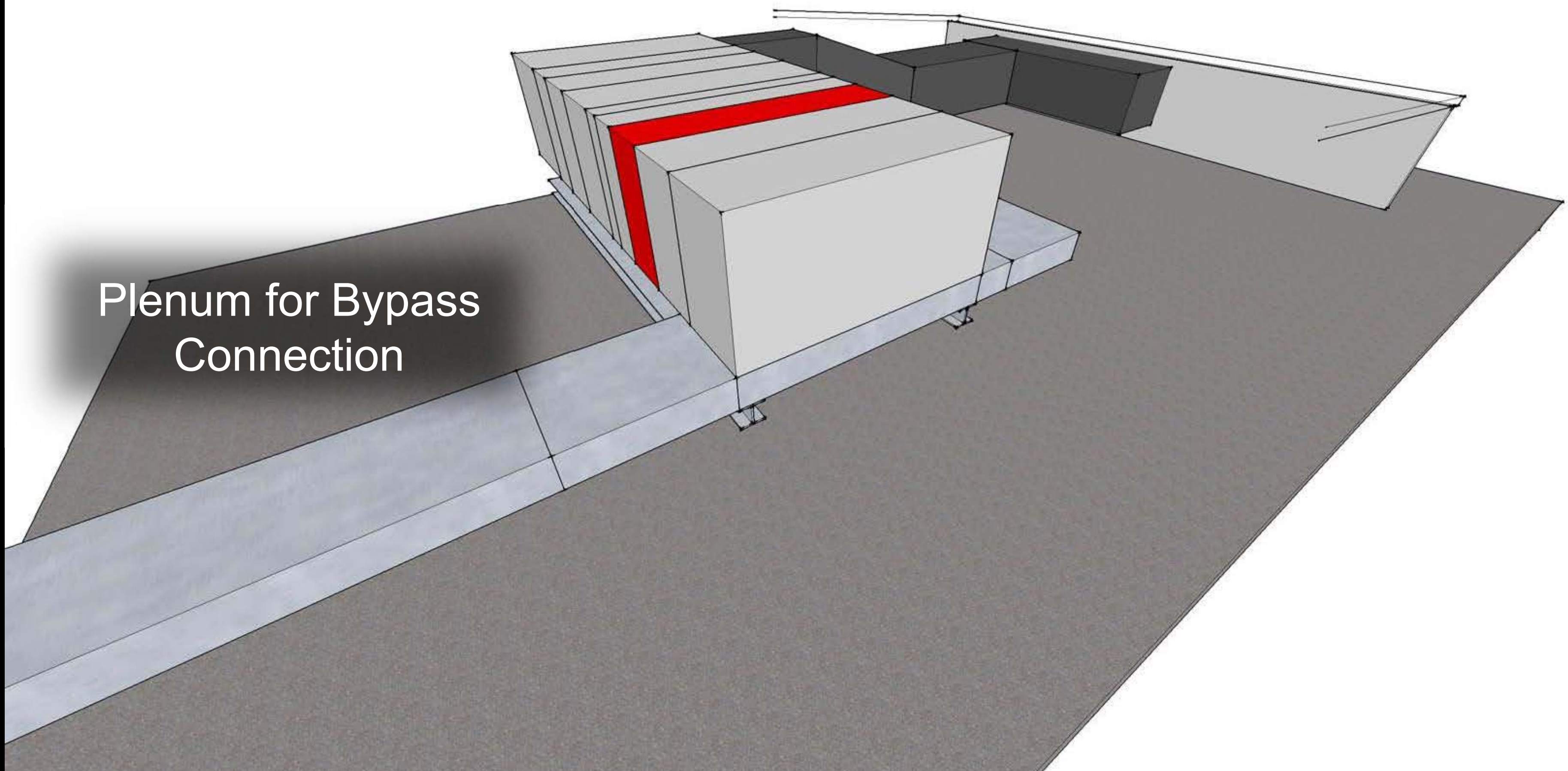

Plenum with Bypass Damper

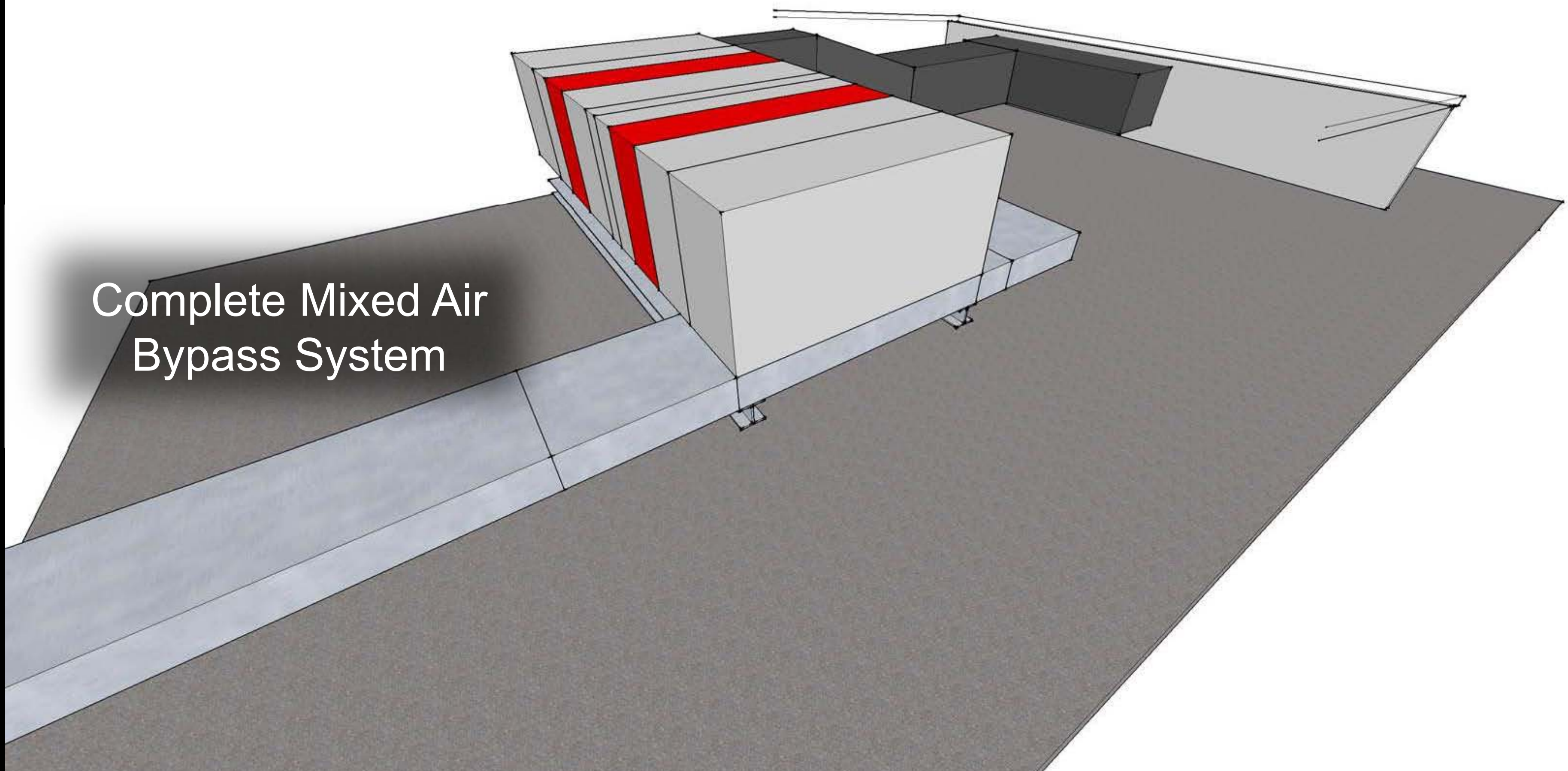

Preheat Coils

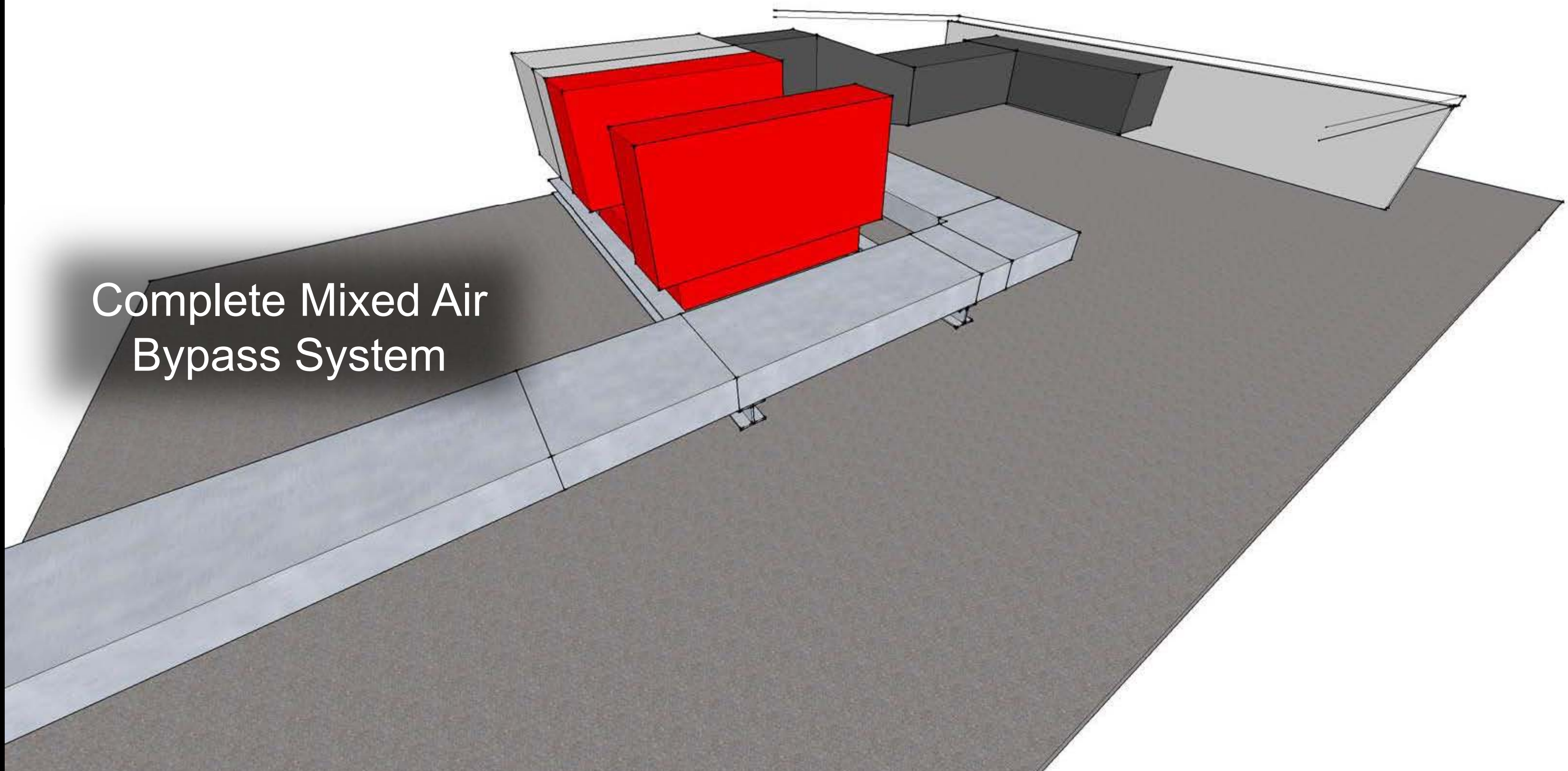


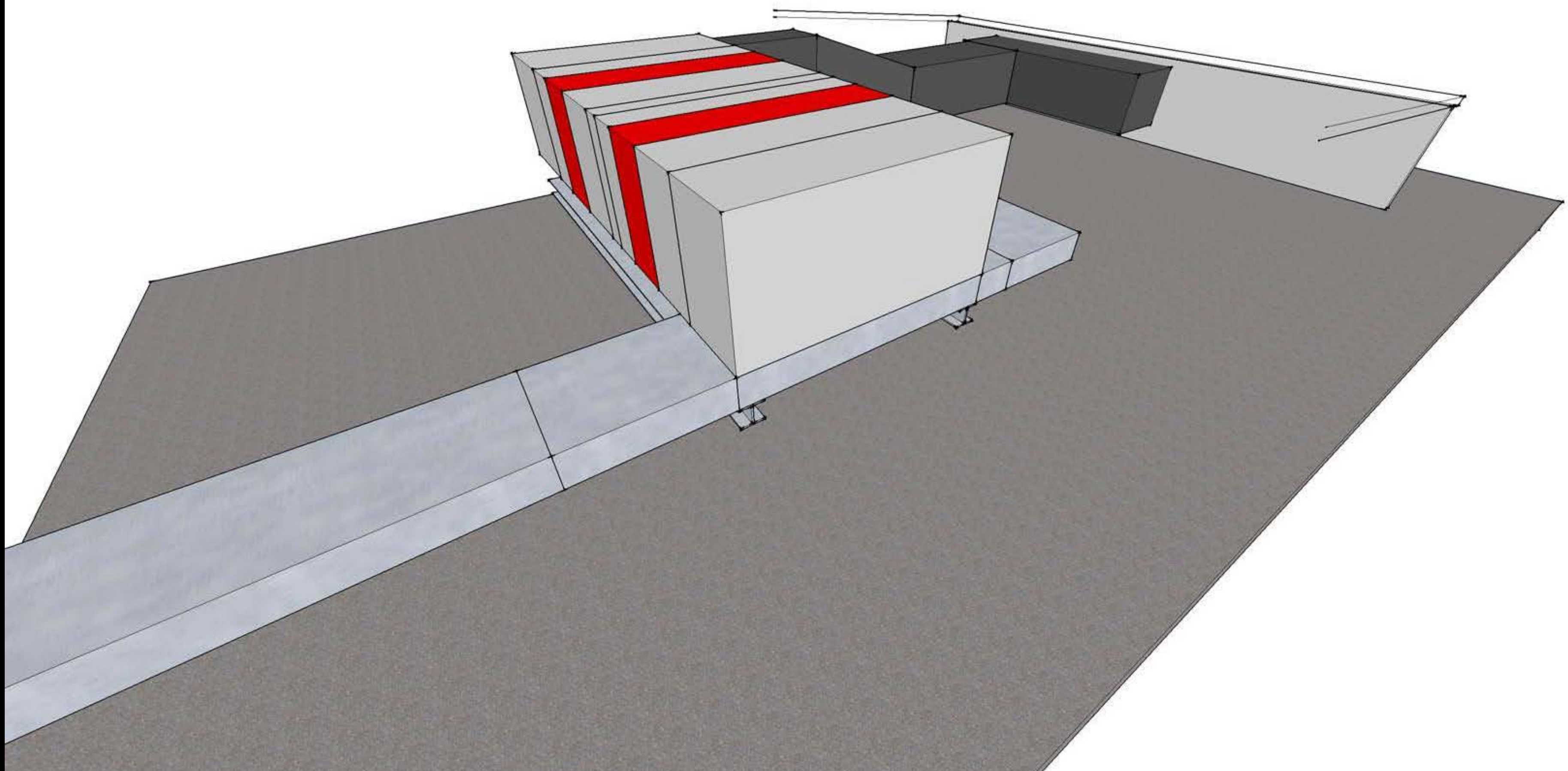
Access Between
Coils

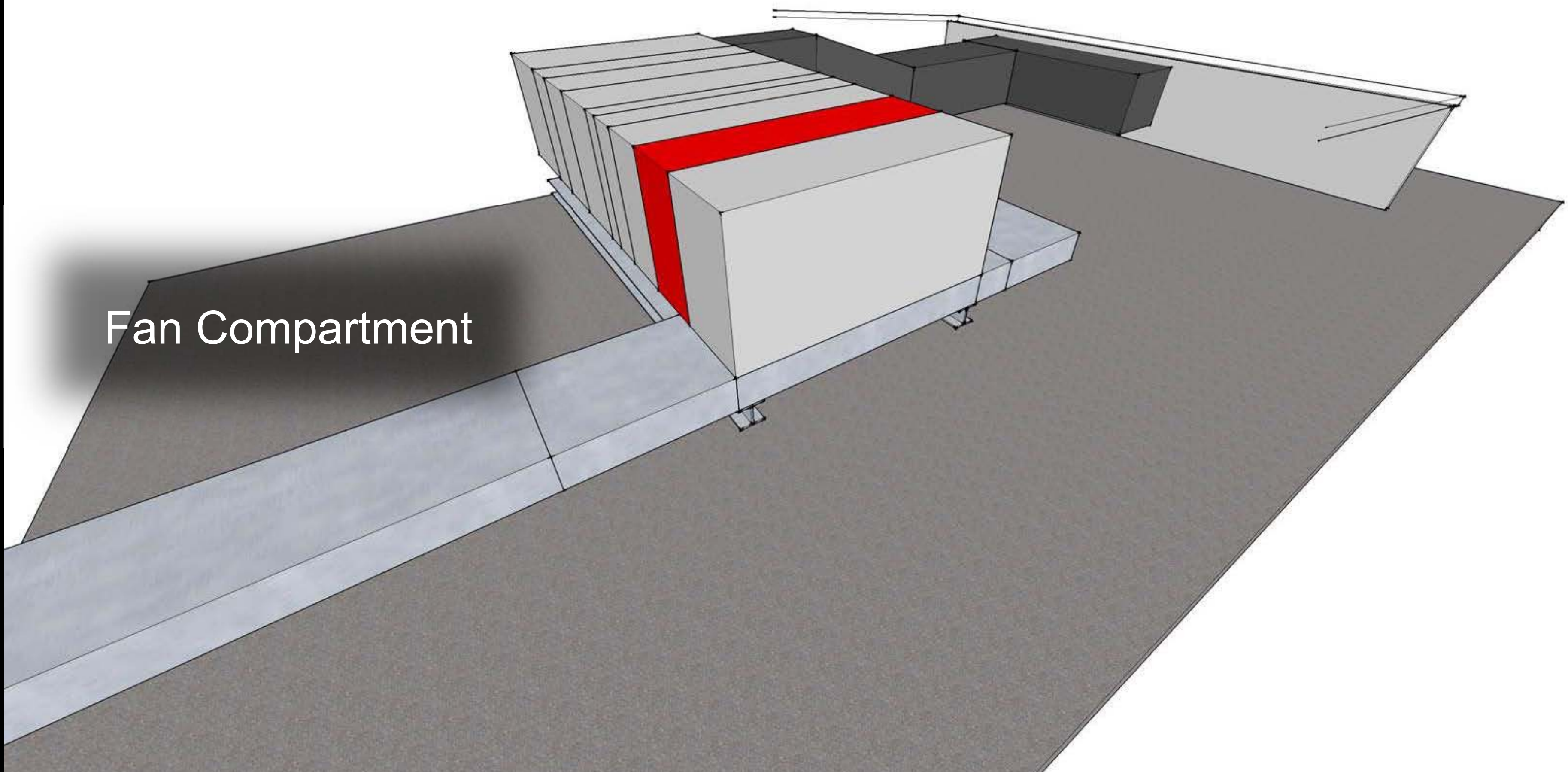

Cooling Coils

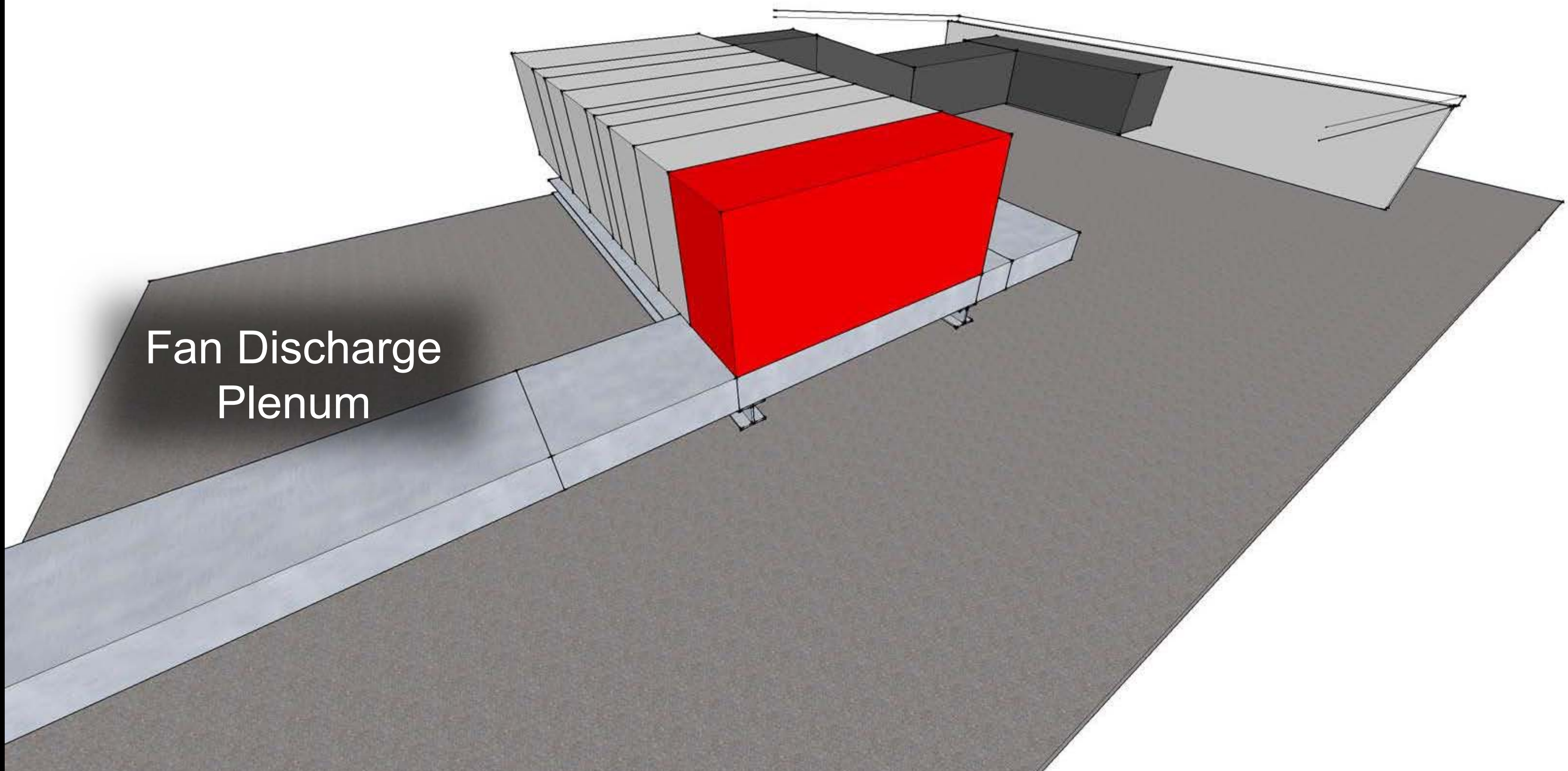

Plenum for Bypass
Connection

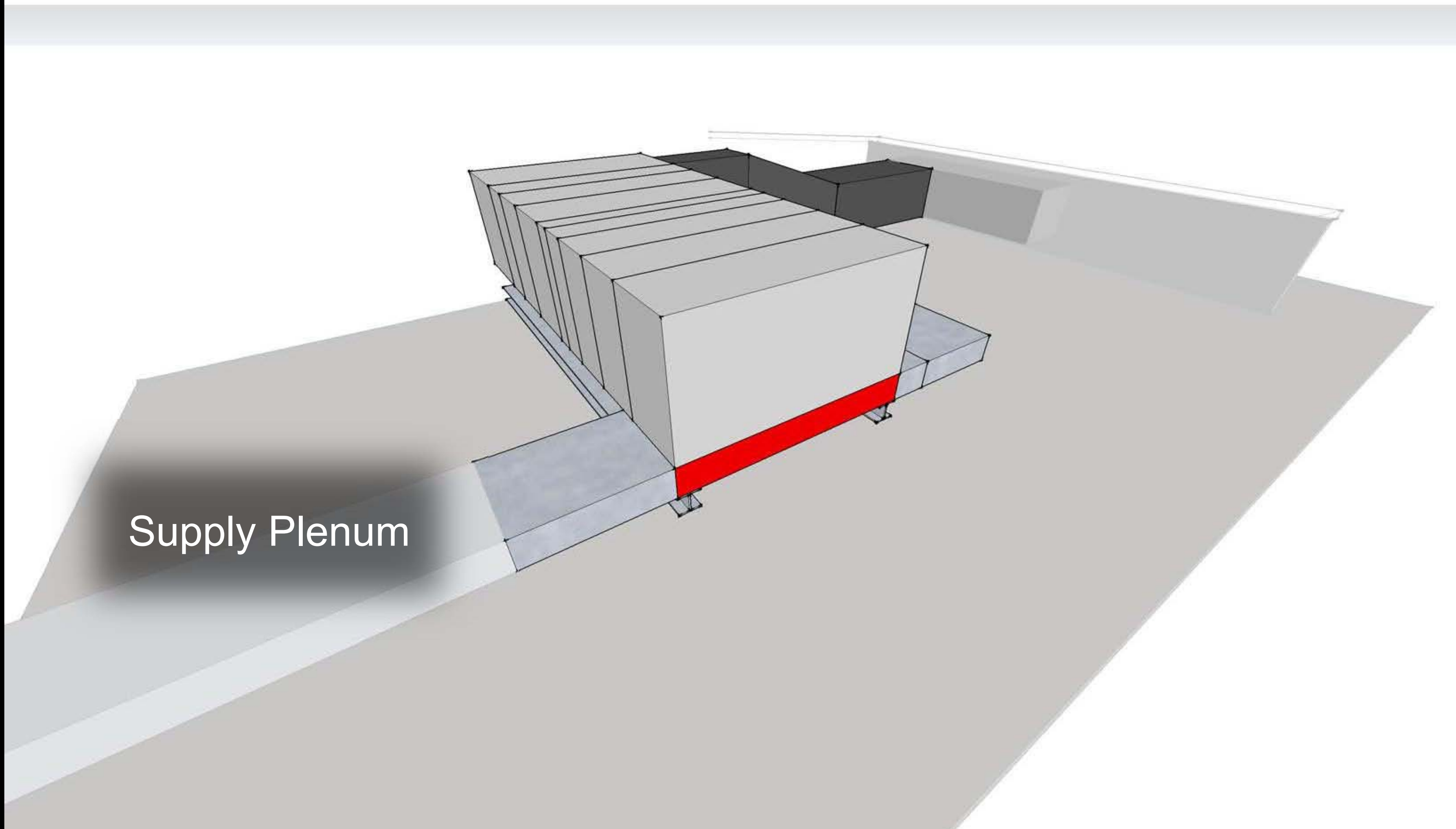

Complete Mixed Air
Bypass System


Complete Mixed Air
Bypass System

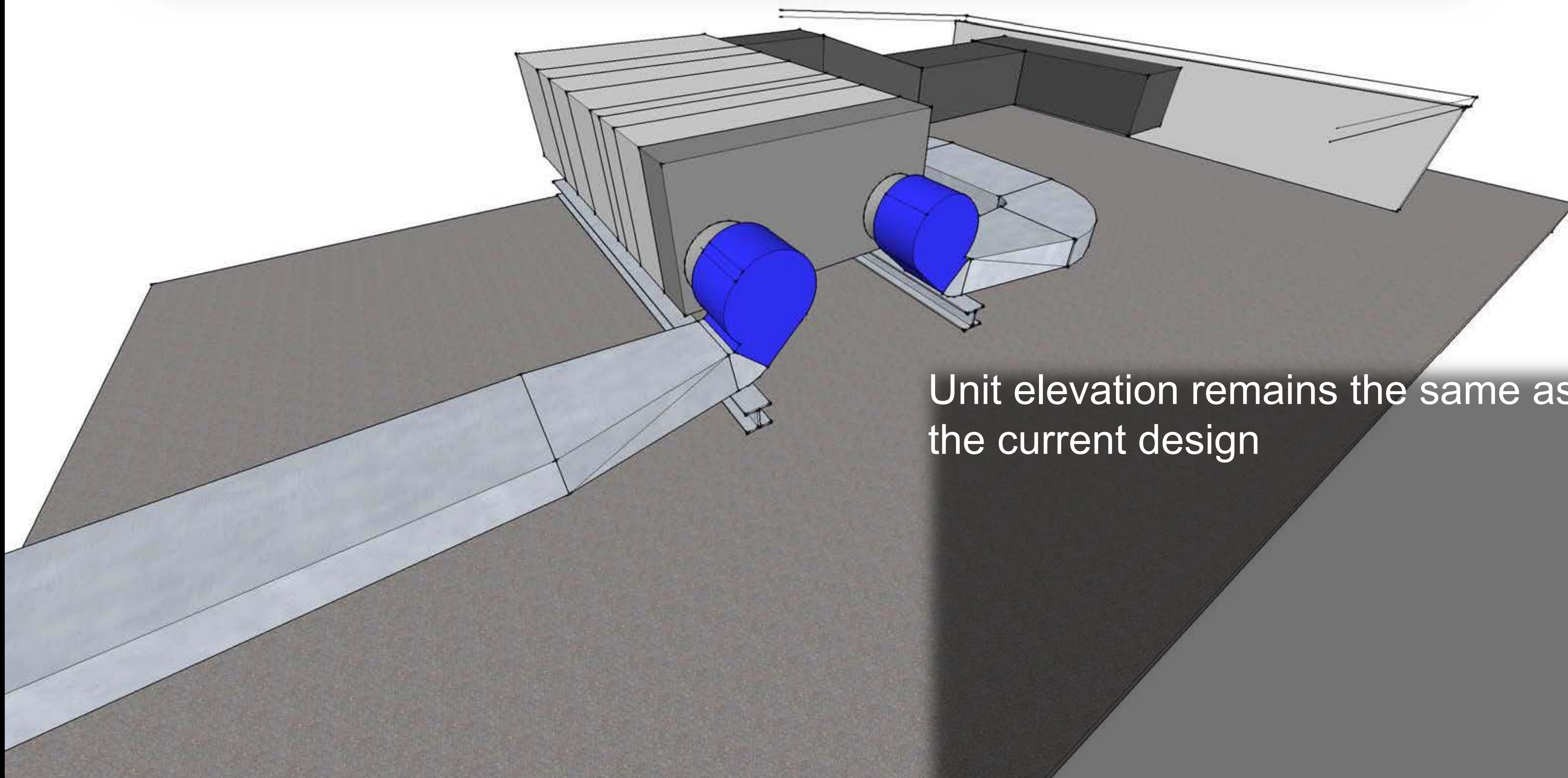



Fan Compartment


Fan Discharge
Plenum

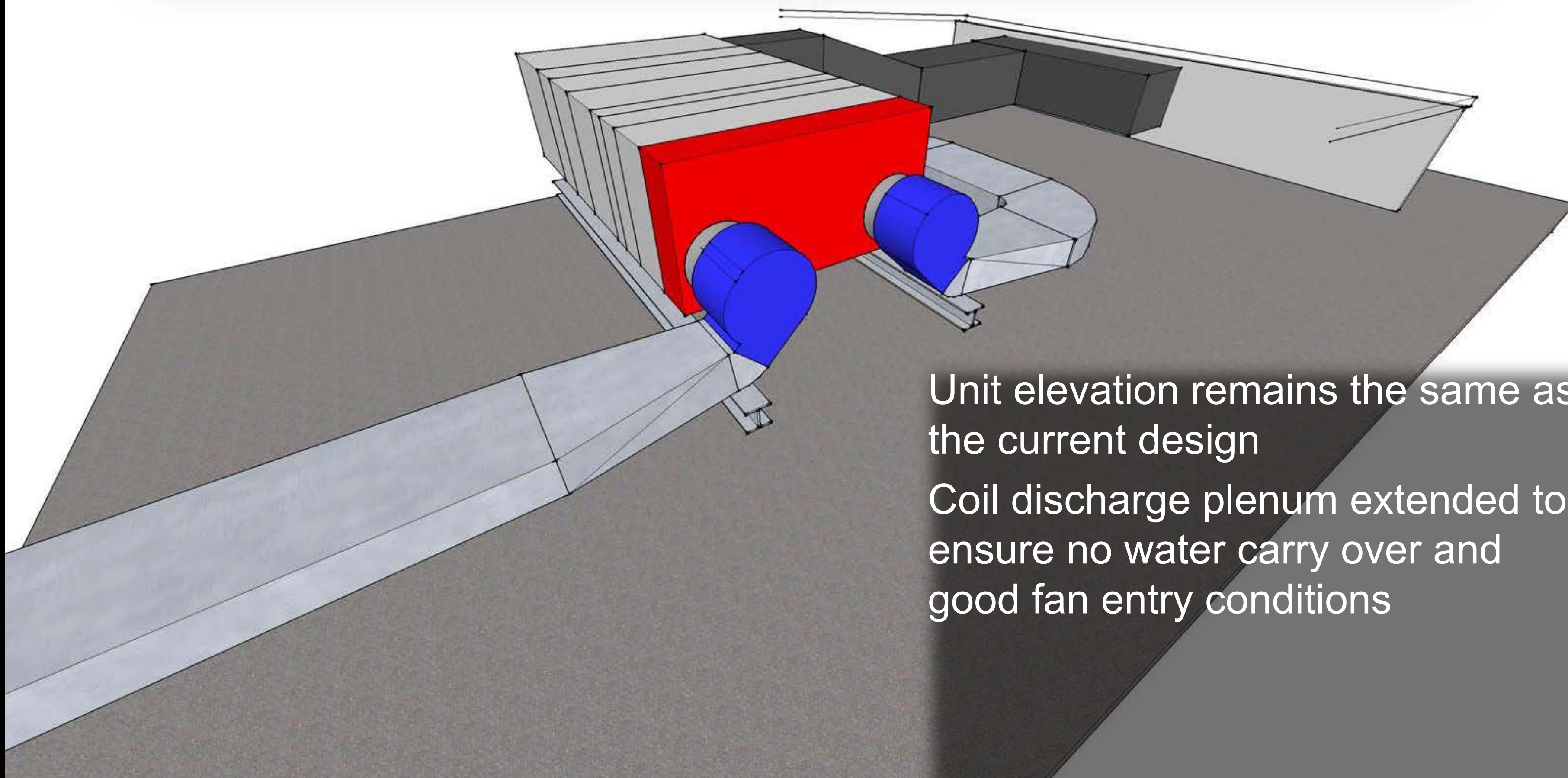

Supply Plenum

Option 1 – Two SWSI Bottom Angle Discharge Fans



Unit elevation remains the same as the current design

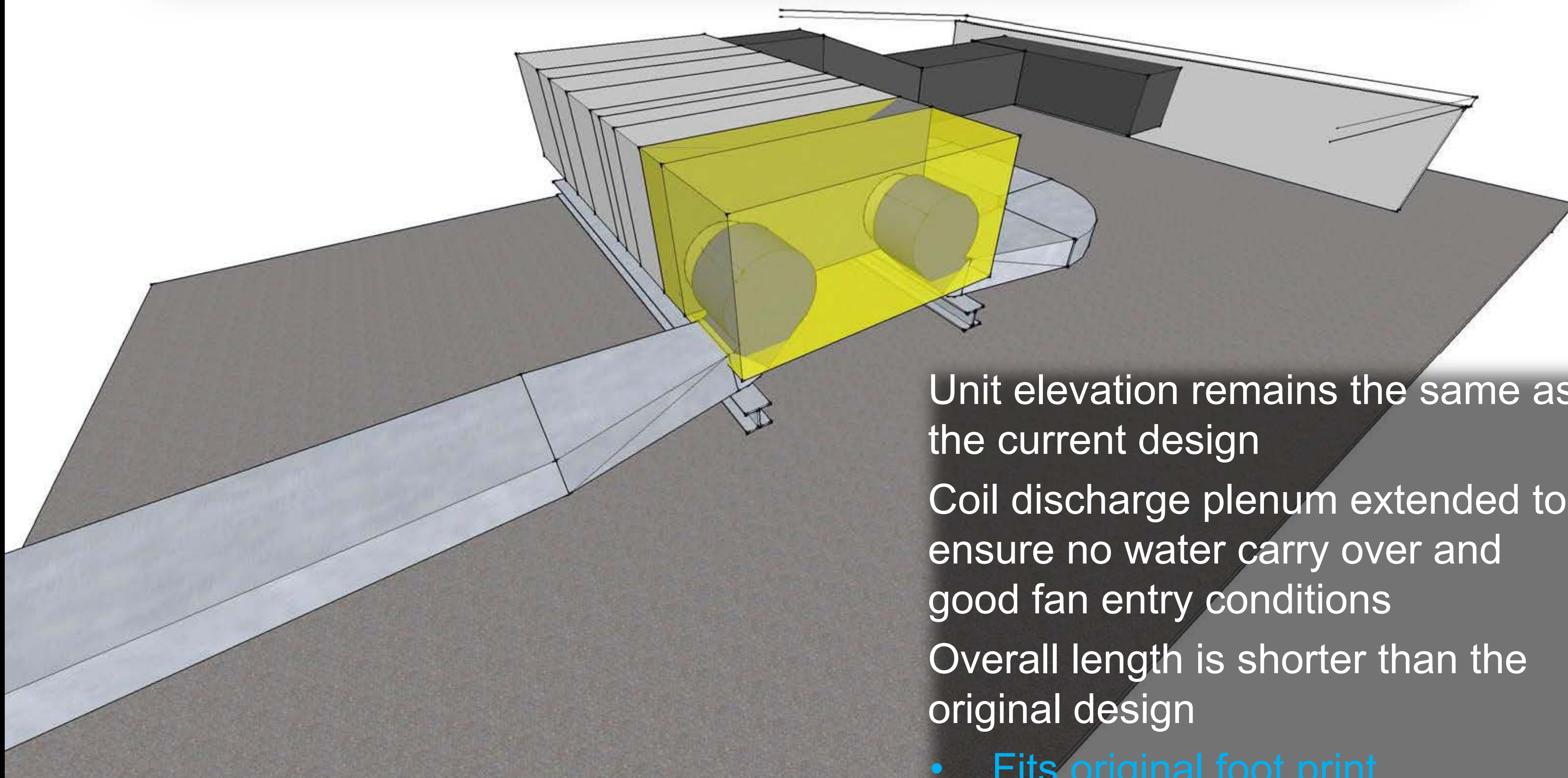
Option 1 – Two SWSI Bottom Angle Discharge Fans



Unit elevation remains the same as the current design

Coil discharge plenum extended to ensure no water carry over and good fan entry conditions

Option 1 – Two SWSI Bottom Angle Discharge Fans



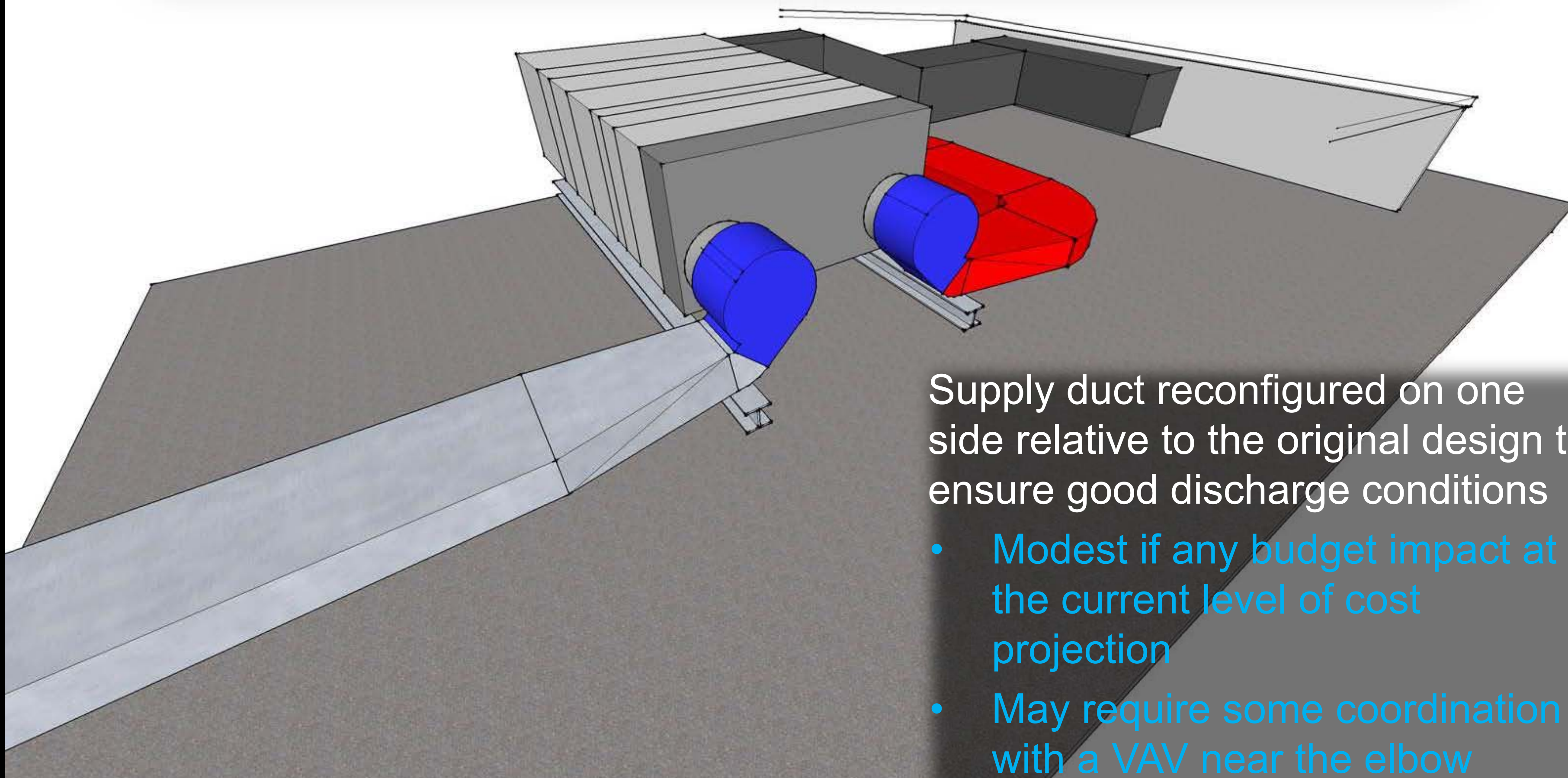
Unit elevation remains the same as the current design

Coil discharge plenum extended to ensure no water carry over and good fan entry conditions

Overall length is shorter than the original design

- Fits original foot print
- Potential first cost reduction due to smaller casing

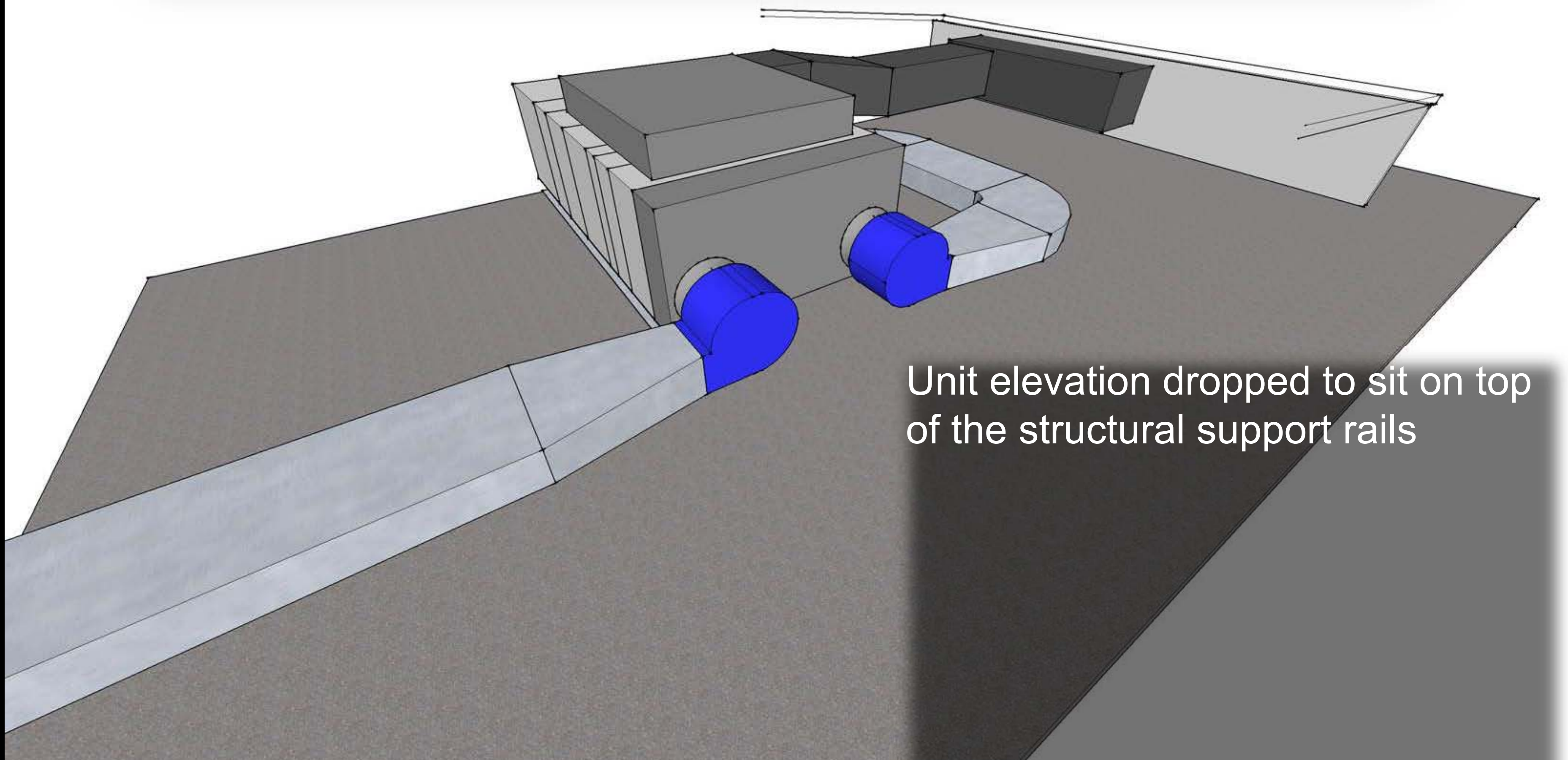
Option 1 – Two SWSI Bottom Angle Discharge Fans



Supply duct reconfigured on one side relative to the original design to ensure good discharge conditions

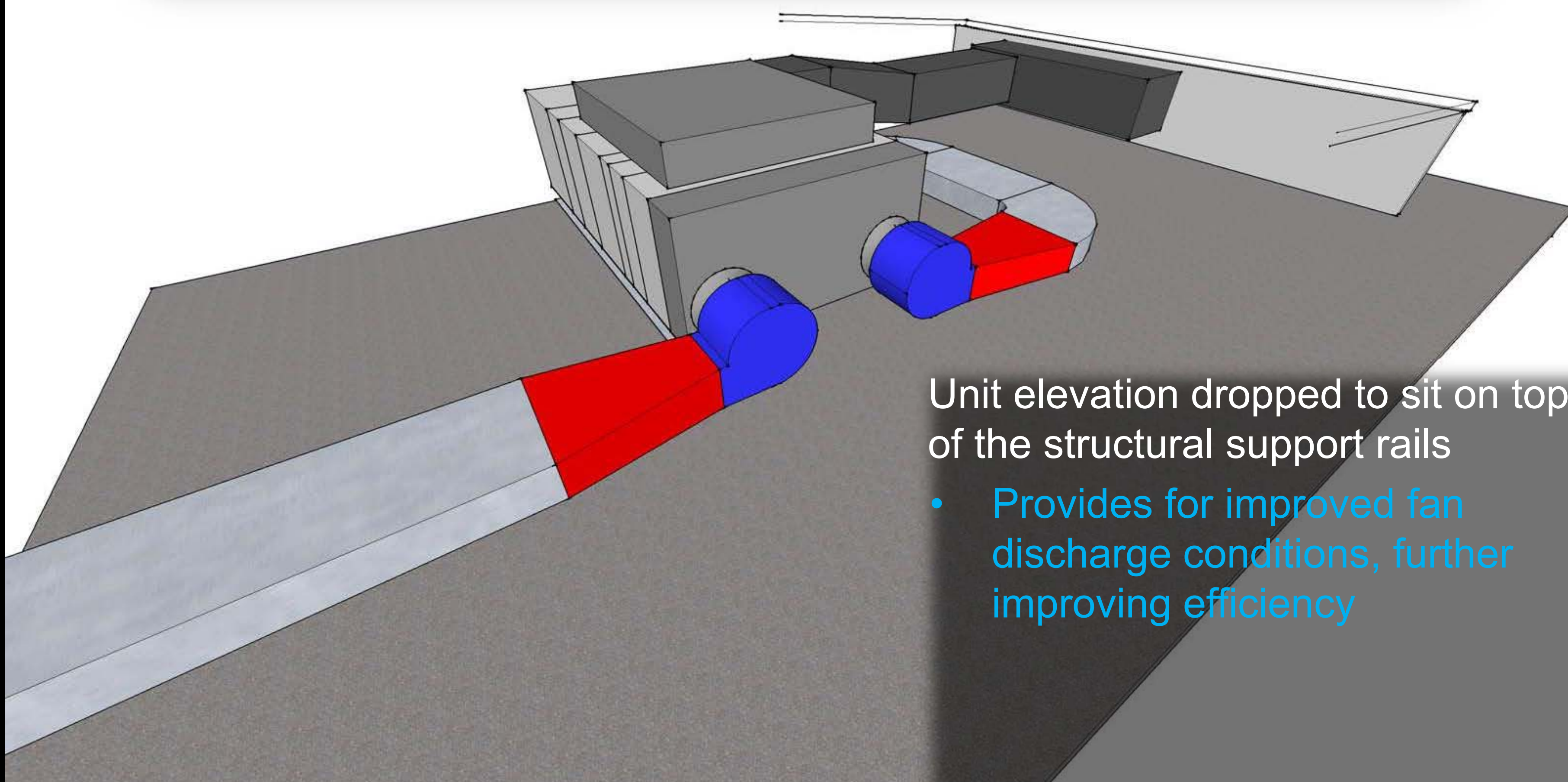
- Modest if any budget impact at the current level of cost projection
- May require some coordination with a VAV near the elbow

Option 2 – Two SWSI Bottom Horizontal Discharge Fans



Unit elevation dropped to sit on top of the structural support rails

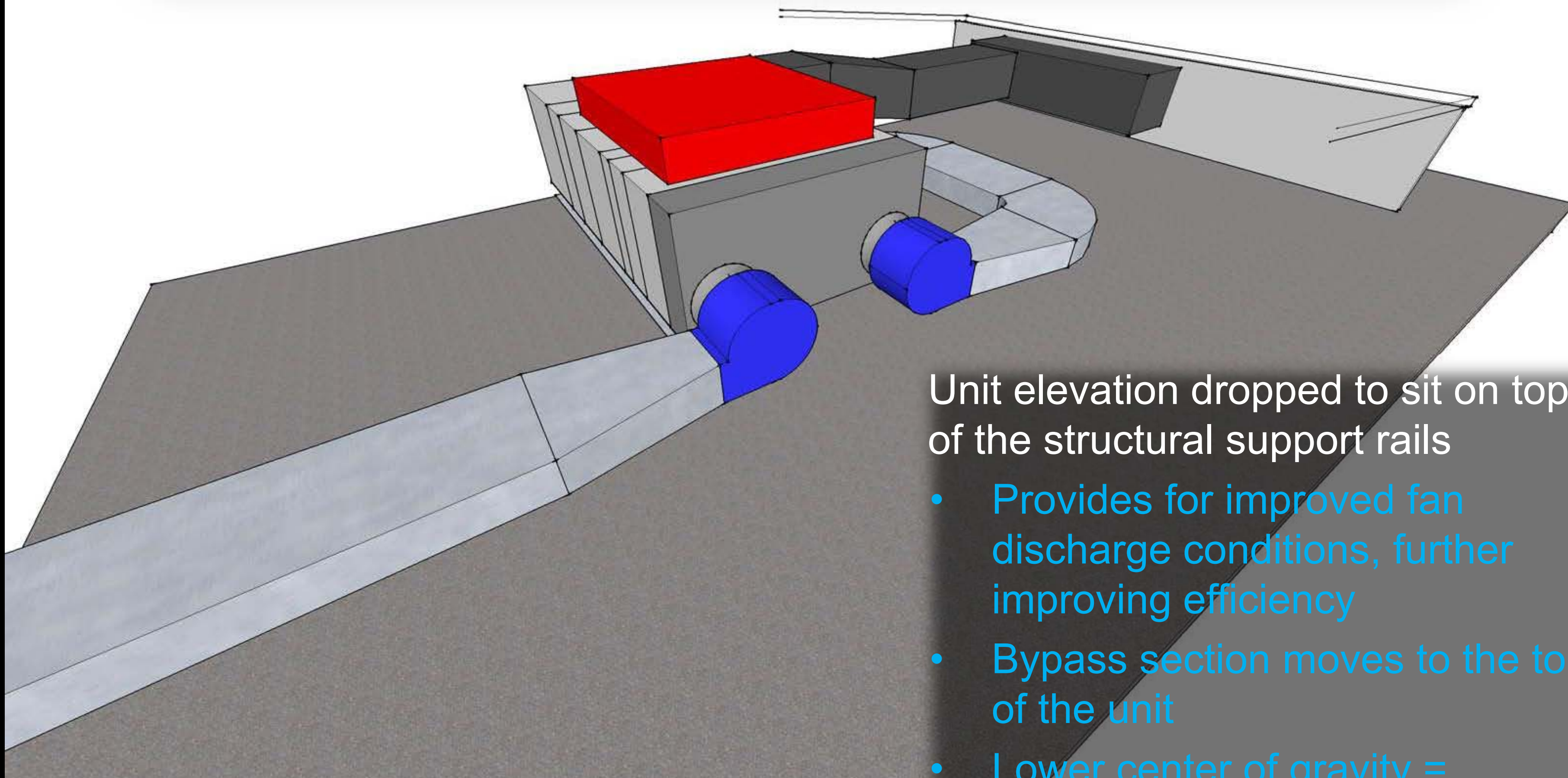
Option 2 – Two SWSI Bottom Horizontal Discharge Fans



Unit elevation dropped to sit on top of the structural support rails

- Provides for improved fan discharge conditions, further improving efficiency

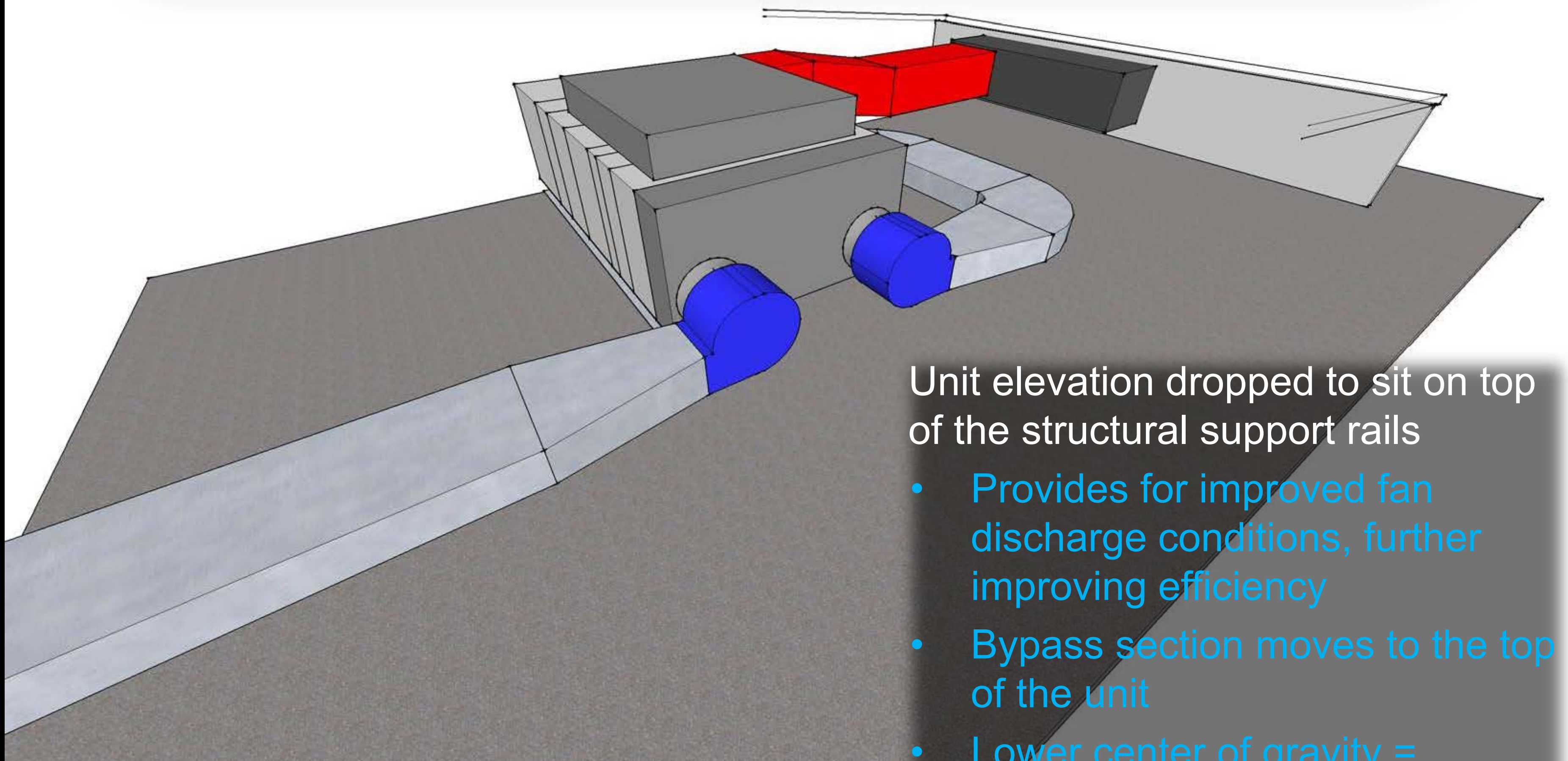
Option 2 – Two SWSI Bottom Horizontal Discharge Fans



Unit elevation dropped to sit on top of the structural support rails

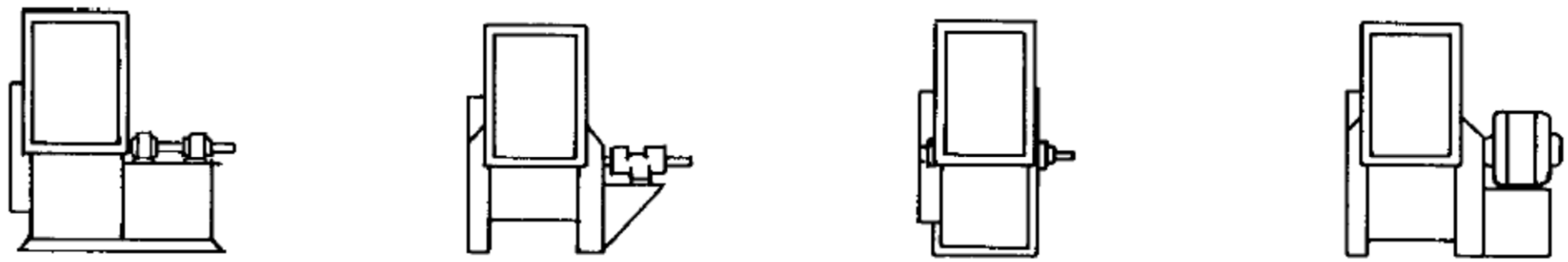
- Provides for improved fan discharge conditions, further improving efficiency
- Bypass section moves to the top of the unit
- Lower center of gravity = reduces seismic load

Option 2 – Two SWSI Bottom Horizontal Discharge Fans



Unit elevation dropped to sit on top of the structural support rails

- Provides for improved fan discharge conditions, further improving efficiency
- Bypass section moves to the top of the unit
- Lower center of gravity = reduces seismic load
- Modest impact on OA duct



Arr. 1 SI

For belt drive or direct connection. Impeller overhung. Two bearings on base.

Arr. 2 SI

For belt drive or direct connection. Impeller overhung. Bearings in bracket supported by fan housing.

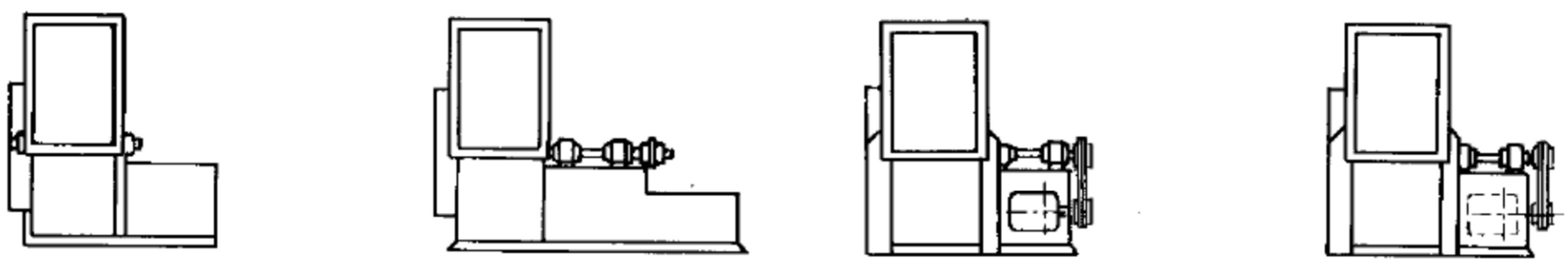
Arr. 3 SI or DI

For belt drive or direct connection. One bearing on each side supported by fan housing or on independent pedestals.

Arr. 4 SI

For direct drive. Impeller overhung on motor shaft. No bearings on fan. Motor mounted on base or supported by fan housing.

Drive and Motor Locations Would Need to be Coordinated with Available Space



Arr. 7 SI or DI

For belt drive or direct connection. Arrangement 3 plus base for motor.

Arr. 8 SI

For belt drive or direct connection. Arrangement 1 plus extended base for motor.

Arr. 9 SI

For belt drive. Impeller overhung, two bearings, with motor outside base.

Arr. 10 SI

For belt drive. Impeller overhung, two bearings, with motor inside base.

SWSI Fan Motors Would Likely Be Out of the Air Stream, Eliminating a Parasitic Load Some of the time Since Motor Heat Ends Up in the Return/Relief Air Stream

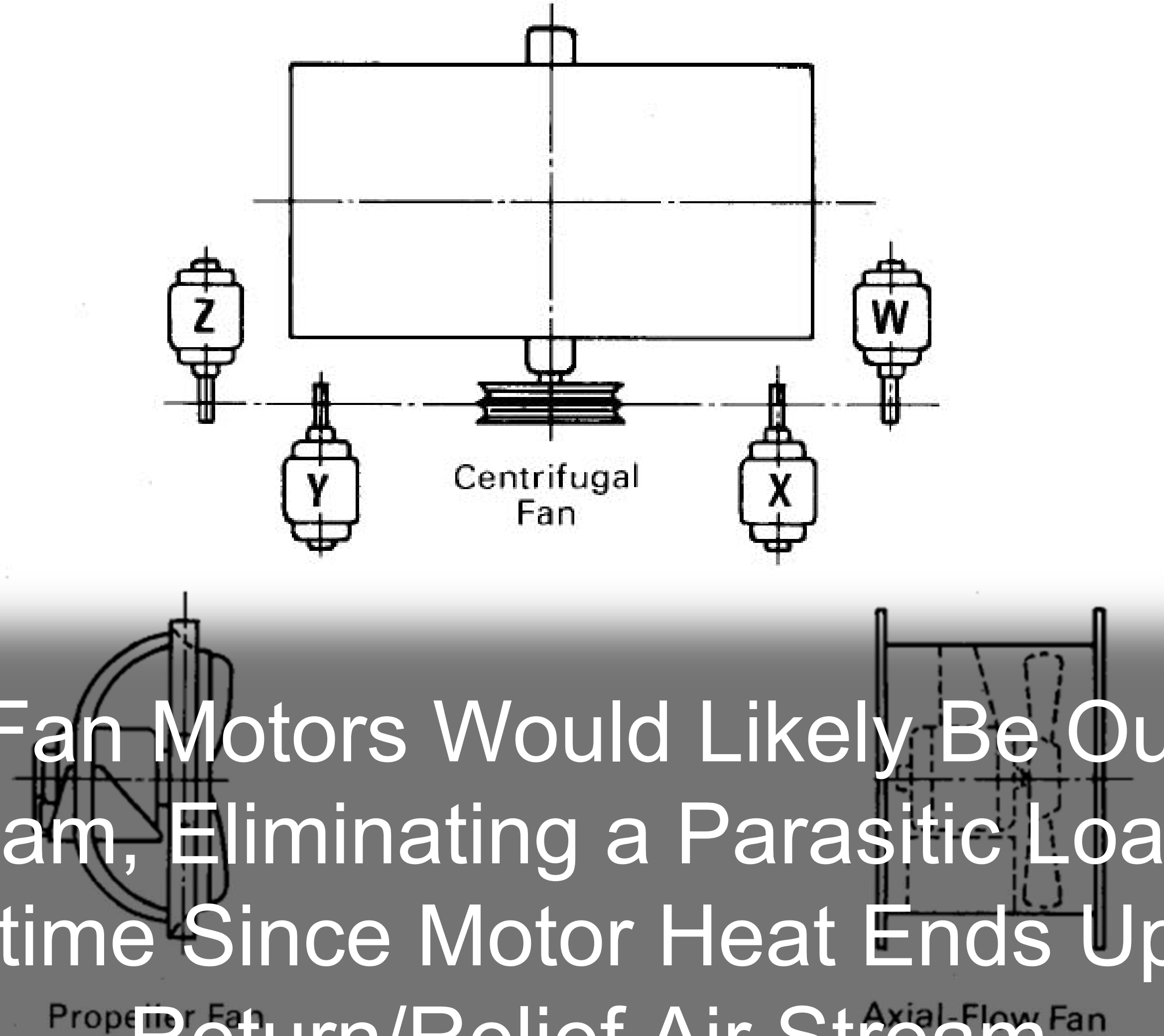
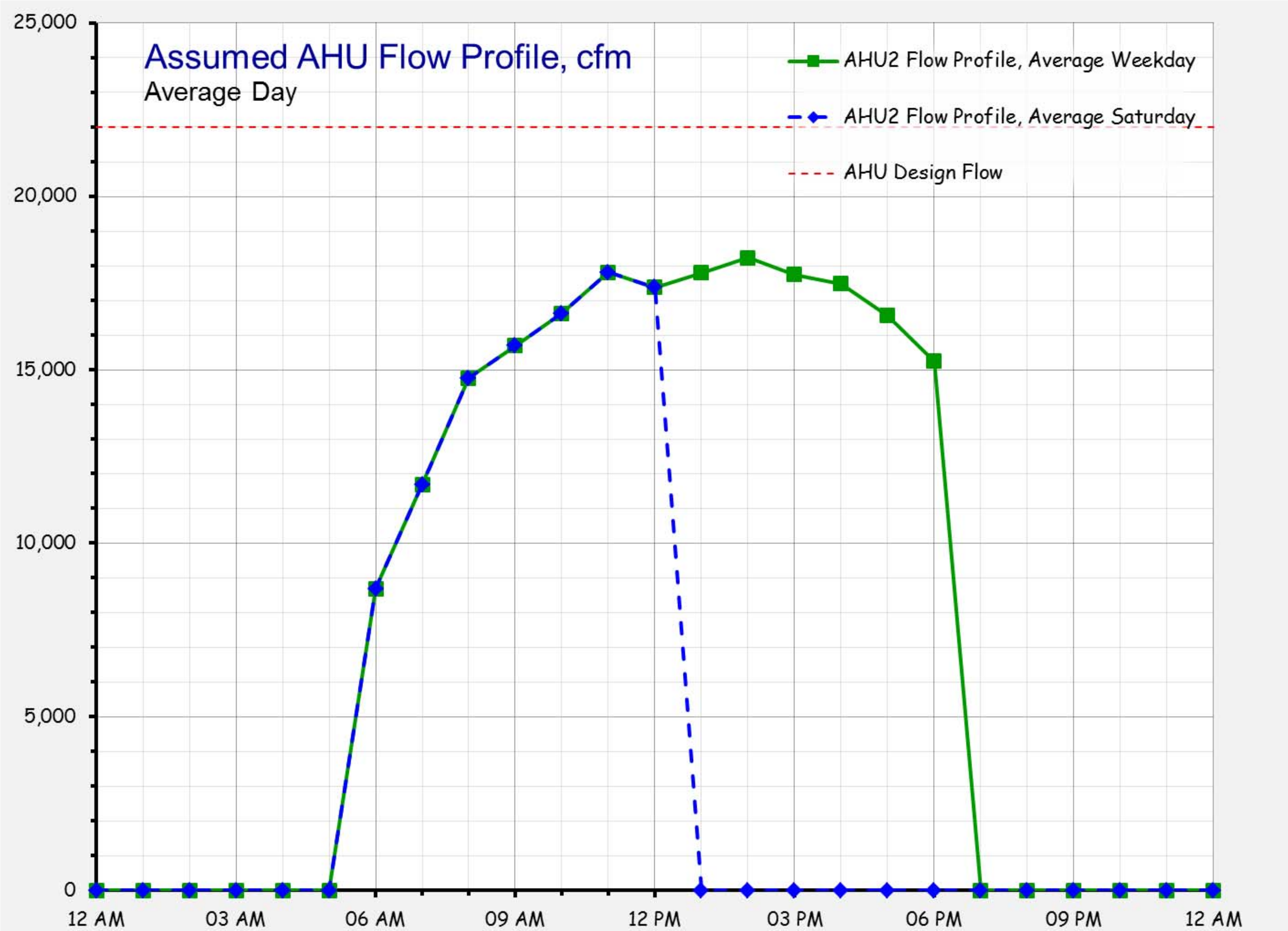


Figure 9.7 Standard Motor Positions

Adapted from the data of AMCA: "Motor Positions for Belt or Chain Drive Centrifugal Fans," AMCA Standard 2407-98, 1998.

Assessing Fan Energy Potential Savings

- Assume an average flow profile based on past data and ASHRAE handbook metrics
- Original fan efficiency based on the current air handling unit schedule
- New fan efficiency based on 2nd best fan selection for a SWSI fan operating at the same conditions
- Assume system static requirement follows the “square law”
- Capture motor efficiency vs. load from US Motor performance curves
- Assume well adjusted and maintain belts (98% efficient)
- Assume VFD efficiency losses are a flat number that will not vary significantly from one case to the other (94.3% based on DOE/Safetronics data for current technology drives)



Assumed AHU Flow Profile, cfm
Average Day
AHU2 Flow Profile, Average Weekday
AHU2 Flow Profile, Average Saturday
AHU Design Flow
25,000
20,000
15,000
10,000
5,000
0
12 AM
03 AM
06 AM
09 AM
12 PM
03 PM
06 PM
09 PM
12 AM

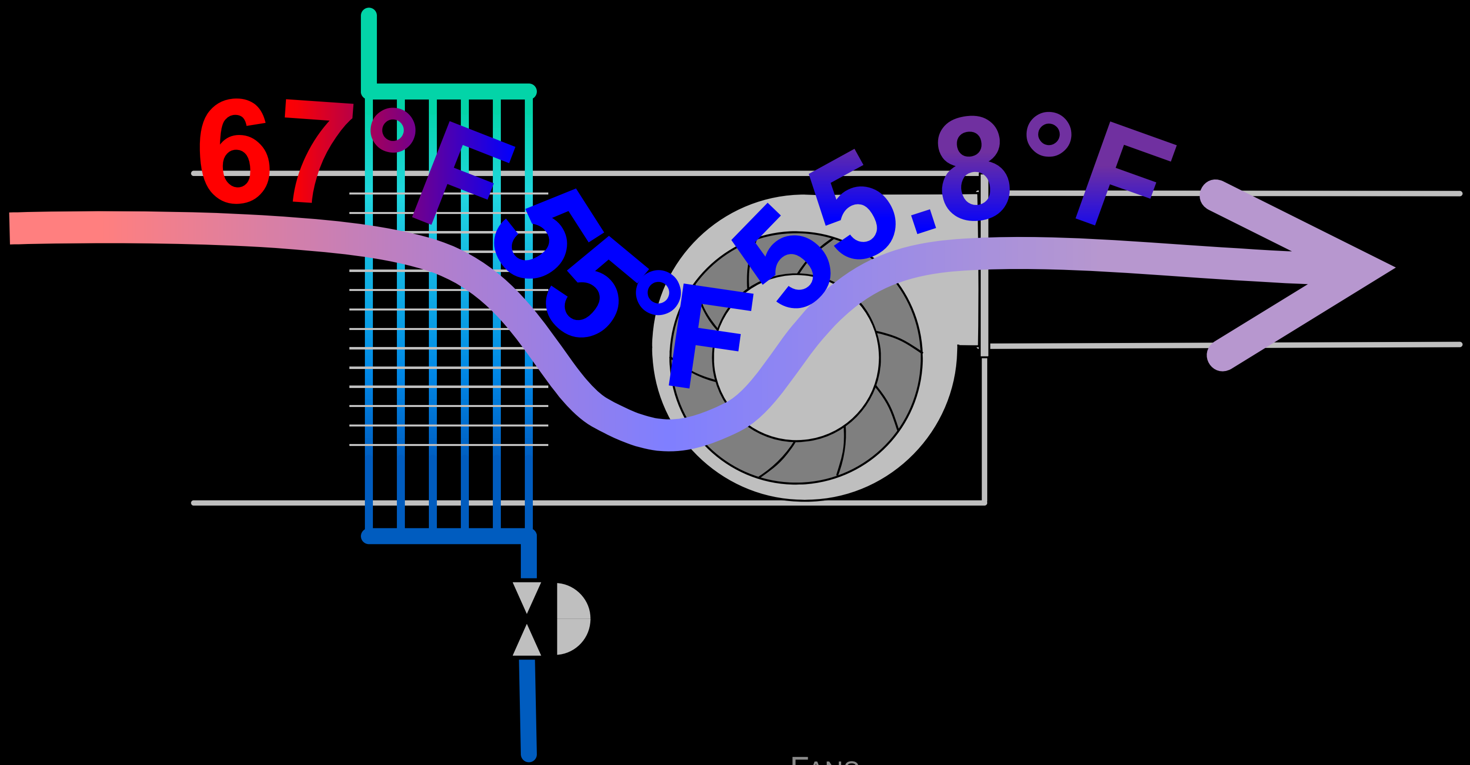
Fan Energy Savings Projection Results

AHU 2 System Type, 8 Similar Building Modules

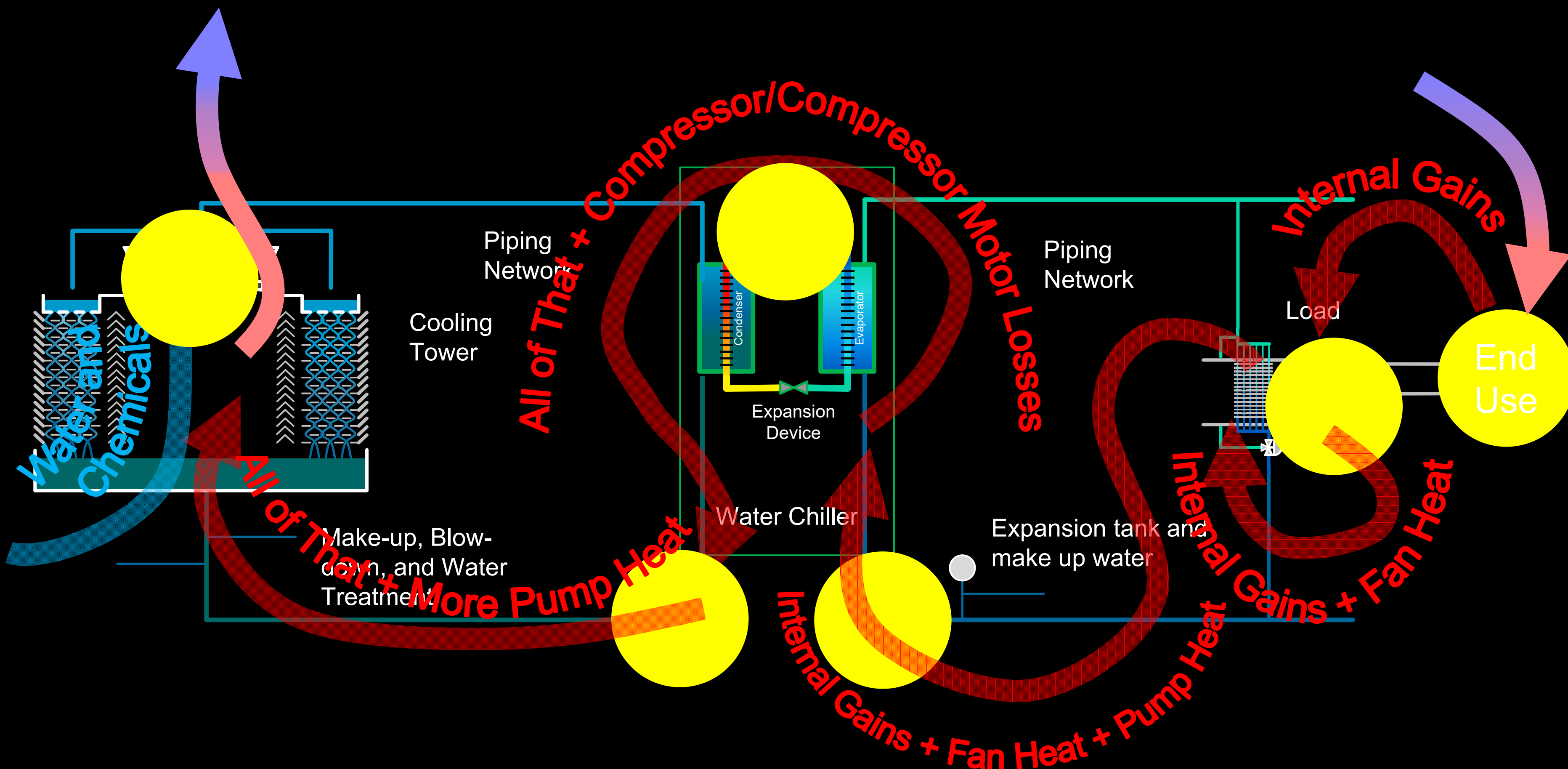
AHU System Type Fan Energy Savings			
Weekday -	143	kWh	
Weekend -	19	kWh	
Total for a week -	162	kWh	
	Low End	High End	
Total for a year -	7,587	8,430	kWh
Assumed electric rate -	$0.1000	$0.1500	per kWh
Annual savings potential -	$759	$1,265	per system
AHU 2 Systems per wedge -	7	7	
Savings per wedge -	$5,311	$8,852	
Number of wedges -	8	8	
Total savings for AHU2 system type -	$42,488	$70,814	

But Wait, There's More!

Fan energy shows up as a temperature rise across the fan due to the work the fan is doing on the air; a phenomenon identified by Willis Carrier and termed "fan heat"



But Wait, There's More



The energy associated with handling the fan heat ripples back through the central plant and is compounded by the various equipment inefficiencies

Fan Heat Savings Projection Results

AHU 2 System Type, 8 Similar Building Modules

AHU 2 Fan Heat Savings			
Fan heat saved for the year -	7,155	kWh (Based on fan energy savings with out the VFD losses since the VFD is not in the supply air stream, just the return air stream and the losses will go out with the relief air a lot of the time)	
	24,419,027	Btu	
Derate the savings potential by the number of hours when the systems would not be operating on an economizer cycle			
Hours per year -	8,760		
Hours per year when on economizezr cycle -	6,473	2009 - 2012 average from climate analysis spreadsheet	[Natural Ventilation v2.xlsx]()
AHU 2 design LAT -	51.5	°F (from fan schedule)	
Assumed drybulb based economizer change-over temperature -	70	°F (Engineering judgement based on Bay Area experience)	
Hours per year above 51.5 °F -	2,808	Hours when the system would have been driven to 100% outdoor air, from bin data, 9 am to 5 pm bin only	
Hours per year above 70 °F -	822	Hours when the system would have been returned to MOA, from bin data, 9 am to 5 pm bin only	
Hours per year below 51.5 °F -	113	Hours when the system be on less than 100% OA using the economizer process, from bin data, 9 am to 5 pm bin only	
Hours per year on 100% outdoor air -	1,986	Hours when motor heat would go out the relief system	
Hours per year when air is recirculated -	935	(fan and motor heat are a chilled water or economizer load)	
Total hours in 9 am to 5 pm bin -	2,921		
% of hours with recircuilation and chilled water cooling -	822	(hours when fan heat shows up as a coil load)	
	28%		
Derated fan heat -	6,871,770	Btu	
-	573	Ton-hours	
Plant over-all kW per ton -	0.85	1.00	
Annual kWh savings from reduced fan heat -	487	573	per system
Annual $ savings from reduced fan heat -	$49	$86	per system
AHU 2 Systems per wedge -	7	7	
Savings per wedge -	$341	$601	
Number of wedges -	8	8	
Total savings for AHU2 system type -	$2,726	$4,810	

Another Energy Benefit

For a plenum fan, the motor and belts are in the air stream

- Motor and belt losses become a cooling load
  - Chilled water load when the cooling coil is active

For a SWSI fan, the motor and belts are out of the air stream

- No load at all if the mechanical room is unconditioned
- Load on the return side if it is a return plenum; discharged with relief air during economizer cycle

Motor Loss Savings Projection Results

AHU 2 System Type, 8 Similar Building Modules

Central Plant Savings from AHU 2 Motors No Longer in the Air Stream			
Motor efficiency losses - Weekday	628,269	Btu	
Motor efficiency losses - Weekend	81,417	Btu	
Total for a week -	709,686	Btu	
Total for a year -	36,903,659	Btu	
% of hours when air is recirculated (see fan heat calc) -	28%	Use this as a derating factor for the savings associated with fan heat the motors no longer being in the air stream	
Derated motor efficiency savings -	10,385,076	Btu	
	865	Ton-hours	
Plant over-all kW per ton -	0.85	1.00	
Annual kWh savings from reduced fan heat -	736	865	per system
Annual $ savings from reduced fan heat -	$74	$130	per system
AHU 2 Systems per wedge -	7	7	
Savings per wedge -	$515	$909	
Number of wedges -	8	8	
Total savings for AHU2 system type -	$4,119	$7,270	

Savings Summary

Item	kWh		Dollars	
	Low End	High End	Low End	High End
Fan Energy Savings	424,882	472,091	$42,488	$70,814
Fan Heat Savings	27,258	32,068	$2,726	$4,810
Motor Heat Savings	41,194	48,464	$4,119	$7,270
TOTALS	493,334	552,623	$49,333	$82,893
Low end savings assessed at $0.10 per kWh; high end savings assessed at $0.15 per kWh				

Fan Walls

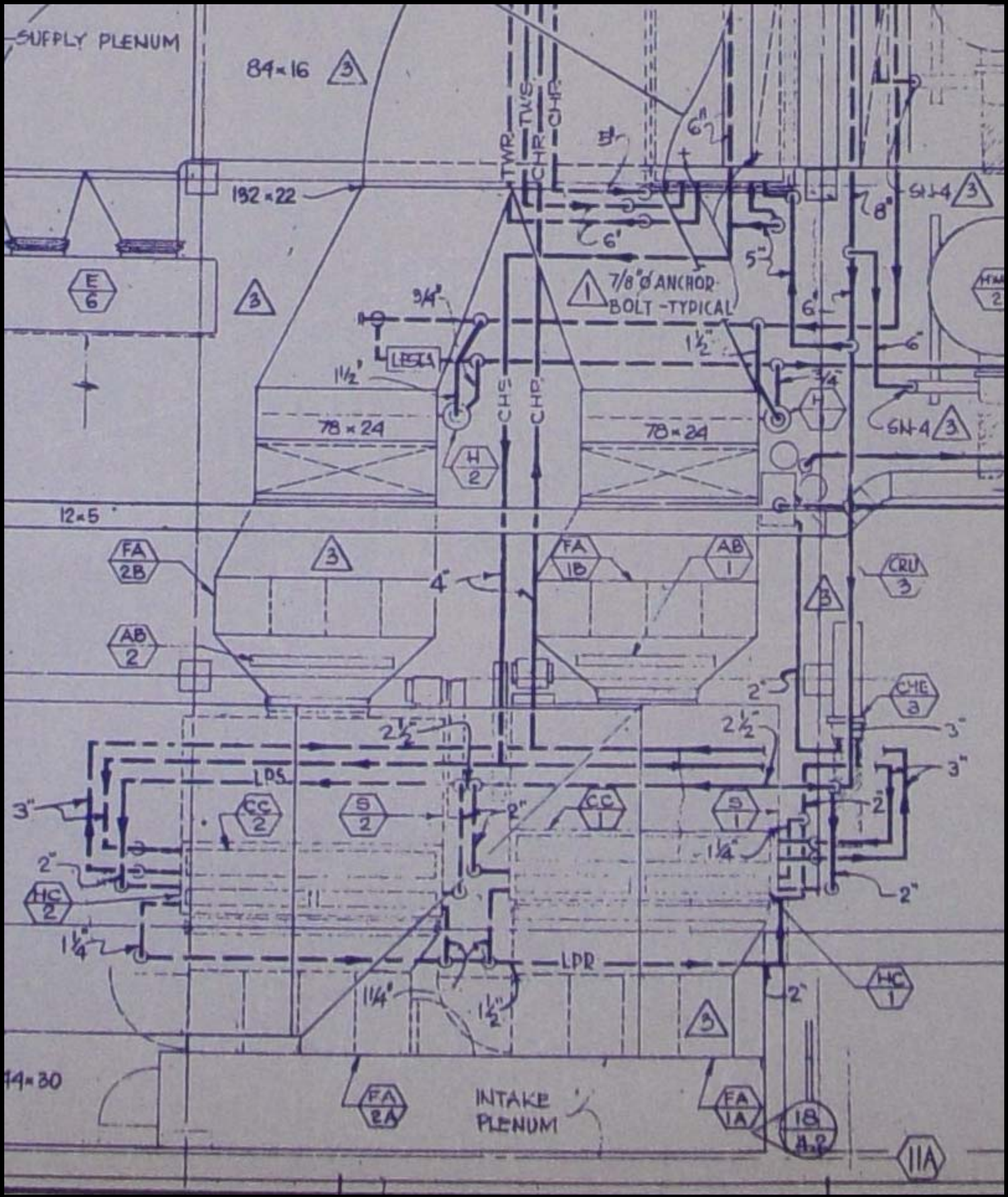
Not a Panacea

- Smaller fan wheels usually less efficiency than bigger ones
- Smaller motors usually less efficient than bigger ones
- Backdraft dampers = system effect
- Backdraft dampers = optional
- Multiple motors on one VFD
  - Possible application issue
  - Possible motor circuit protection issue
  - Possible reverse spinning motor start issue

Fan Walls

A Tool in the Efficiency Tool Box

- Existing fan selection at 60% efficiency
- Poor discharge conditions
  - Manual backdraft damper
  - Air blender
  - Short diffuser/evase’
- Fans run round the clock
- Mission critical application; redundancy important
- System turn-down potential during unoccupied hours



Fan performance optimization

Specify in terms of fundamentals

- Flow
- Fan total or static pressure
- Maximum bhp
- Minimum fan efficiency
- Minimum motor efficiency
- Minimum motor power factor
- Maximum motor speed

Allow the manufacturers to exploit their technology

Get What you Asked For

If you *<u>don't</u>* need it, *<u>don't</u>* specify it

If you *<u>do</u>* need it, *<u>enforce</u>* the specification requirement

Require shop drawings

- Standard catalog data – A good *<u>starting</u>* point
- Fan performance curves
- Motor performance curves
- Seismic qualification certification statement
- Documentation of special features and requirements
- Require O&M data upon approval of shop drawings for commissioning support

Review shop drawings

Fan Efficiency Is Only Part Of The Equation

The fan's characteristics need to be matched to the system's requirements

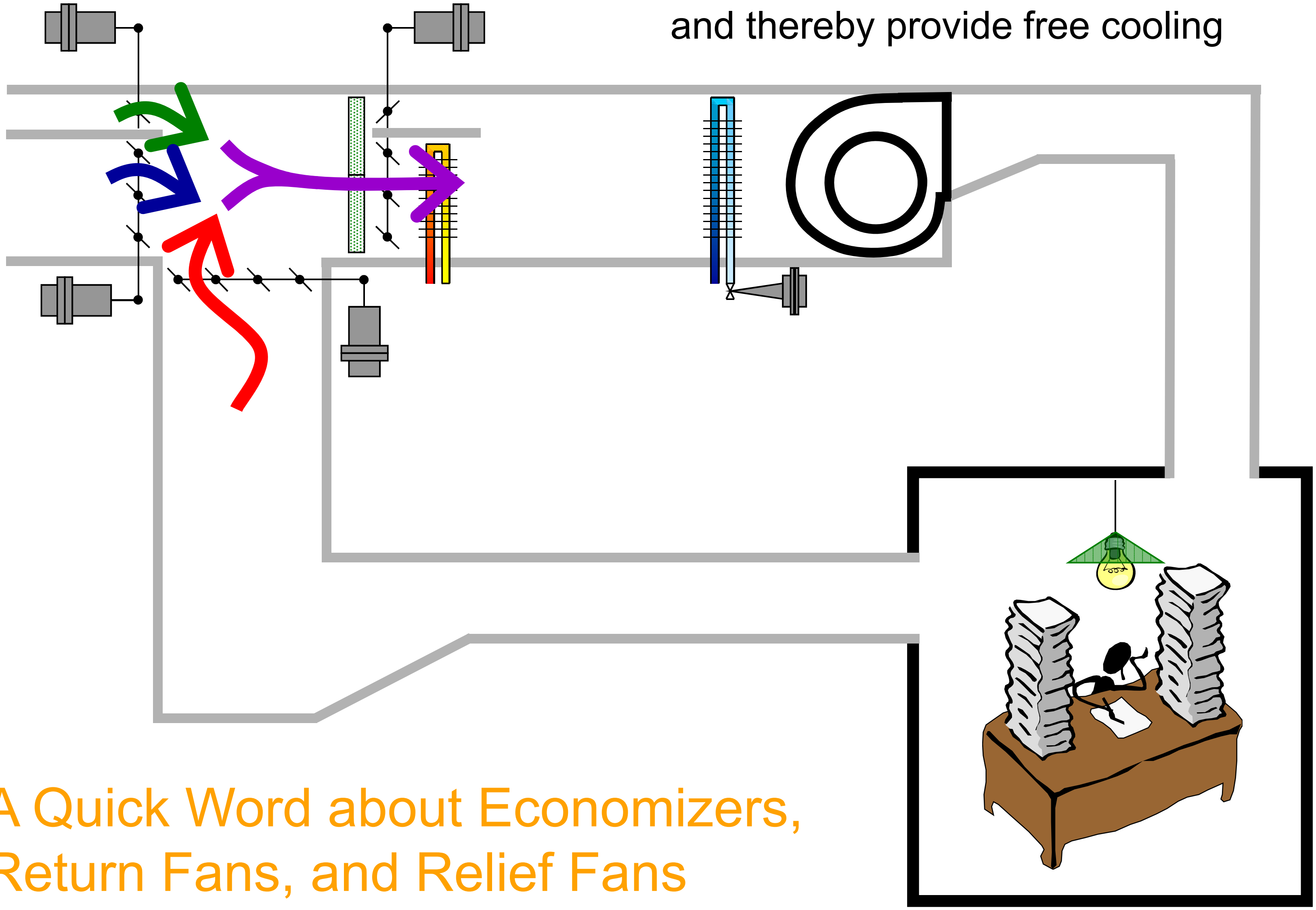
The air handling unit components need to be optimized to the application

Distribution efficiency is critical

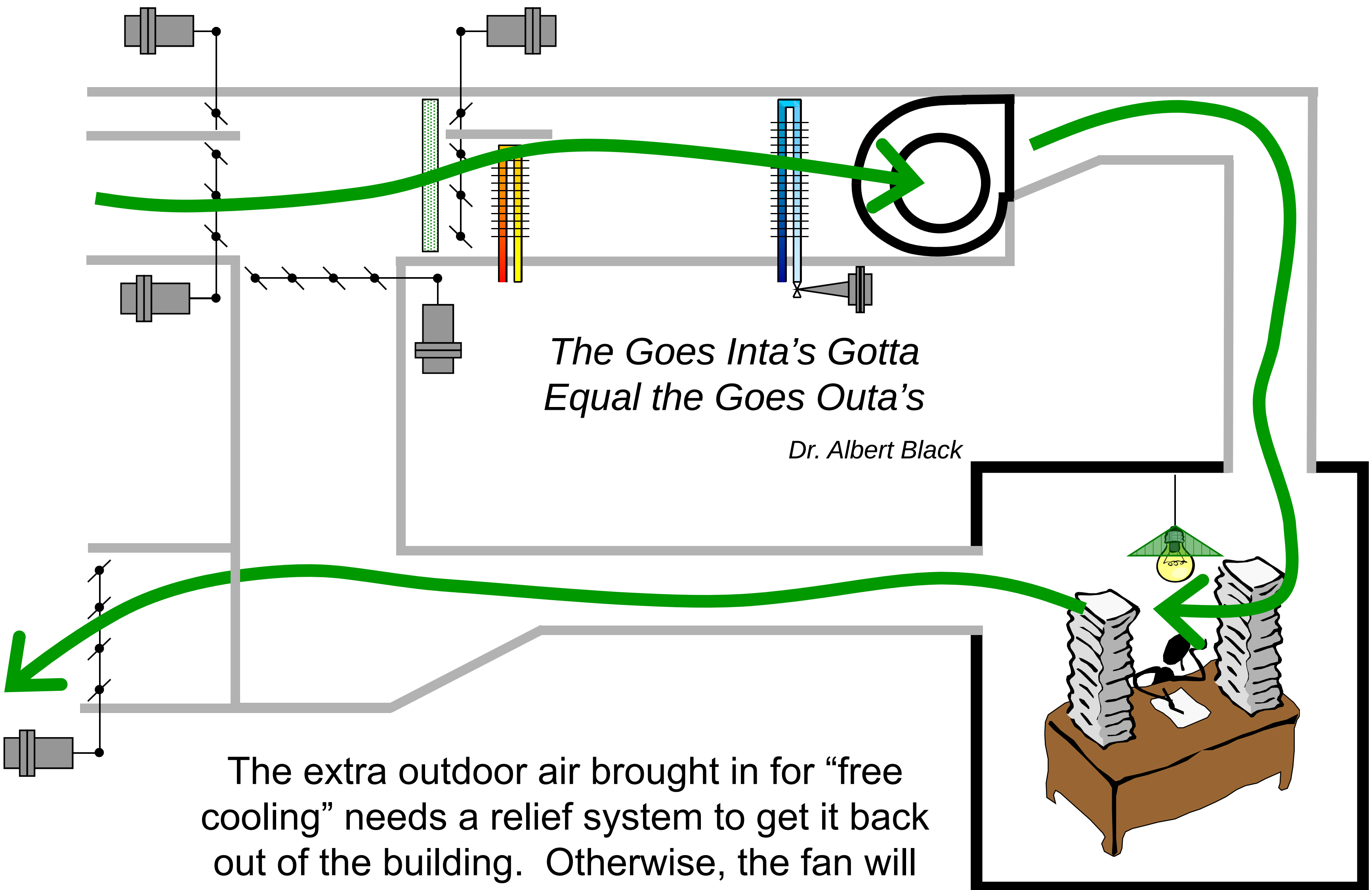
The air handling system needs to be tuned to the actual operating requirements

- Flexible, robust design
- Commissioning
- Training

Economizers bring in outdoor air above and beyond the ventilation requirement, mix it with return air as required to control set point and thereby provide free cooling



A Quick Word about Economizers, Return Fans, and Relief Fans



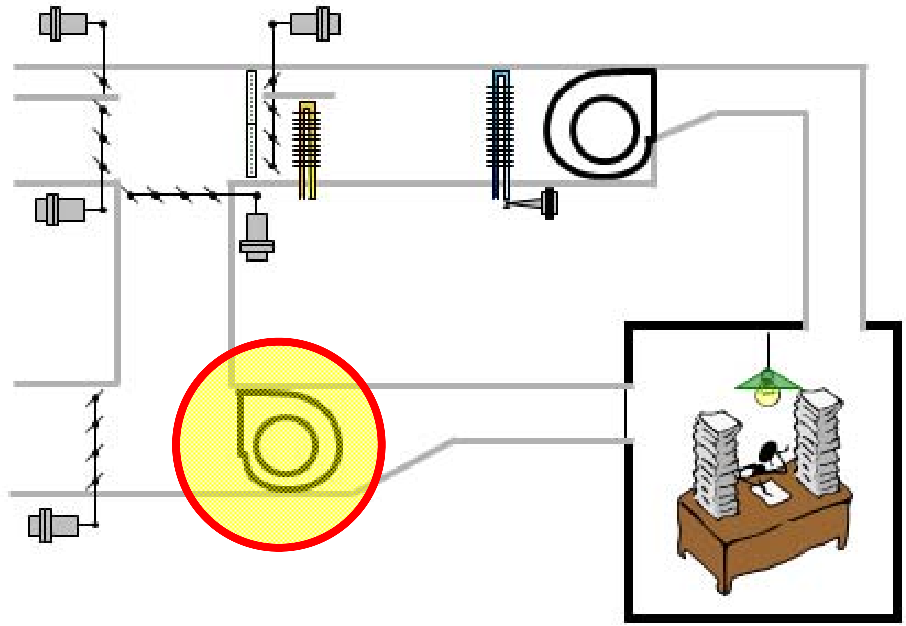
The extra outdoor air brought in for "free cooling" needs a relief system to get it back out of the building. Otherwise, the fan will pressurize the building but move no air

Return Fans

Overcome the static pressure loss *between the zone and the air handling system*

Operate any time the supply fan runs

- Return air for recirculation
- Frequently, deliver air to the relief louver for discharge to the exterior when operating on an economizer cycle



Relief Fans

Overcome the static pressure loss *between the air handling unit location and the relief louver*

- Only operate during an economizer cycle
- VFD operation often coordinated with building pressure