COMPRESSED AIR BEST PRACTICES
airbestpractices.com

How to Size VSD Air Compressors

Sponsored by

Atlas Copco

Tim Dugan, P.E., *Compression Engineering Corporation*
Keynote Speaker

For your free subscription, please visit
www.airbestpractices.com/magazine/subscription.

COMPRESSED AIR BEST PRACTICES
airbestpractices.com

How to Size VSD Air Compressors

Tim Dugan, P.E., *Compression Engineering Corporation*
Keynote Speaker

The recording and slides of this webinar will be made available to attendees via email later today.

PDH Certificates will be e-mailed to Attendees within two days.

Sponsored by

Atlas Copco

For your free subscription, please visit
www.airbestpractices.com/magazine/subscription.

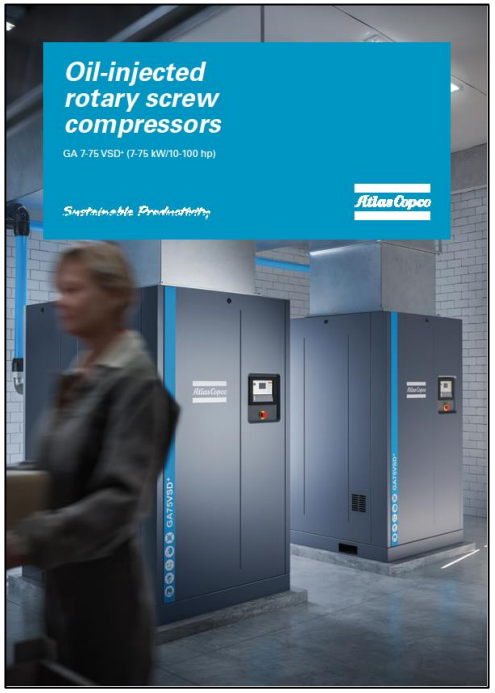
COMPRESSED AIR
BEST PRACTICES
airbestpractices.com

Handouts

COMPRESSION ENGINEERING CORPORATION

Engineering Services
2017

- **Energy analysis services:**
  For industrial compressed air, process vacuum, pneumatic conveying, process pumping, industrial process cooling and other similar electric motor-driven rotating machinery systems:
  - Walk-through and development of potential opportunities and solutions
  - Energy efficiency measure selection
  - Data-logging
  - Data-reduction
  - Analysis and simulation
  - Project budgeting
  - Report writing
  - Peer review
  - Commissioning
  - Inspection
  - Re-tuning/re-commissioning
  - Energy management
- **Project technical services:**
  - Control system specification
  - P&ID development
  - Equipment layout and piping design
  - Ventilation design
  - Submittal review
  - Commissioning
- **Miscellaneous services:**
  - Performance testing
  - Tuning and re-tuning
  - Leak assessments
  - Remote monitoring of key performance indicators
  - Project management
  - System start-up assistance and trouble-shooting
  - Standards and procedures development
  - Training



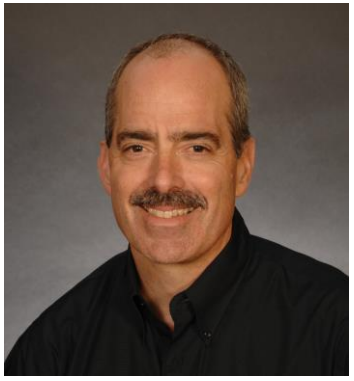
COMPRESSED AIR
BEST PRACTICES
airbestpractices.com

All rights are reserved. The contents of this publication may not be reproduced in whole or in part without consent of Smith Onandia Communications LLC. Smith Onandia Communications LLC does not assume and hereby disclaims any liability to any person for any loss or damage caused by errors or omissions in the material contained herein, regardless of whether such errors result from negligence, accident, or any other cause whatsoever.

All materials presented are educational. Each system is unique and must be evaluated on its own merits.

COMPRESSED AIR
BEST PRACTICES
airbestpractices.com

About the Speaker



Tim Dugan, P.E.
Compression Engineering Corp.

- President and Principal Engineer of Compression Engineering Corporation

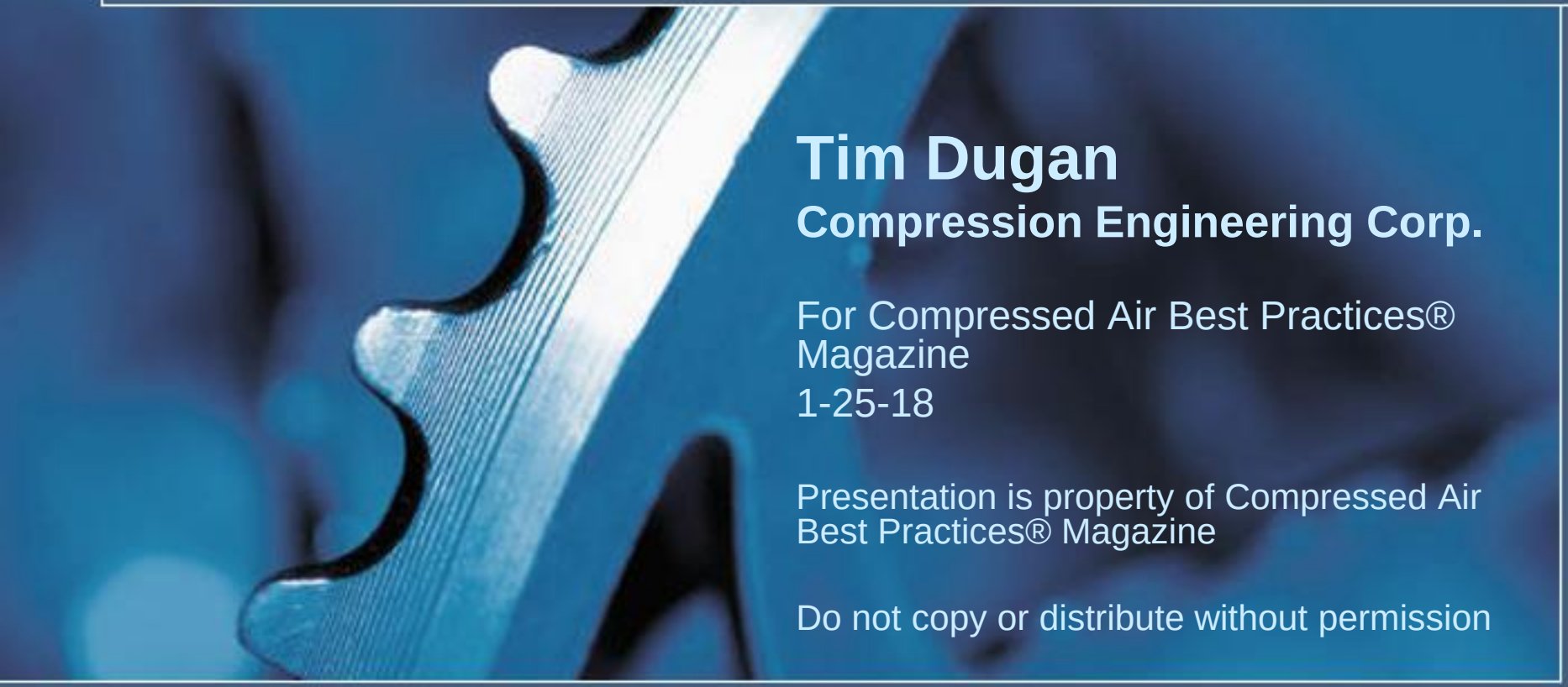
- Over 25 years of experience in the industry

Sponsored by

Atlas Copco

For your free subscription, please visit
www.airbestpractices.com/magazine/subscription.

How to Size VSD Air Compressors



Tim Dugan
Compression Engineering Corp.

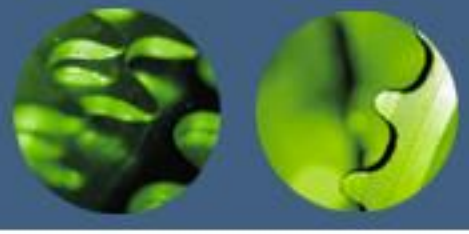
For Compressed Air Best Practices® Magazine
1-25-18

Presentation is property of Compressed Air Best Practices® Magazine

Do not copy or distribute without permission

Outline

- Why Install a Single VSD Compressor
- Data-Logging Flow
- Analyzing Flow Data, 2 Examples
- Matching Compressor to Data



Why Install a VSD Compressor

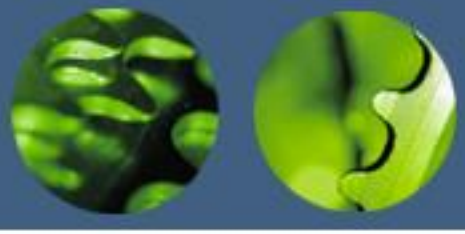
- All Systems Have Flow Variance
- All Systems Should have a “Trim” Compressor, to Follow the Typical Variance.
- Trim Compressor Technologies Include Variable Speed (VSD), Variable Displacement, Start-stop, and Load-unload.
- A Very Efficient Mode of Part-load Control For Lubricated Screw Compressors is Variable Speed.
- If Flow Changes at Least 50% of Time, VSD is a Good Option.

Data-logging Flow

- Method 1: Flow Metering
- Method 2: Amp-logging and Calculate Flow
- Flow Metering is More Accurate, Less Complicated Analysis, & Fewer Arguments
- Amp-logging is Less Intrusive, no Shut-down or Hot-tap Required

Data-logging Flow

- If You Flow Meter, Put One Meter After Your Dryer, Thermal Mass Recommended
- If You Amp log, Measure All Compressors Concurrently, with Pressure
- Amp to Flow Correlation - Depends on Compressor Controls
- Amp / Pressure Scatter Plots to Confirm Controls
- Flow Calculation Column
- Log for at Least a Week, 1-minute Sample Rate or Finer (1/4 of Cycle Rate)



Metering Equipment

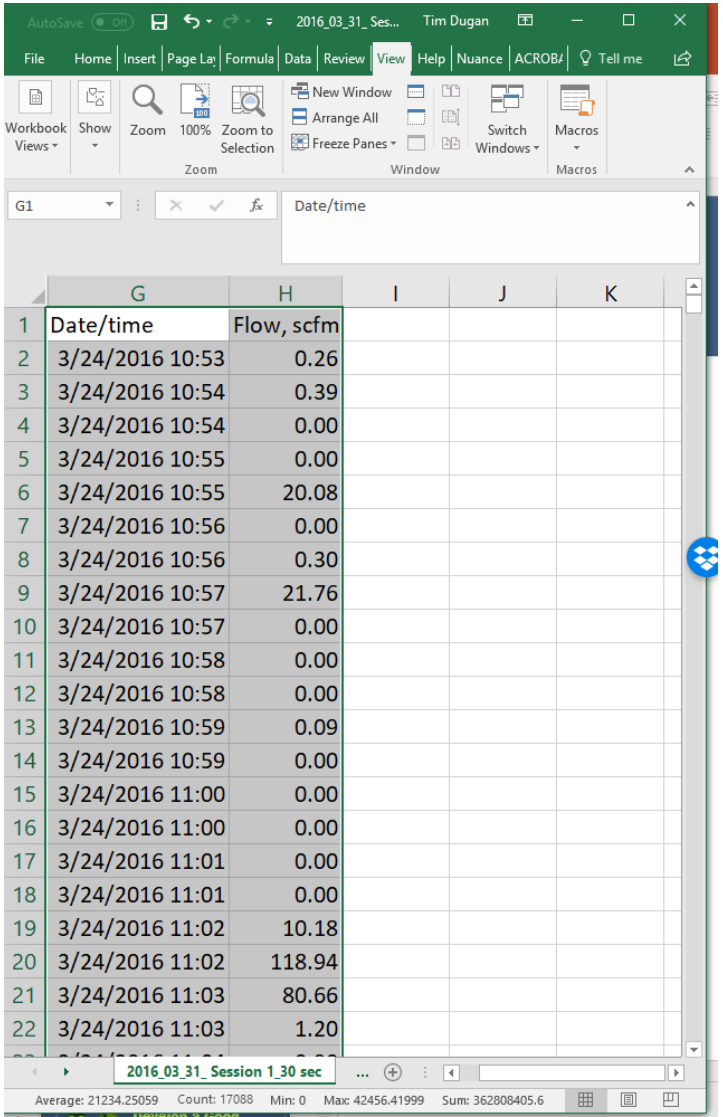
- Flow Metering:
- 1-2” Pipe: In-Line
- >2” Pipe: Insertion
- Thermal mass (cheaper), After Dryer(s)
- DP, Vortex, and Other Types for Before Dryers
- Clamp-on Meter, Thermal Mass

Metering Equipment

- Current Metering:
- Clamp-on CTs for All Compressors
- Discharge Pressure Transducer
- Data Logging:
- 4-20mA Loops
- Data Logger
- Some Flow Meters Data-log Internally

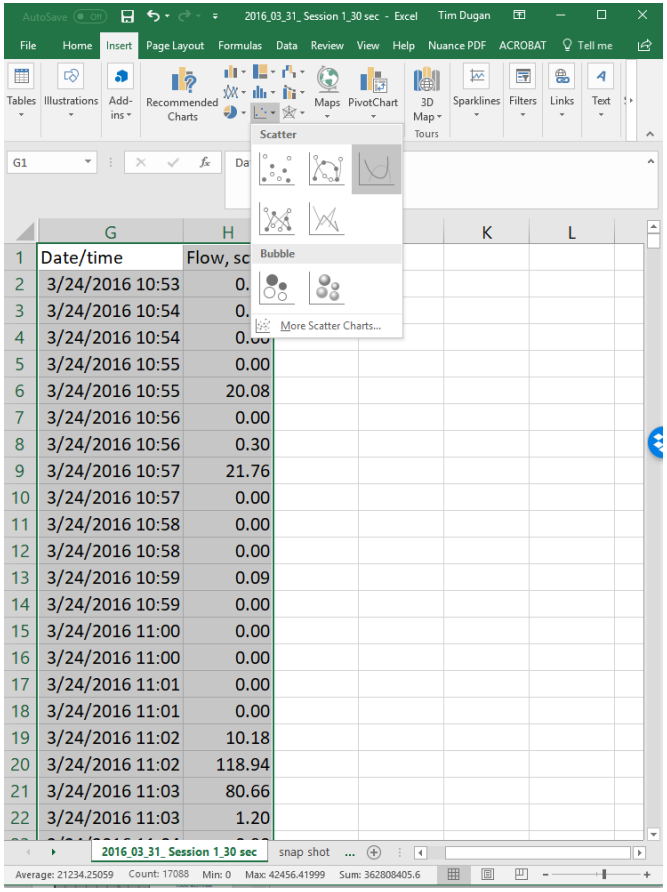
Simplified Analysis – Example 1, Low Flow

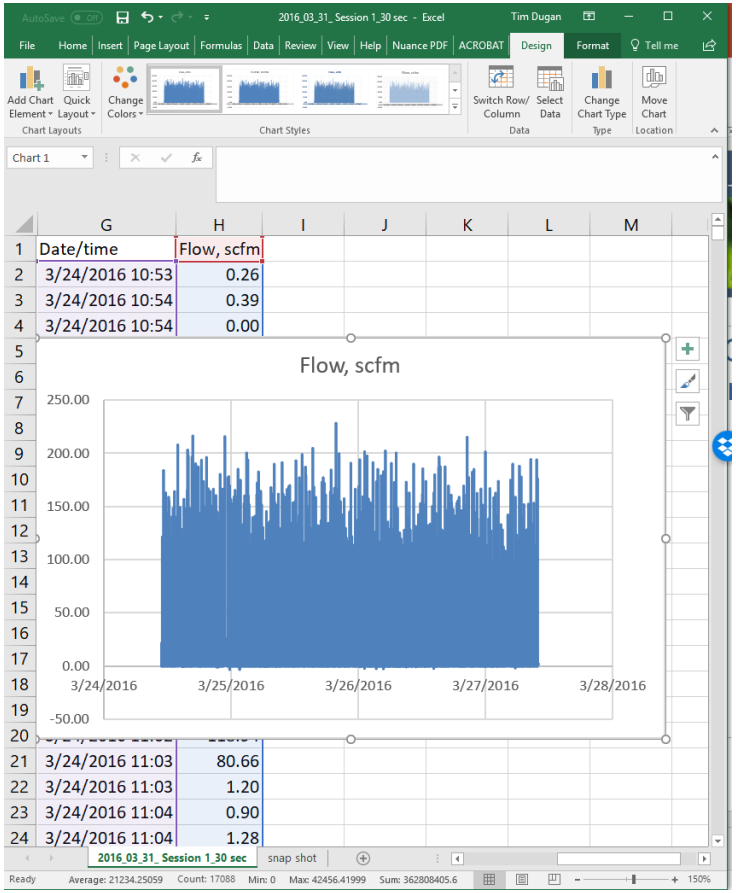
- Open the ".csv" File in Excel
- Click on Date/time Header.
- Shift-Arrow to Right to Highlight Top of Flow Column.
- Shift-Ctrl-Arrow Down to Highlight All Time/Date & Data



Example 1 - Ctd

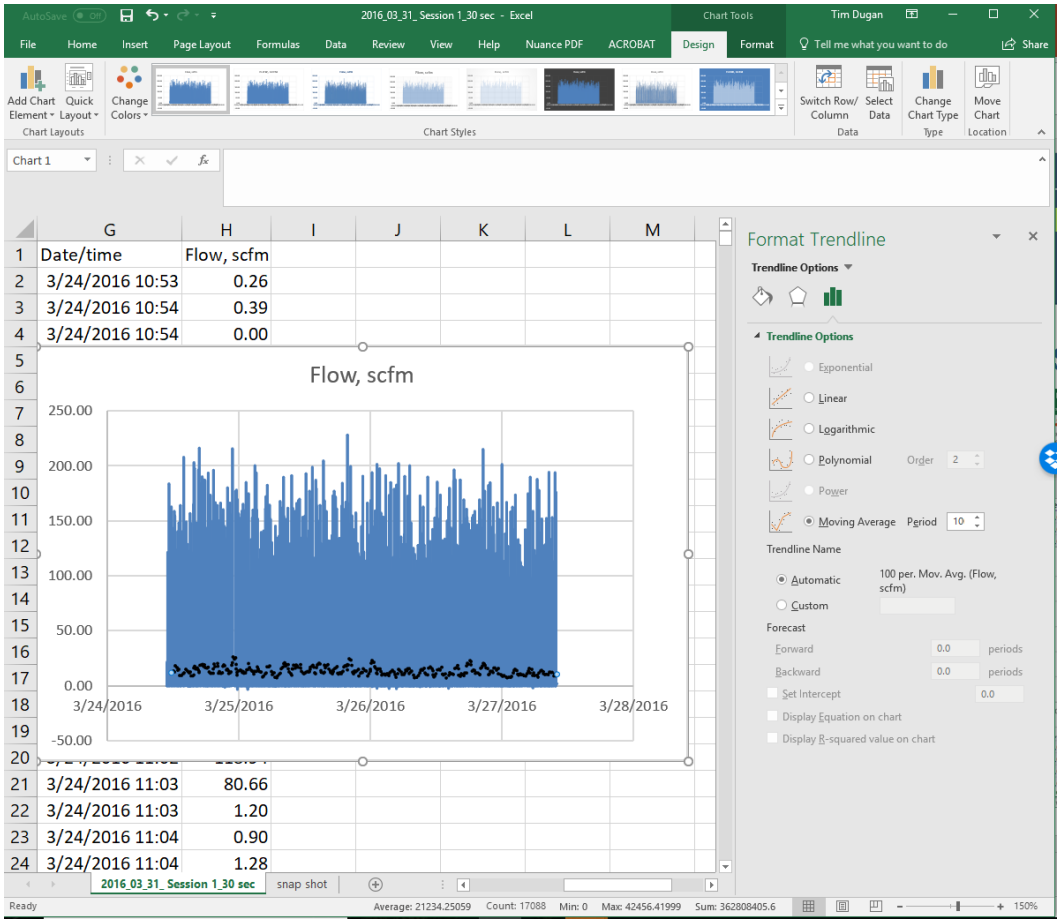
- Insert Chart – Scatter With Smooth Lines



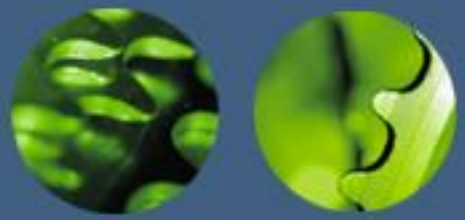


Example 1 - Ctd

- Insert Trendline – Moving Average (Make it Black)



	G	H
1	Date/time	Flow, scfm
2	3/24/2016 10:53	0.26
3	3/24/2016 10:54	0.39
4	3/24/2016 10:54	0.00
21	3/24/2016 11:03	80.66
22	3/24/2016 11:03	1.20
23	3/24/2016 11:04	0.90
24	3/24/2016 11:04	1.28

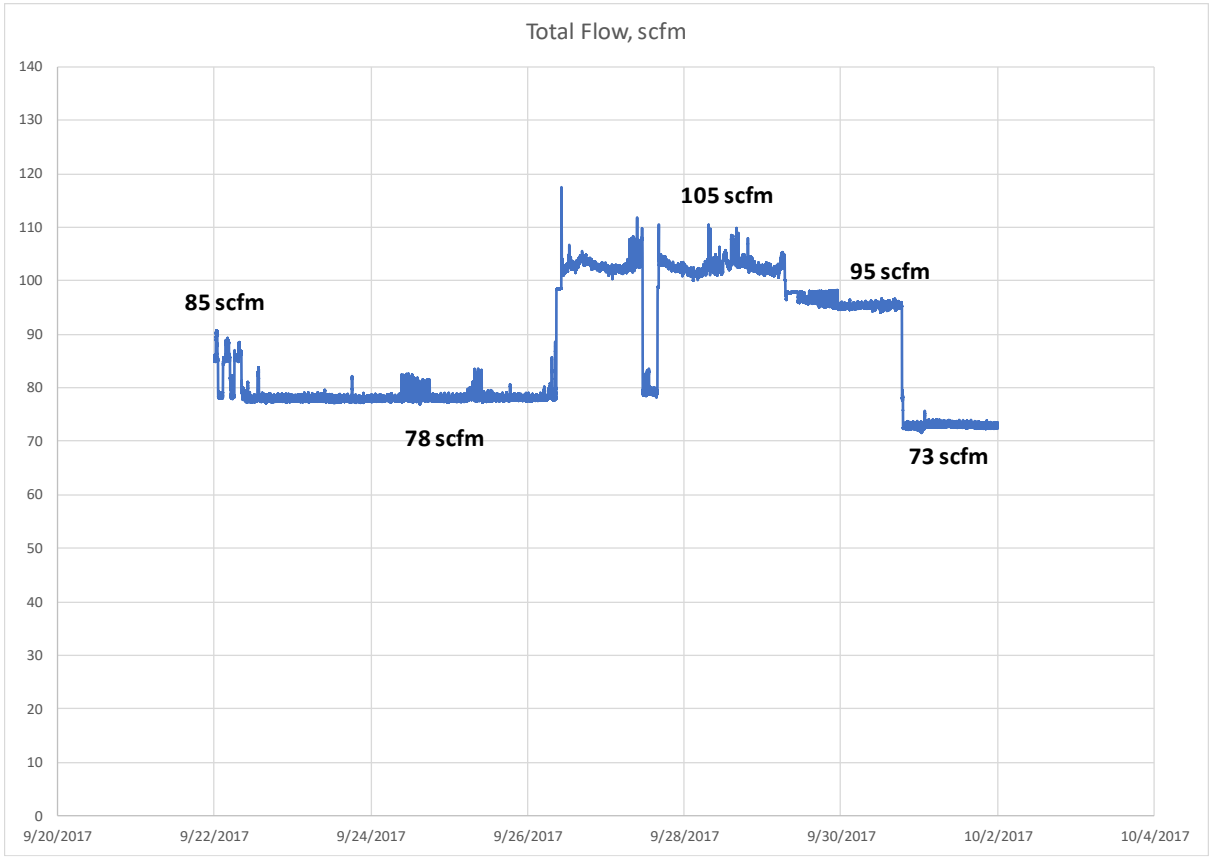


Conclusions, Example 1

- Original (& Anecdotal) Data Seemed to Indicate High Flow.
- Average Logged Data Shows Low, Flat Flow.
- Low Demand Scenarios Often Have an Unpredictable Peak.
- In This Case, Peak was Real, Infrequent, & Unknown Magnitude.
- Oversizing for Estimated Peak Would Put VFD Compressor at Min Load 99% of Time.
- *Not the Best Application for a Single VFD Compressor.*

Simplified Analysis – Example 2, 4 Bin Flow

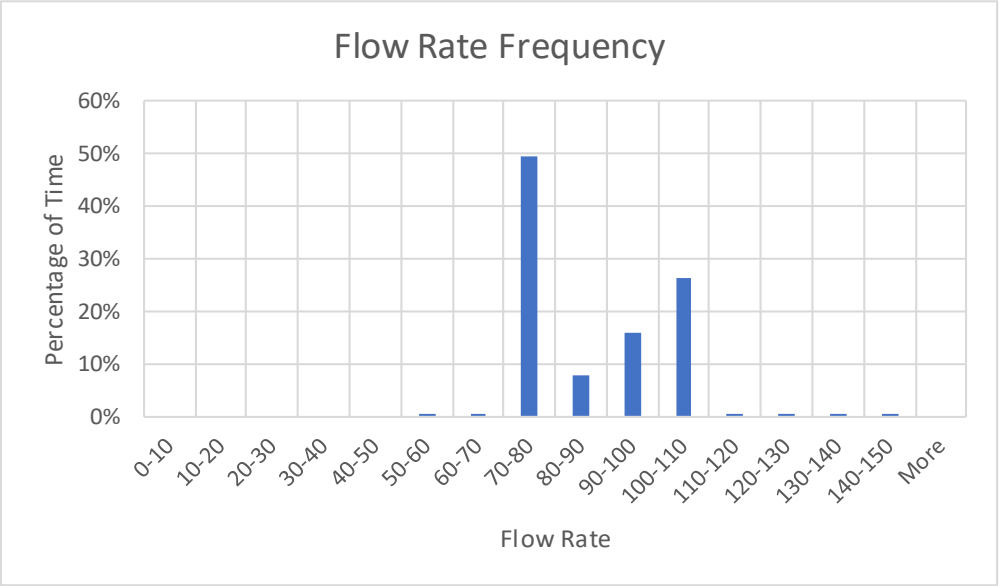
Date/time	Flow, scfm
9/22/17 12:02 AM	85.2
9/22/17 12:03 AM	85.2
9/22/17 12:03 AM	85.2
9/22/17 12:03 AM	85.2
9/22/17 12:03 AM	85.2
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.3
9/22/17 12:03 AM	85.2
9/22/17 12:03 AM	85.1
9/22/17 12:03 AM	85.1
9/22/17 12:03 AM	85.0
9/22/17 12:03 AM	85.0
9/22/17 12:03 AM	85.1
9/22/17 12:03 AM	85.2
9/22/17 12:04 AM	85.3
9/22/17 12:04 AM	85.3
9/22/17 12:04 AM	85.3
9/22/17 12:04 AM	85.2



Example 2, Ctd

- Perform “Bin Analysis”
- Get Excel Data Analysis ToolPak
- Create “Histogram” with “Bins”

Bin	*Frequency*	*% of Time*
0-10	0	0%
10-20	0	0%
20-30	0	0%
30-40	0	0%
40-50	0	0%
50-60	2	0%
60-70	1352	0%
70-80	142453	49%
80-90	21998	8%
90-100	45889	16%
100-110	75746	26%
110-120	544	0%
120-130	3	0%
130-140	2	0%
140-150	2	0%
More	9	

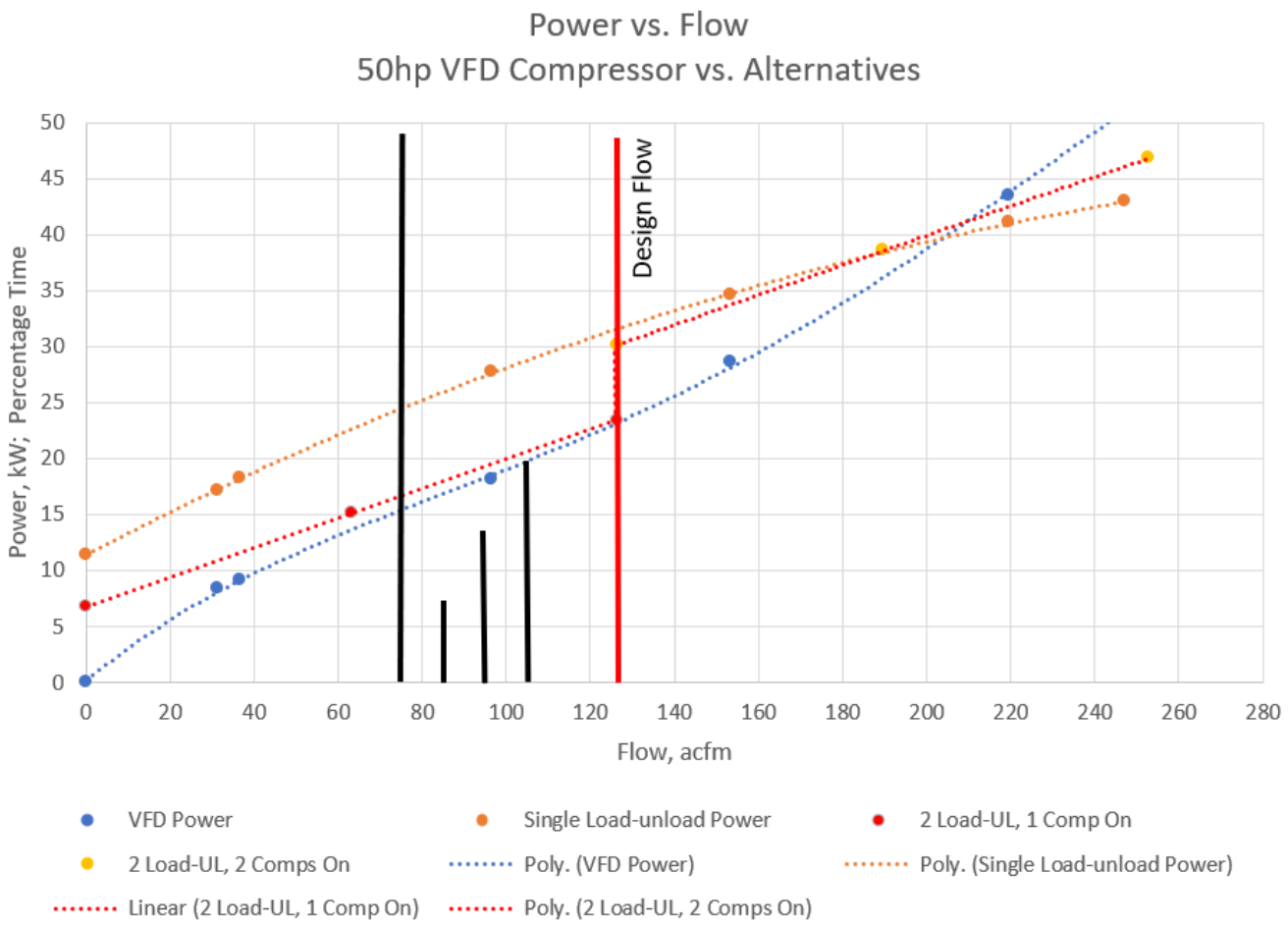


Matching Compressor to Data

- Try Larger One First, Then Reduce, Then Back Up
- In This Case, Start With 50hp, 250acfm
- Get Curve for VFD & Alternatives, or Use AirMaster™ https://energy.gov/eere/amo/articles/airmaster
- Place Predominant Flows on Curve
- Look at Relative Efficiencies at Predominant Flows
- Keep Headroom for Growth (at Least 20%)
- Try to be in “Sweet Spot” (30-80%)
- Avoid Prolonged Time at Min Speed Flow (or Below)

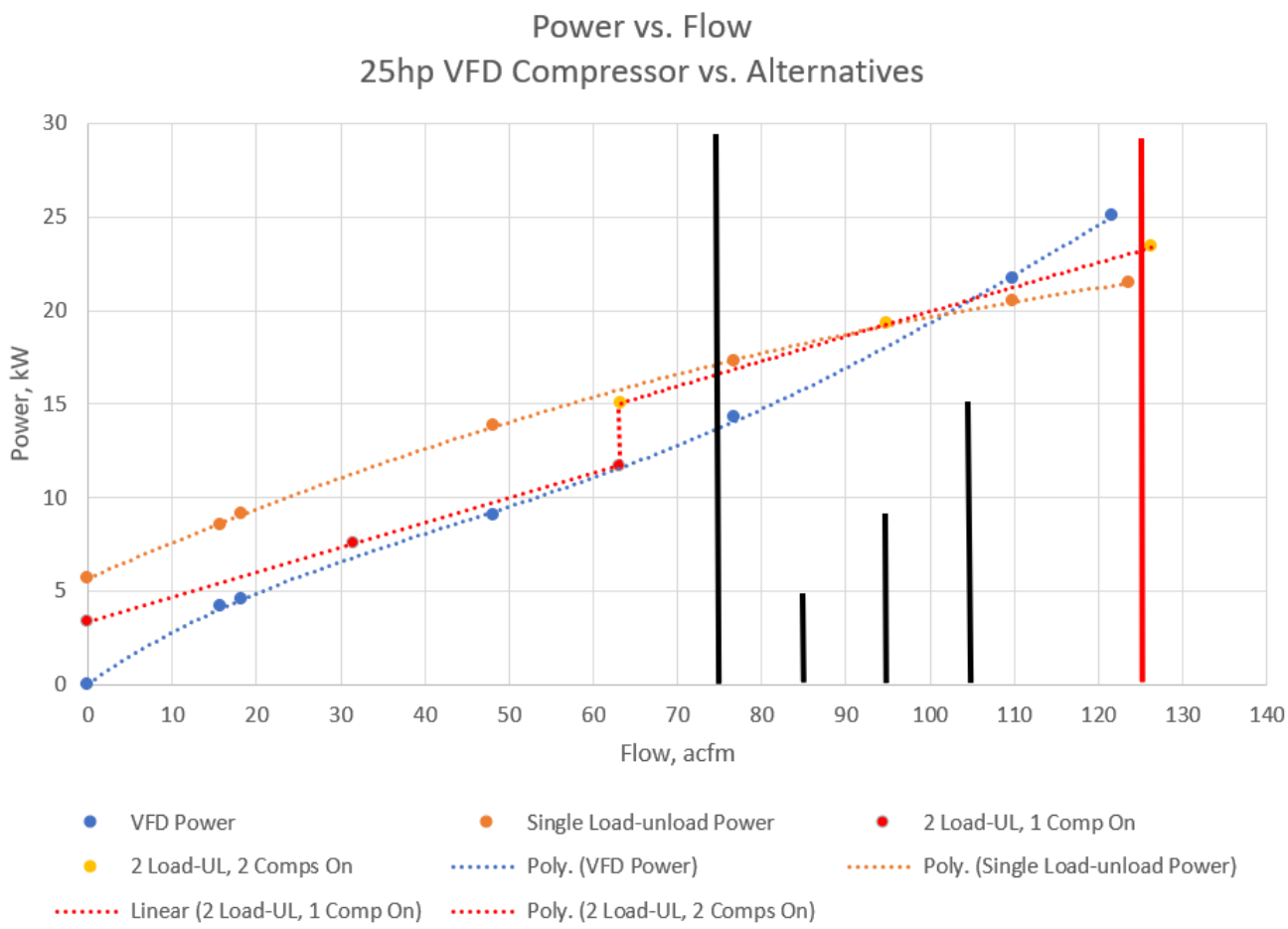
Matching Compressor to Data

- 50hp?
- Fairly Efficient
- Too Large



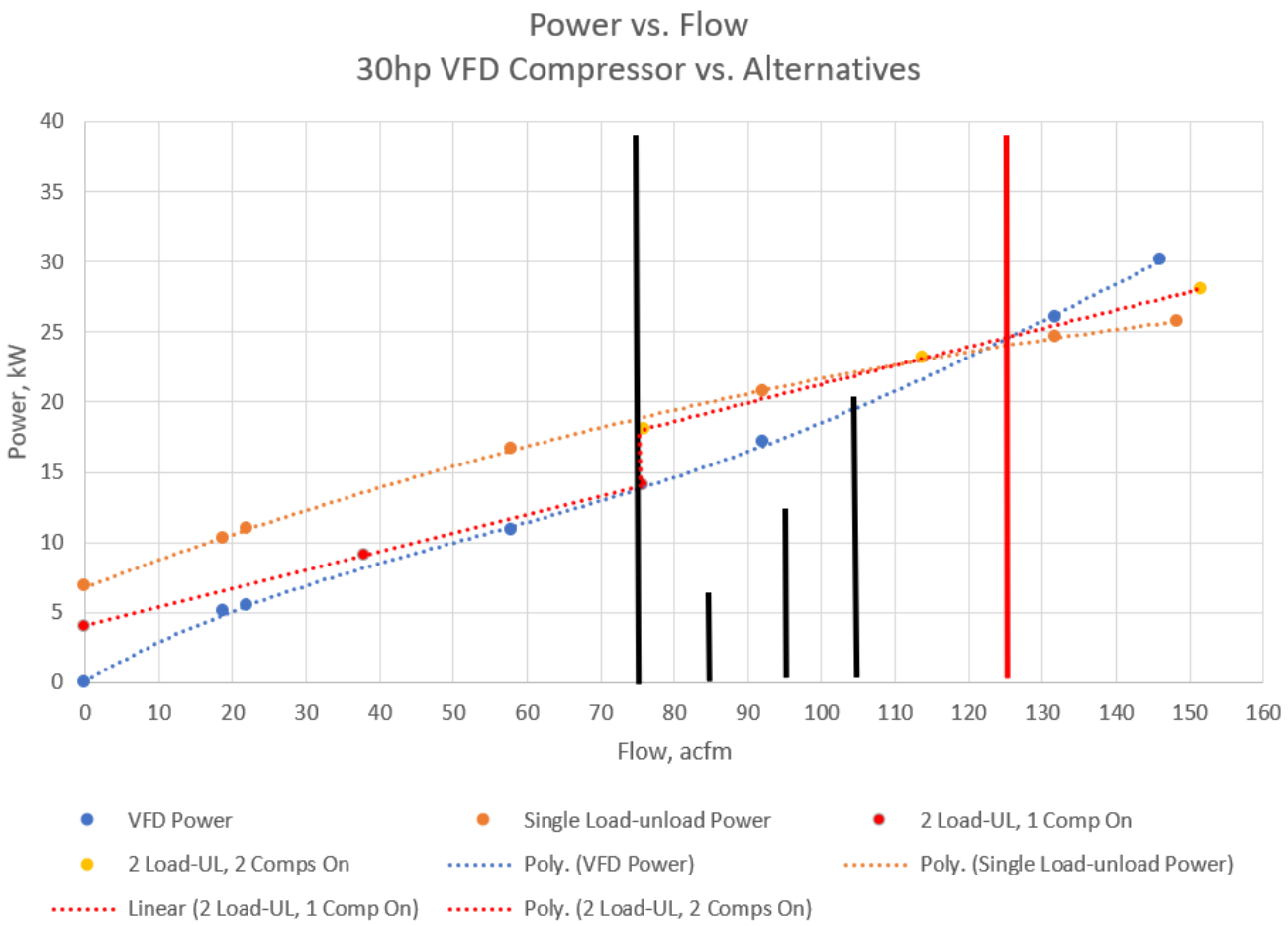
Matching Compressor to Data

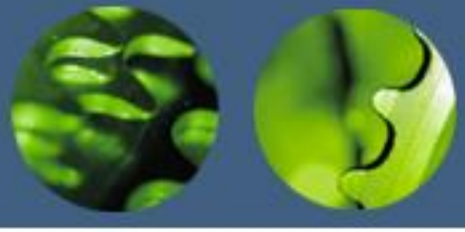
- 25hp?
- Very Efficient
- Too Small



Matching Compressor to Data

- 30hp?
- Very Efficient
- Just Right

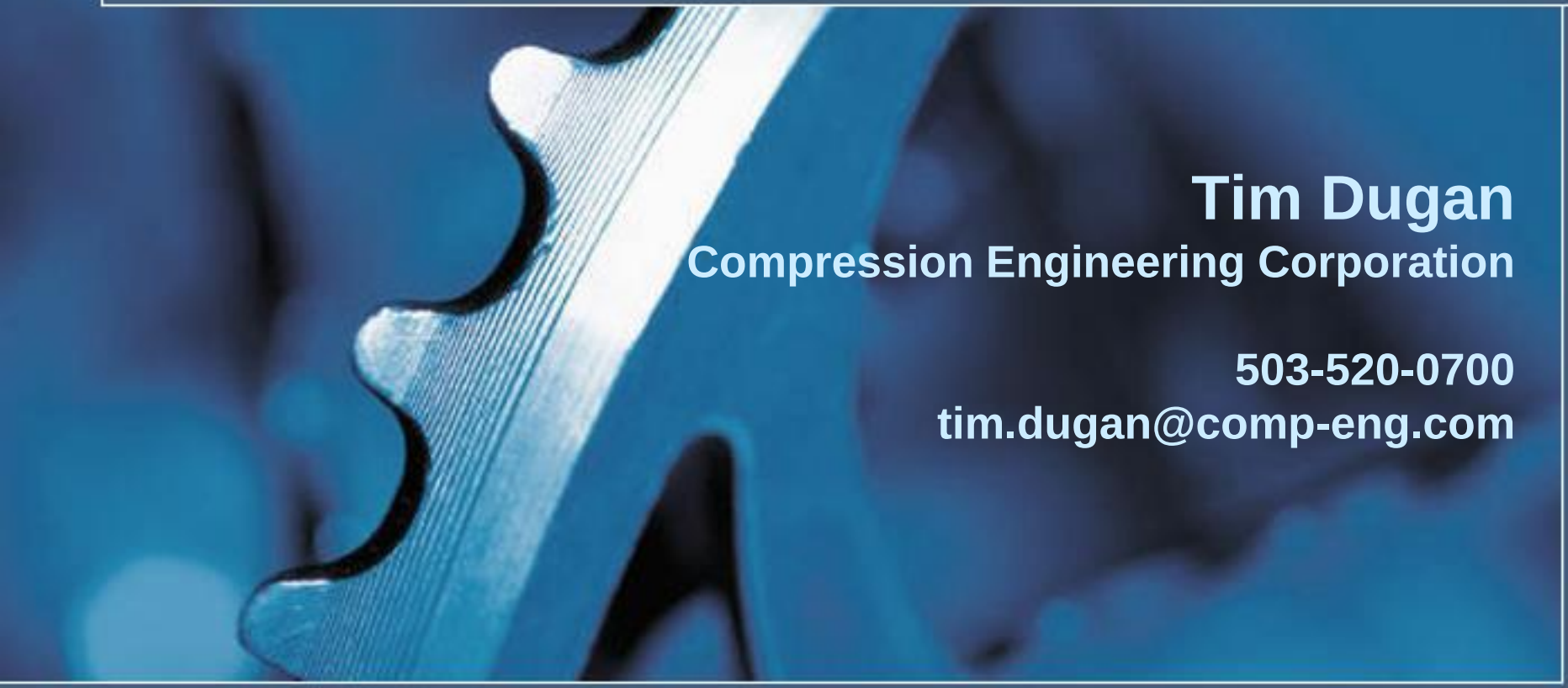




Conclusions

- Use a Flow Meter or CTs & PTs and Log Your Flow
- Use Excel to Evaluate Flows:
- Smooth Out Data if Noisy
- Create Bins
- Decide if a Single VFD is Even a Good Fit
- Get Performance Curves for High, Low, and Mid-sized VFD Units & Alternative or Use Generic
- Plot Main Bin Flows On Curves
- Keep Headroom for Growth (at Least 20%)
- Avoid Prolonged Time at Min Speed Flow (or Below)
- Try to be in “Sweet Spot” (30-80%)

Thank you



Tim Dugan
Compression Engineering Corporation

503-520-0700
tim.dugan@comp-eng.com

COMPRESSED AIR BEST PRACTICES
airbestpractices.com

About the Speaker

Steve Bruno
Atlas Copco Compressors

• Product Marketing Manager for Oil Injected Screw Compressors 30kW – 90 kw and Controls for Atlas Copco Compressors

Atlas Copco

For your free subscription, please visit
www.airbestpractices.com/magazine/subscription.

VSDs in Multiple Compressor Systems

Steve Bruno

Product Marketing Manager

Atlas Copco Compressors

January 25, 2018

Agenda

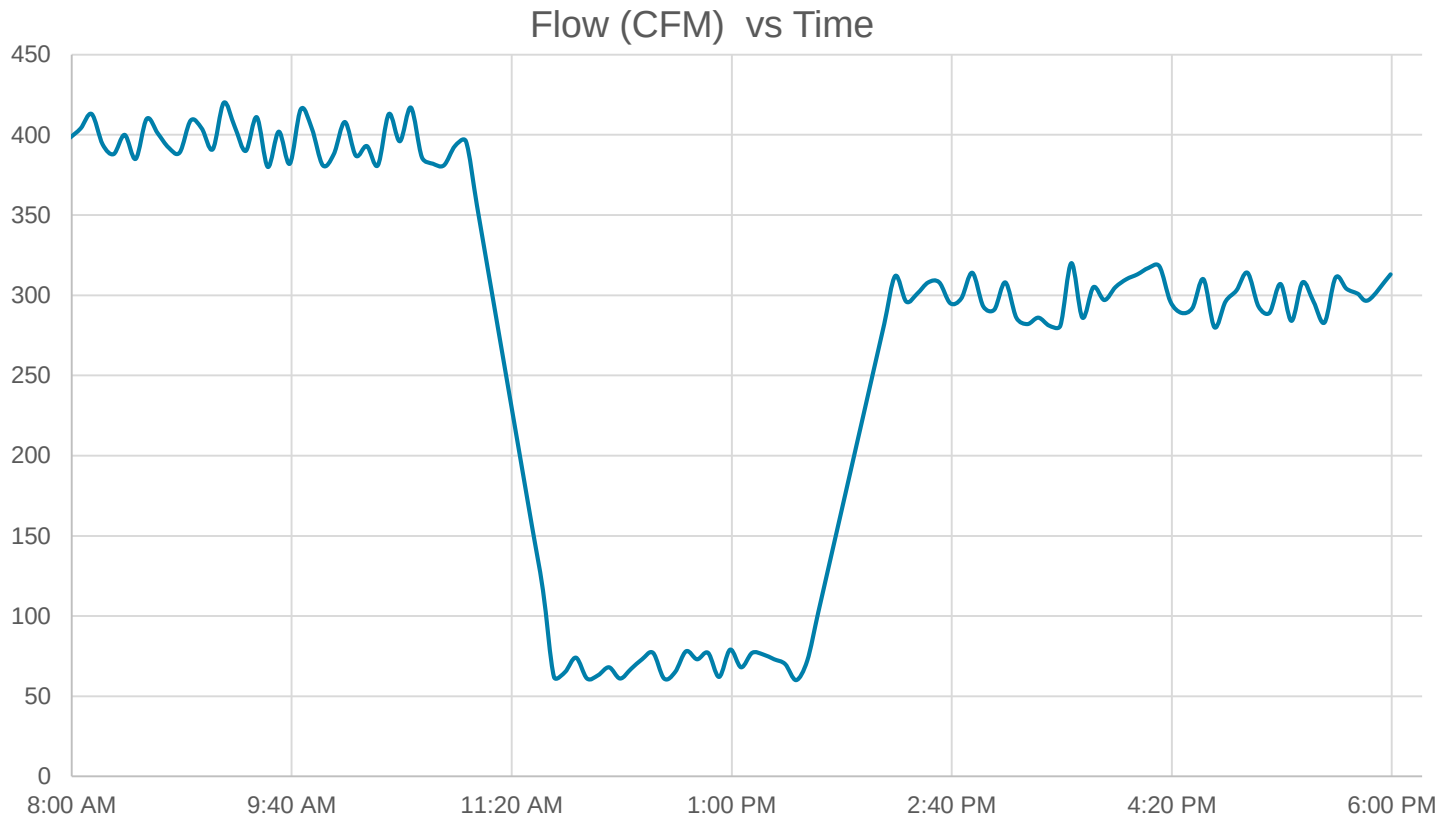
- Determining flow curve
- Utilizing a VSD and fixed speed compressors
- Potential Issues

Determining Flow Curve

- For existing installations its always best to perform an audit
- For new installations, find out how the customer plans to run their equipment.
- Do not guess
- Incorrect sizing results in poor performance
- Ask questions and educate customers

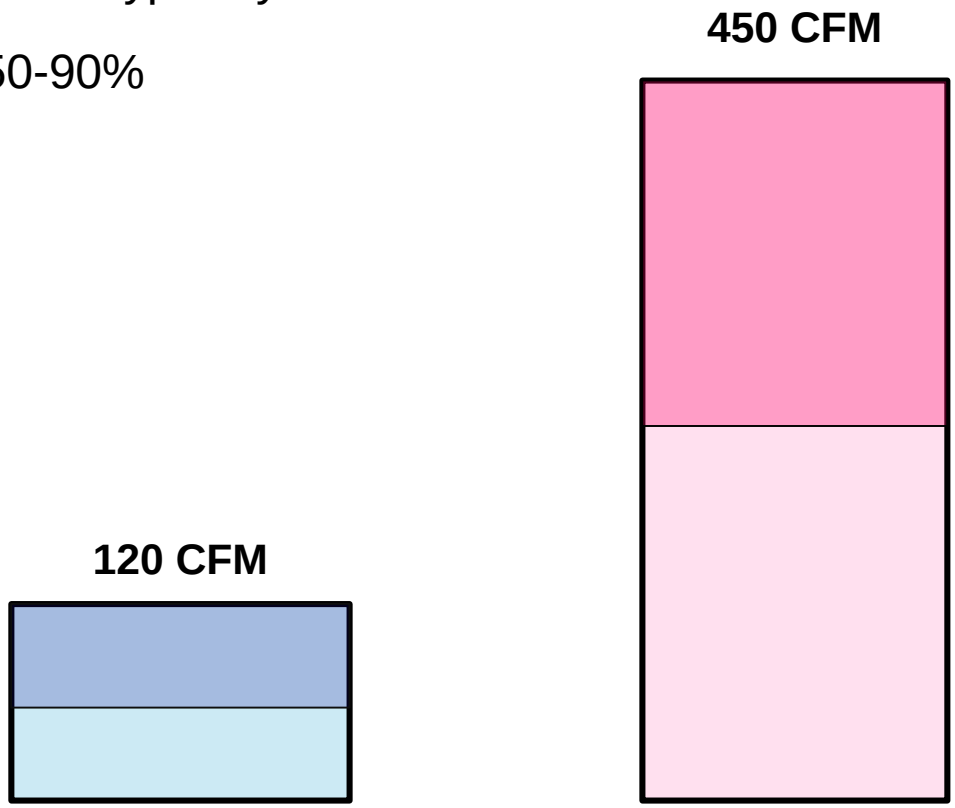
Determining Flow Curve

- New Installation - Customer Runs 3 Shifts
  - Morning ~ 400 CFM Lunch ~75 CFM Afternoon ~ 300 CFM



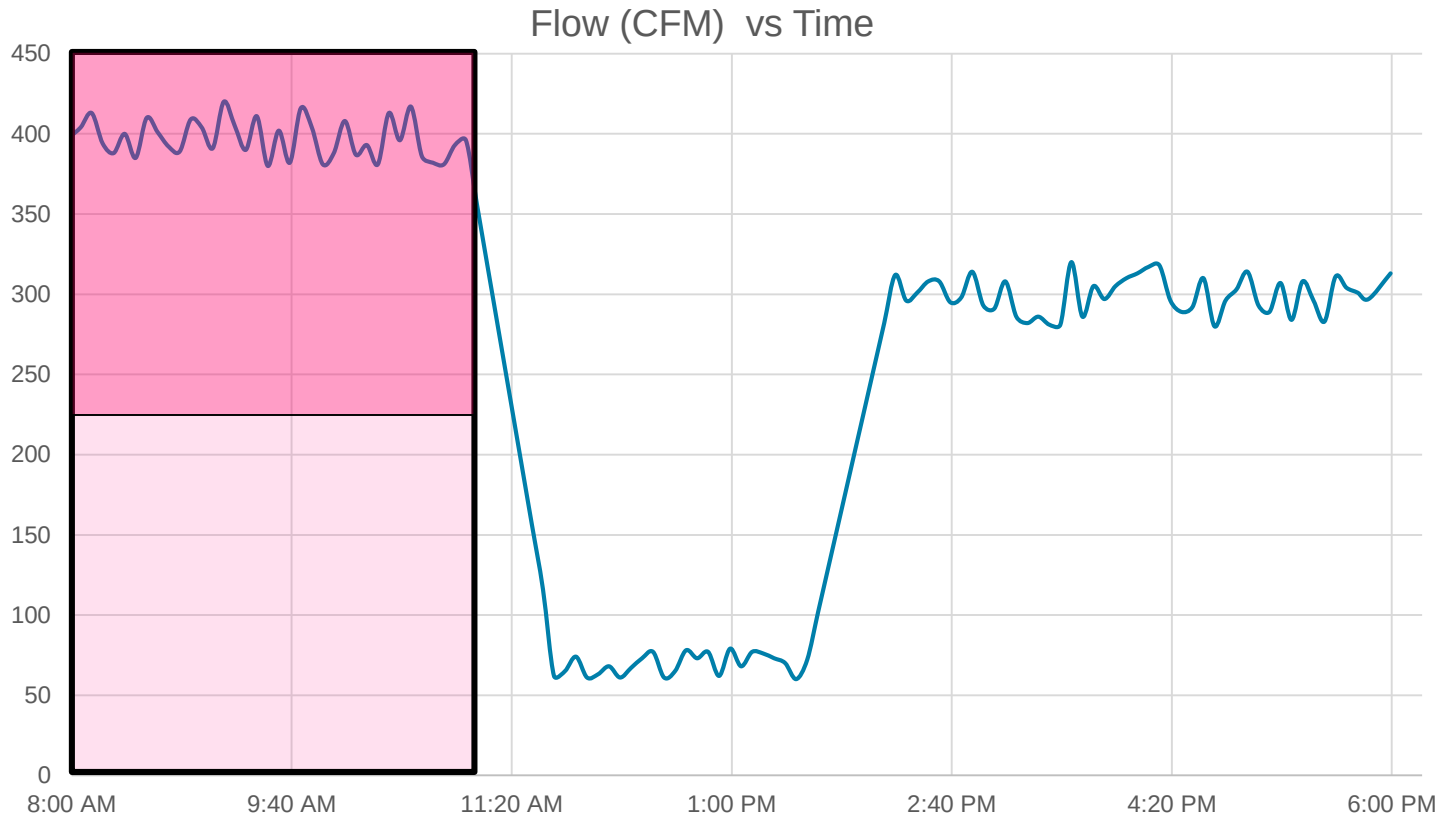
Efficient Range of VSD

- Entire possible flow typically 40-100%
- Most efficient 50-90%



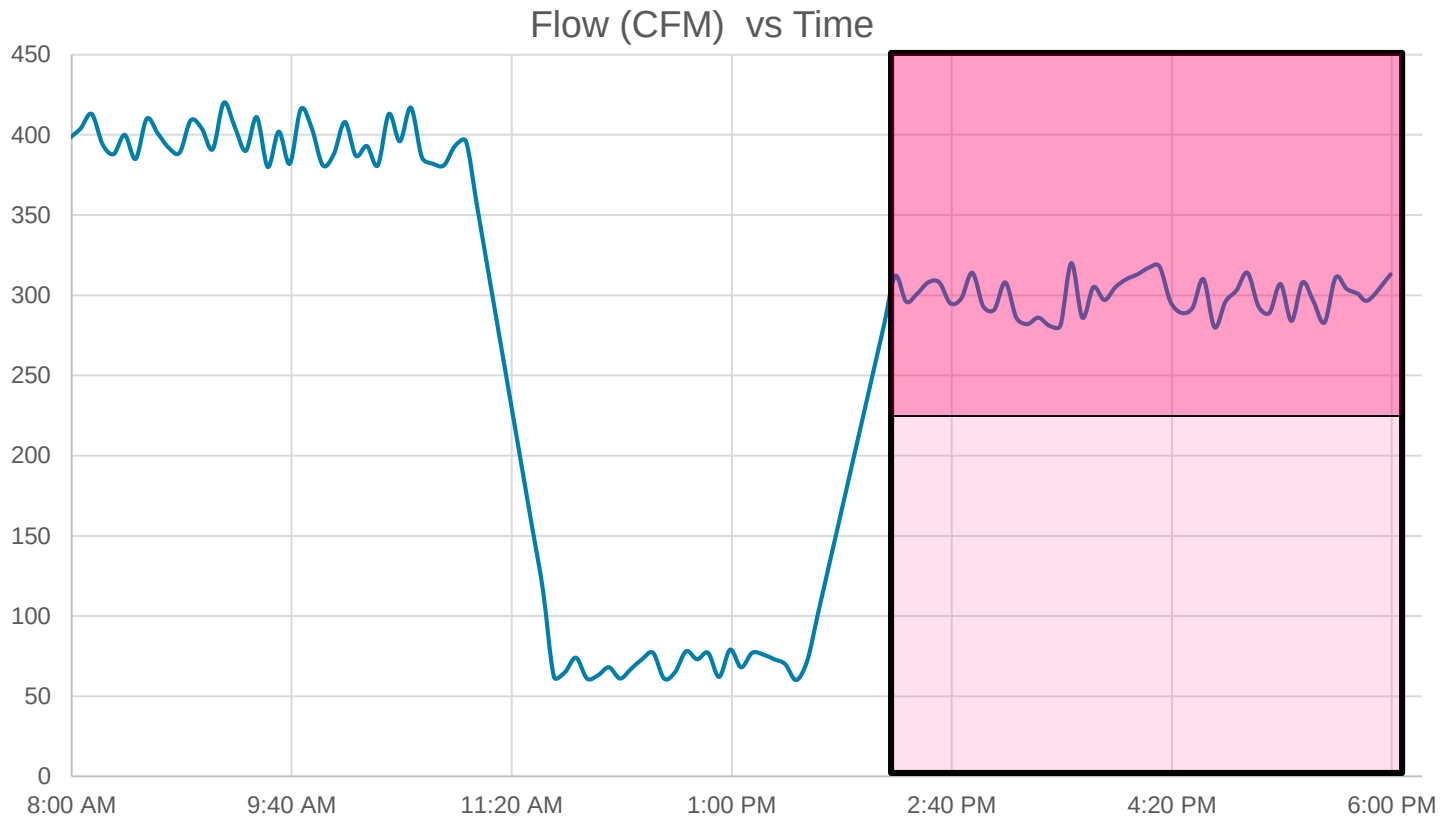
Trying to use a single VSD

- Need to size for max cfm
- Use 450 CFM compressor



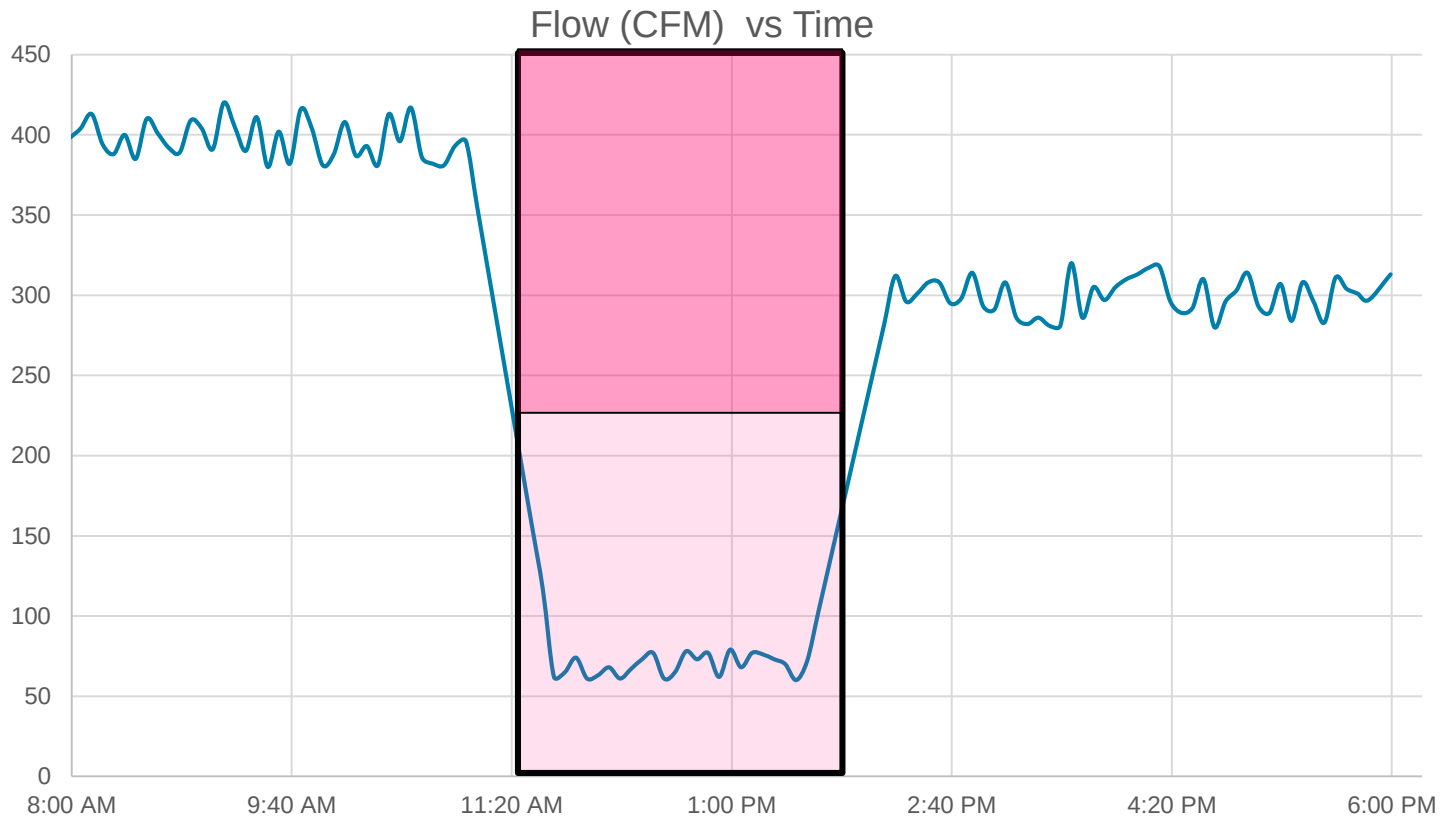
Trying to use a single VSD

- Still inside optimal range



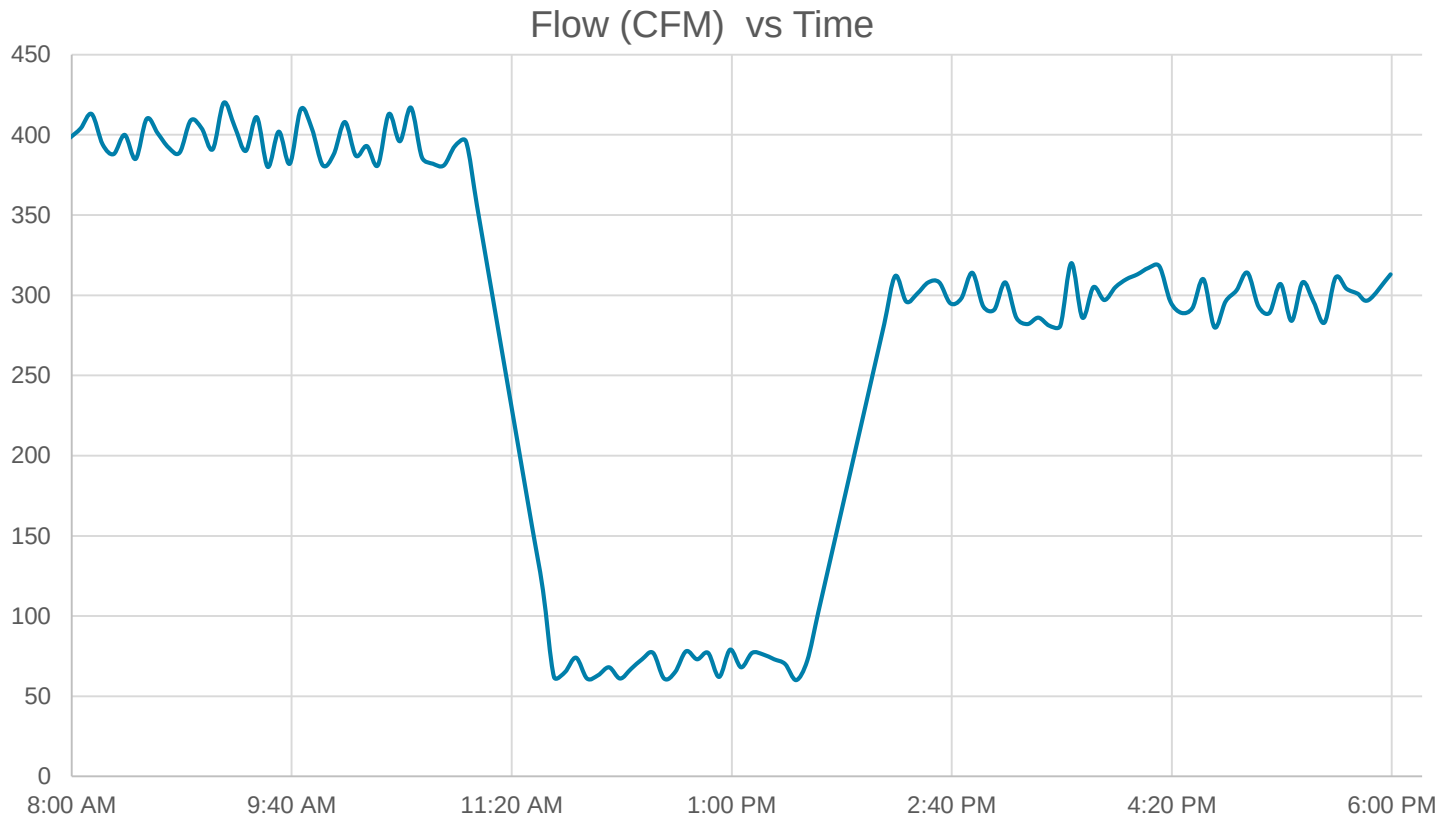
Trying to use a single VSD

- Oversized for lunch shift – VSD reliability issues could occur



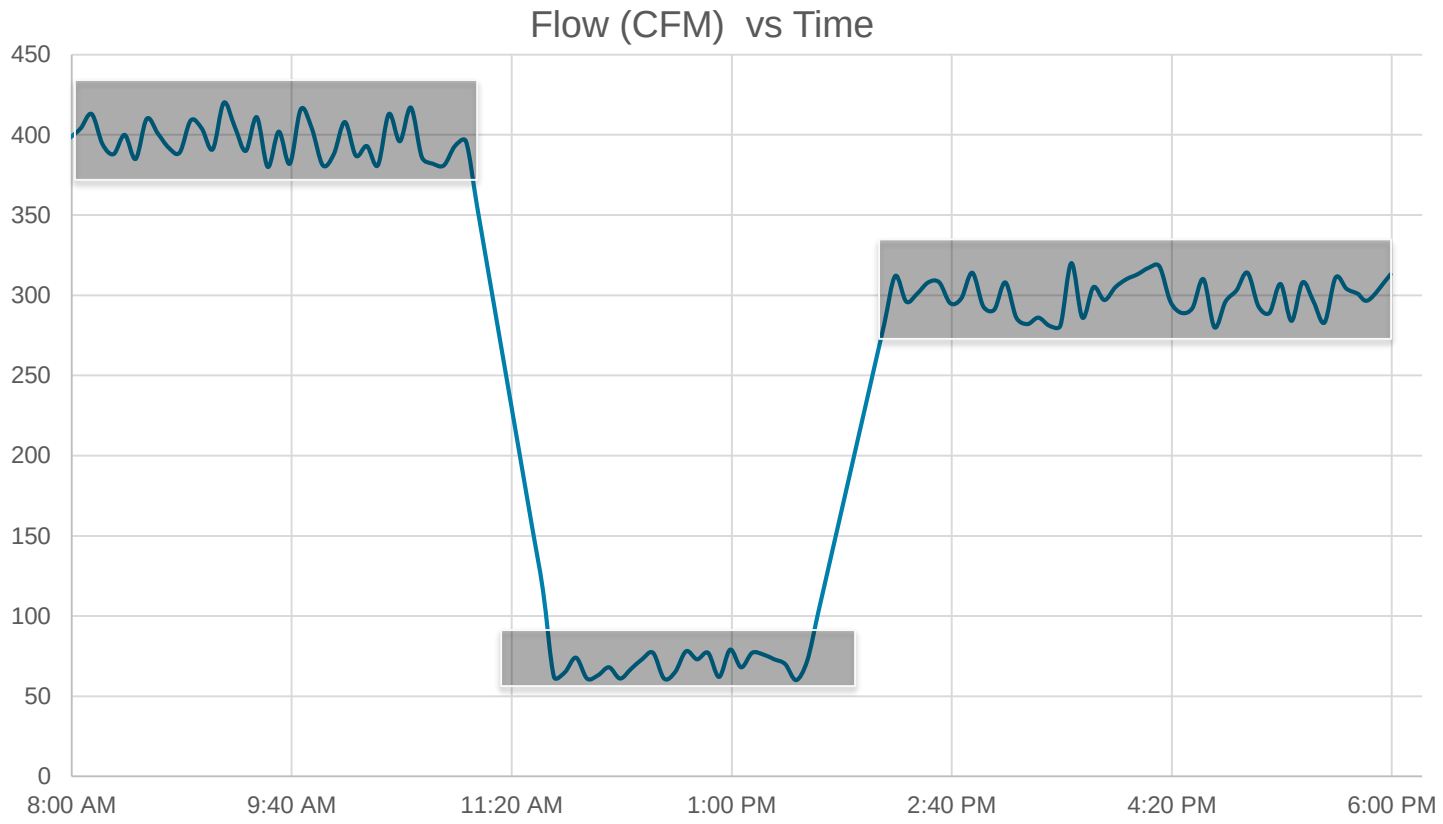
Sizing VSD

- Look at the smaller variance in flow



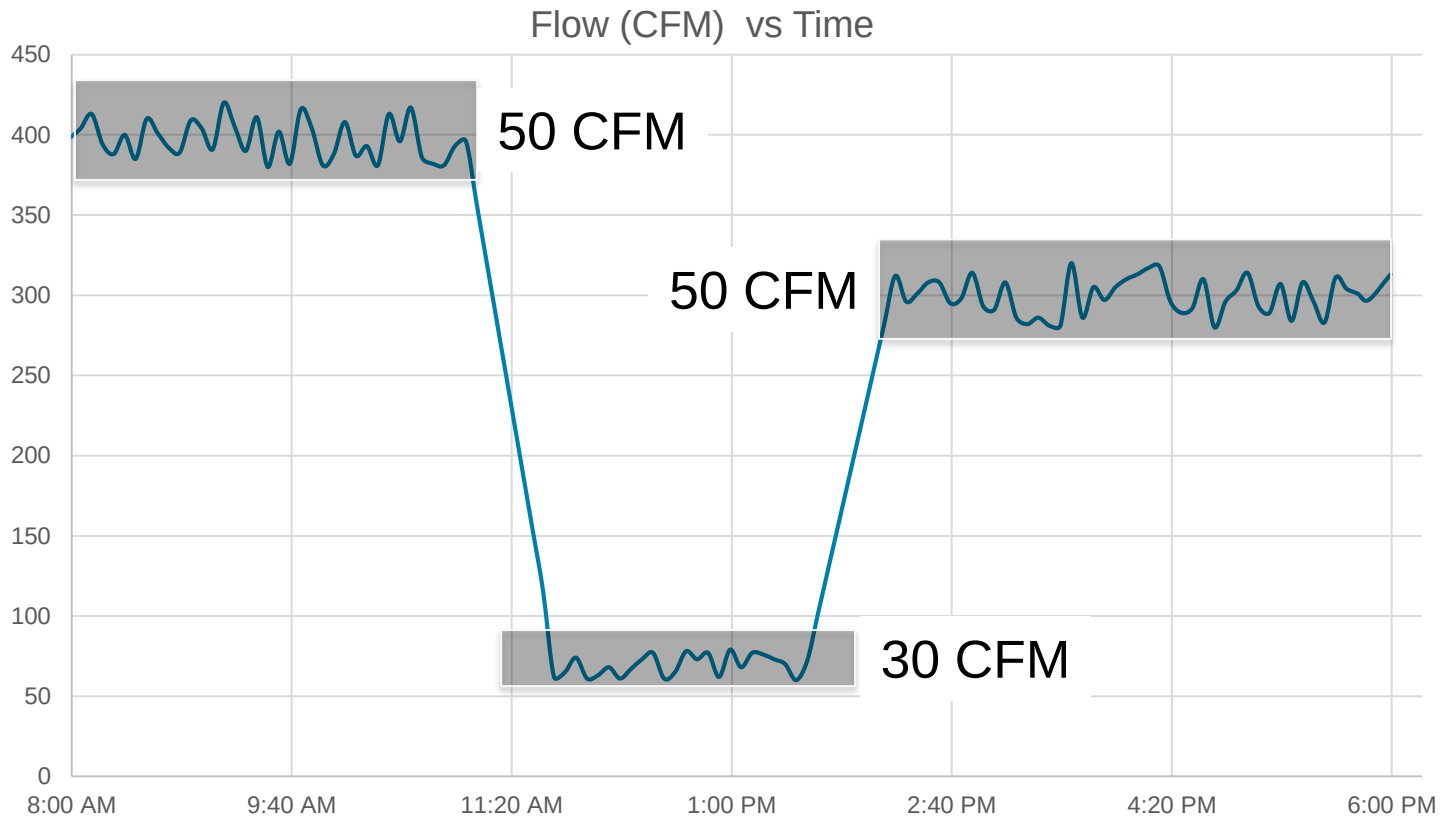
Sizing VSD

- Look at the smaller variance in flow



Sizing VSD

- Look at the smaller variance in flow



Sizing VSD

- Look at the smaller variance in flow
- Size your VSD Compressor to be able to match the smaller changes
- Use additional compressors to account for large changes

Sizing VSD

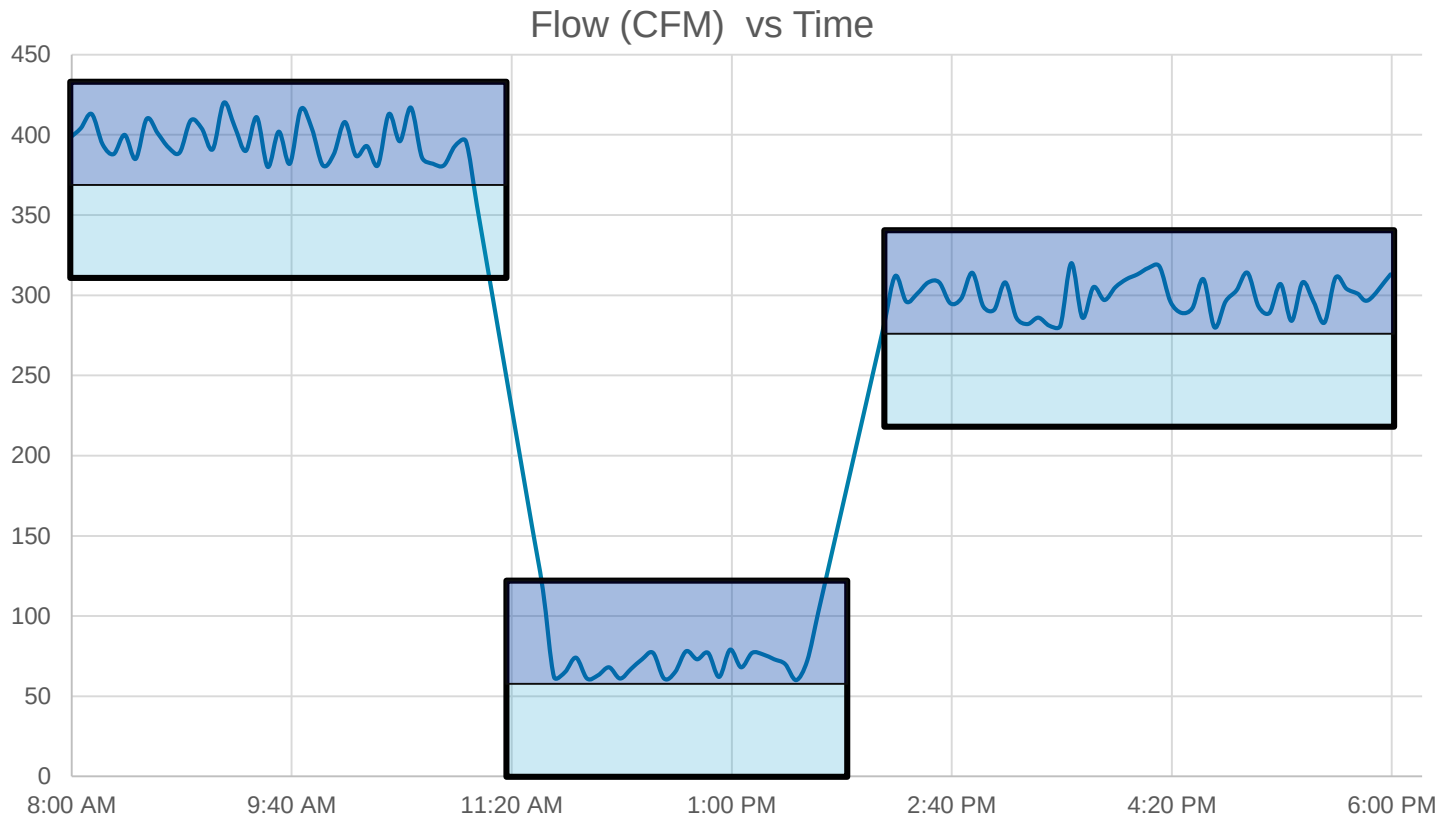
- Look at the smaller variance in flow
- Size your VSD Compressor to be able to match the smaller changes
- Use additional compressors to account for large changes

- Small Changes = 50 CFM
  - Choose VSD who's most efficient flow bandwidth (50-90%) is ~50 CFM
  - A 120 CFM compressor's entire flow range (40-100%) is 50-120 CFM

Atlas Copco

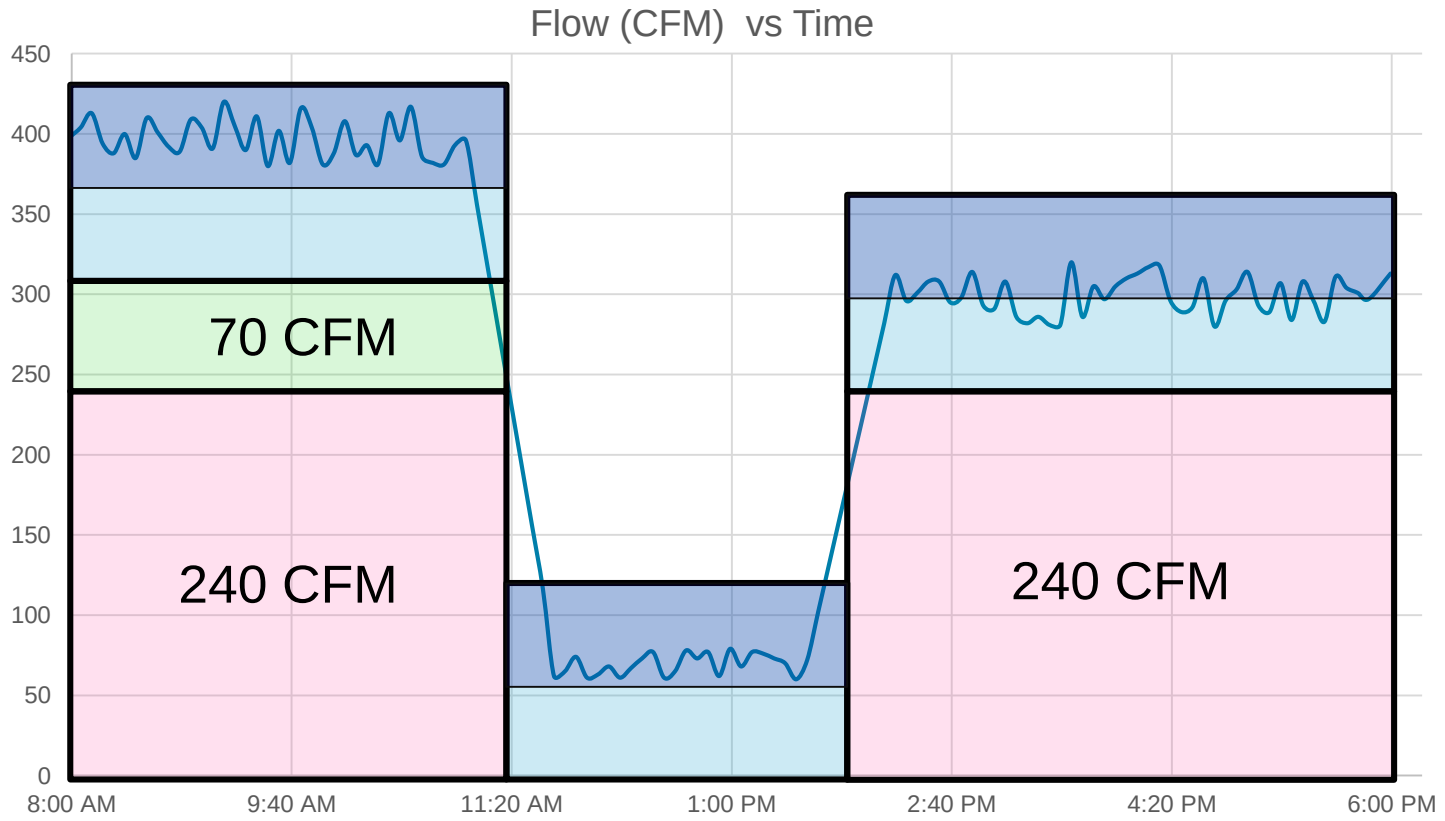
Multiple compressors with a single VSD

- Placing our 120 CFM VSD



Multiple compressors with a single VSD

- Fill in the Remaining with Fixed speed machines
- 1 x 70 CFM, 1 x 240 CFM



Control Gap

- A flow value where the VSD is not able to match the flow required

- Example:
  - Our 120 CFM VSD can turn down to 40%
  - Able to produce 50 to 120 CFM.

Control Gap

- A flow value where the VSD is not able to match the flow required

- Example:
  - Our 120 CFM VSD can turn down to 40%
  - Able to produce 50 to 120 CFM.
  - If the demand is below 50, the VSD will have reliability issues
    - Water in the oil
    - Overheating drive
    - Lack of airflow through motor
  - Never run system in the control gap.

Control Gap

- Example:
  - Our 120 CFM VSD can turn down to 40%
  - Able to produce between 50 to 120 CFM
  - The variable capacity band is 70 CFM

  - To eliminate control gap one fixed speed compressor must be 70 CFM or smaller

Control Gap – Multiple Compressors

- Example:
  - 120 CFM VSD, 70 CFM Fixed Speed (A) , 240 CFM Fixed Speed (B)

  - Our compressor options are:
    - VSD
    - VSD + A
    - VSD + B
    - VSD + A + B

Control Gap – Multiple Compressors

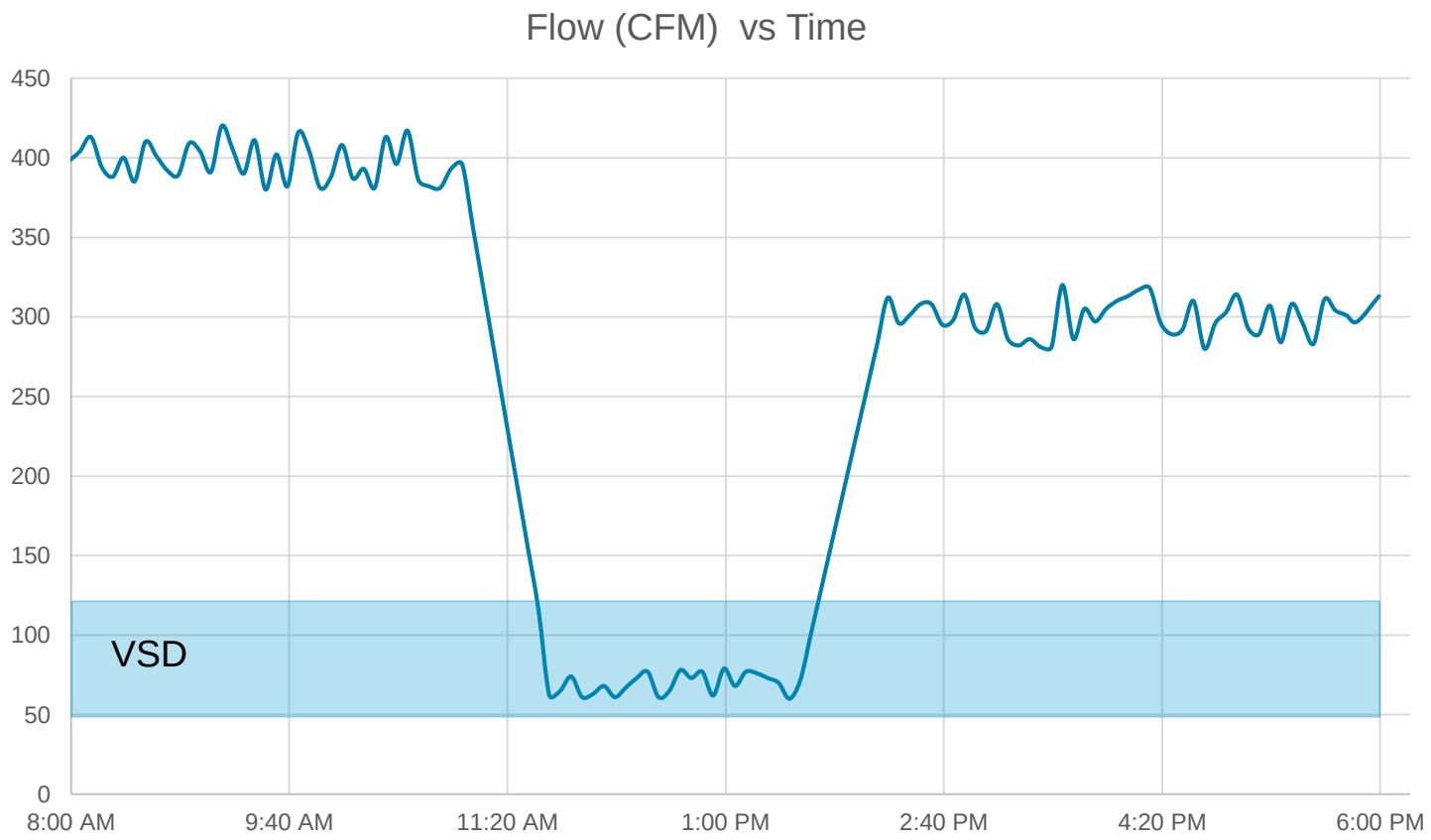
- Example:
  - 120 CFM VSD, 70 CFM Fixed Speed (A) , 240 CFM Fixed Speed (B)

  - Our compressor options are:
    - VSD = 50 to 120 CFM
    - VSD + A = 120 to 190 CFM
    - VSD + B = 290 to 360 CFM
    - VSD + A + B = 360 to 430 CFM

Atlas Copco

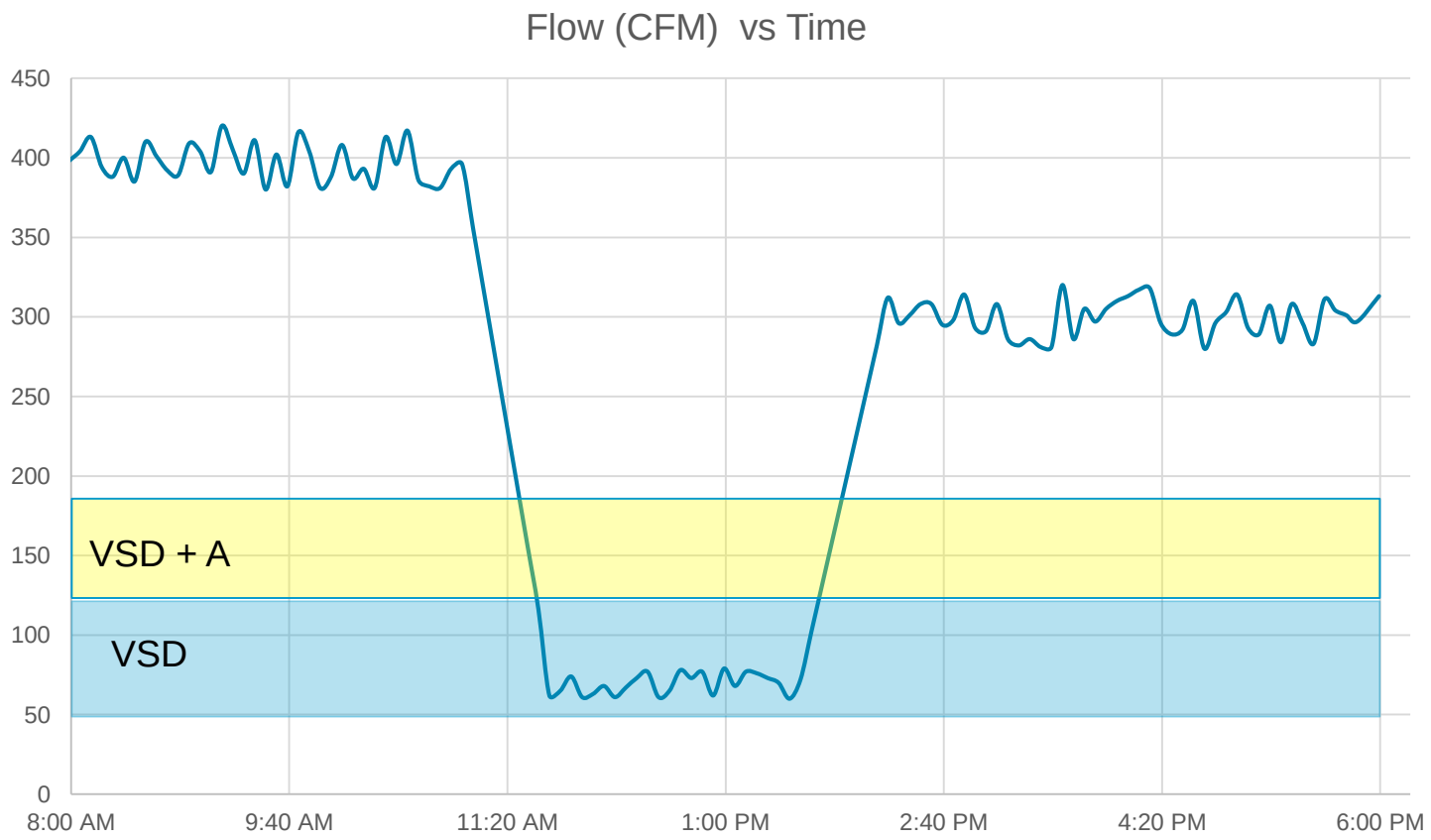
Control Gap – Multiple Compressors

- VSD Only = 50 to 120 CFM



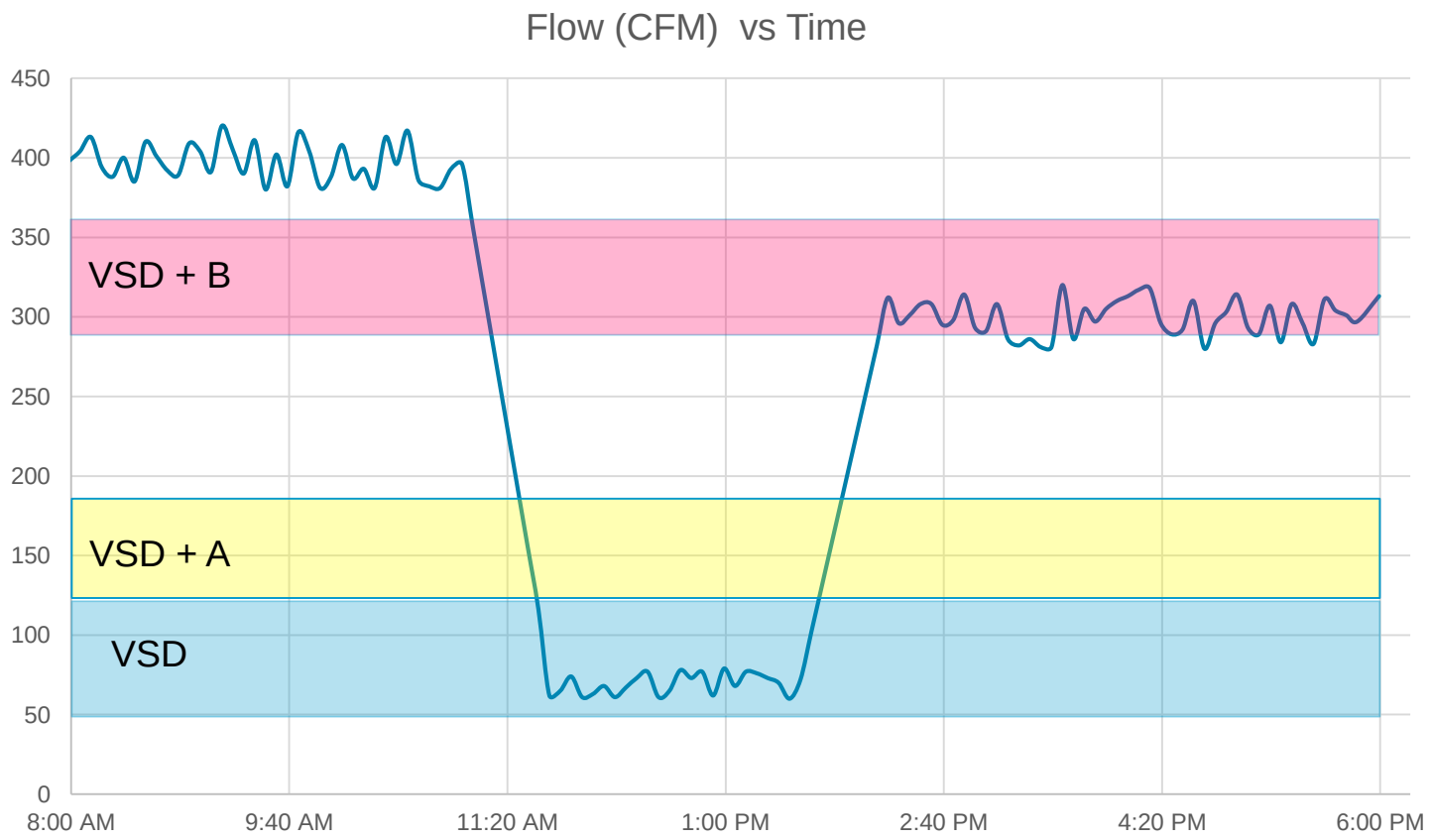
Control Gap – Multiple Compressors

- VSD and Fixed Speed A = 120 to 190 CFM



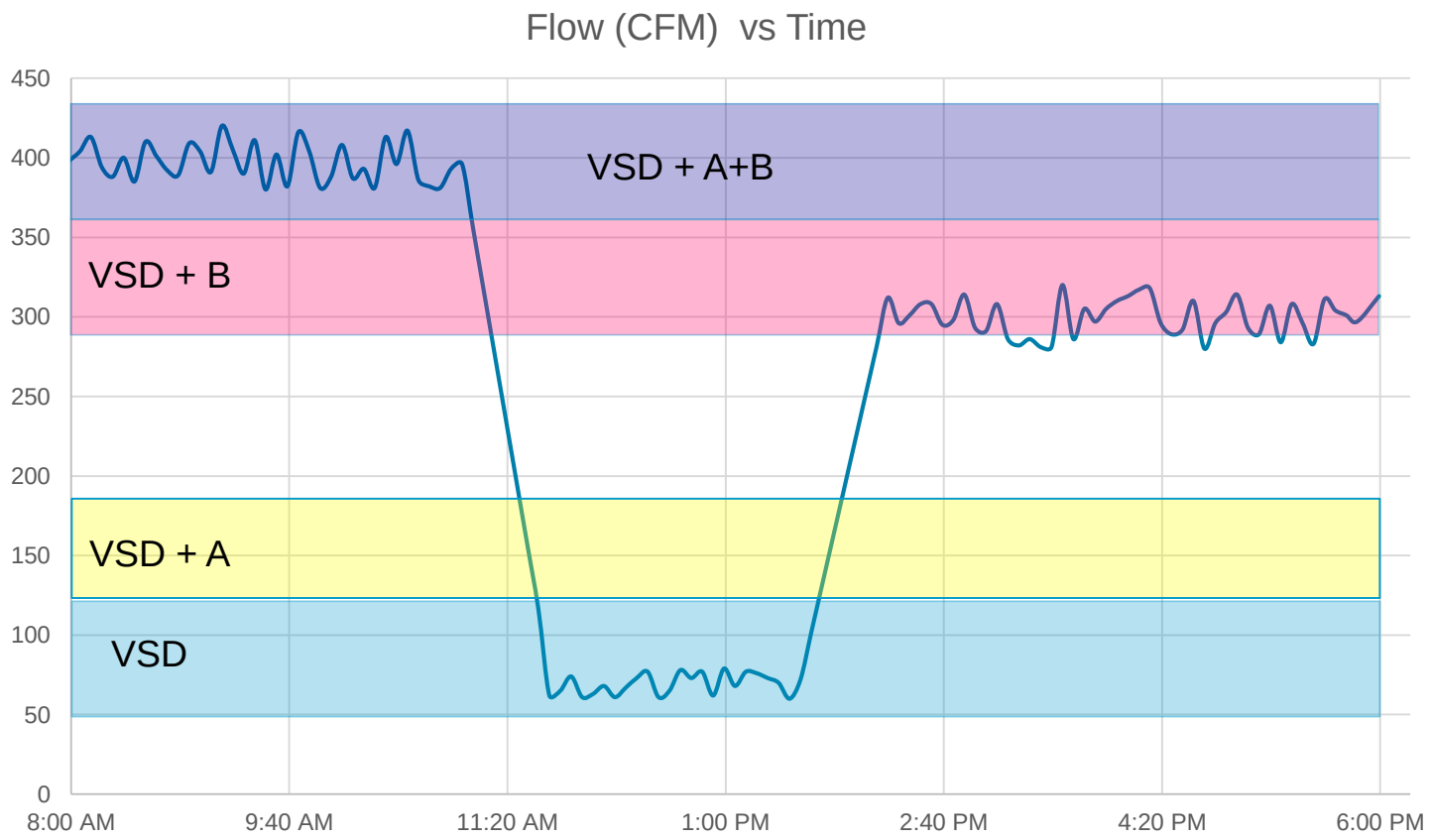
Control Gap – Multiple Compressors

- VSD and Fixed Speed B = 290 to 360 CFM



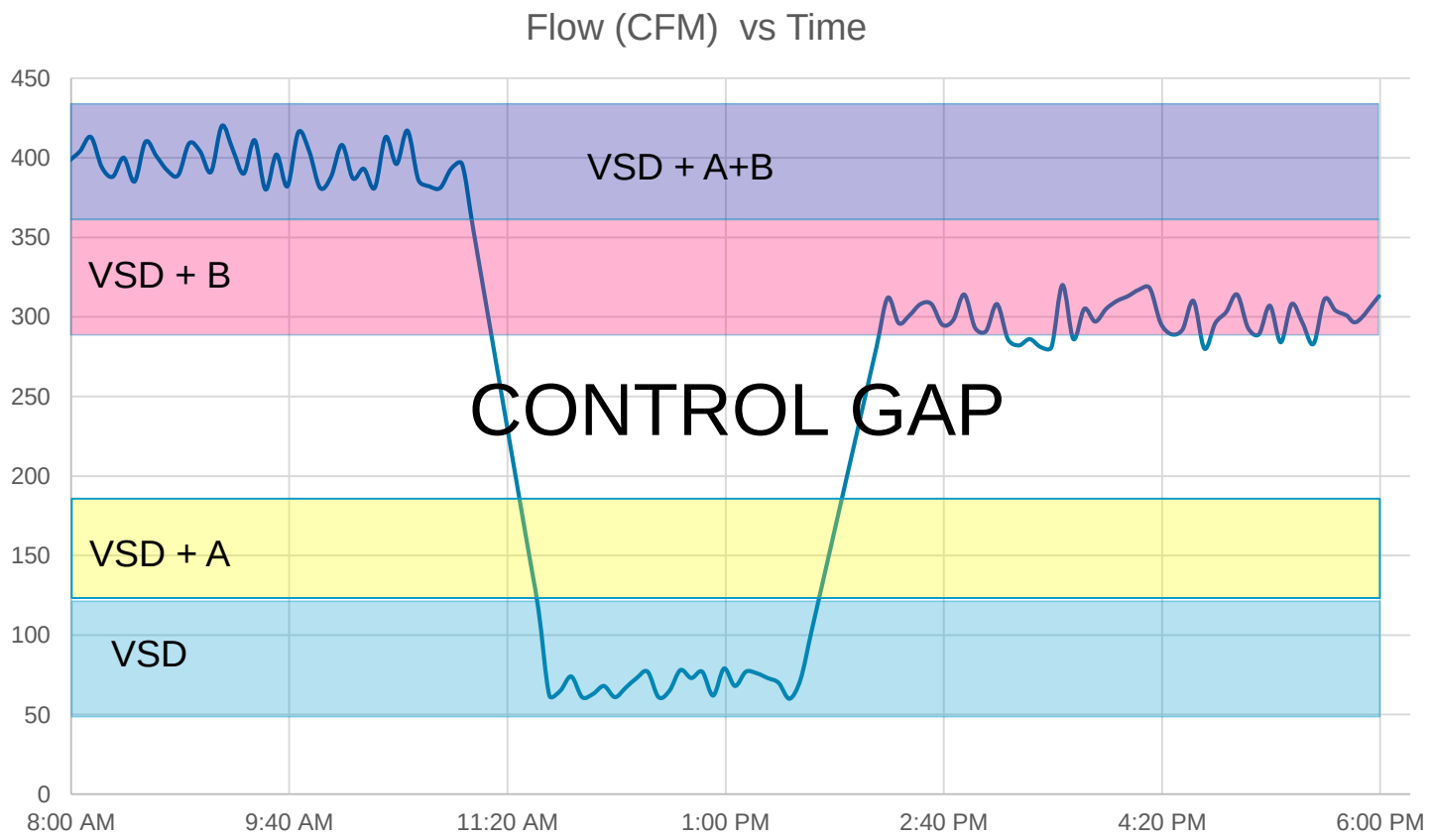
Control Gap – Multiple Compressors

- VSD and Fixed Speed A = 120 to 190 CFM



Control Gap – Multiple Compressors

- VSD and Fixed Speed A = 360 to 430 CFM

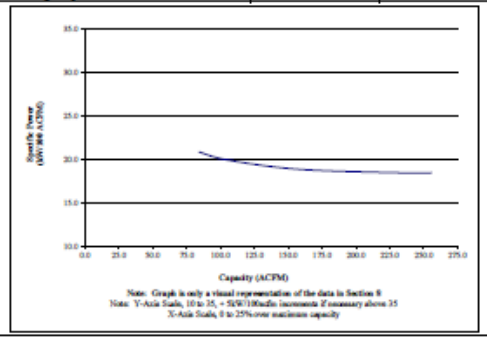


Comparing VSD Compressor Efficiencies

- Sample CAGI sheet

Atlas Copco

COMPRESSOR DATA SHEET
Rotary Compressor: Variable Frequency Drive

MODEL DATA - FOR COMPRESSED AIR			
1	Manufacturer: Atlas Copco		
2	Model Number: GA37VSD+ 175 AP	Date:	8/1/2016
	[X] Air-cooled [ ] Water-cooled	Type:	Screw
	[X] Oil-injected [ ] Oil-free	# of Stages:	1
3	Rated Operating Pressure	125	psig[b]
4	Drive Motor Nominal Rating	50	hp
5	Drive Motor Nominal Efficiency	96	percent
6	Fan Motor Nominal Rating (if applicable)	1.3	hp
7	Fan Motor Nominal Efficiency	73	percent
8*	Input Power (kW)	Capacity (acfm)[a,d]	Specific Power (kW/100 acfm)[d]
	47.2 Max	255.7	18.4
	44.8	243.6	18.4
	33.0	176.3	18.7
	26.6	139.1	19.1
	20.4	101.7	20.0
	17.6 Min	84.2	20.8
9*	Total Package Input Power at Zero Flow[a, d]	1.1	kW
10			

*For models that are tested in the CAGI Performance Verification Program, these items are verified by program administrator

Consult CAGI website for a list of participants in the third party verification program: www.cagi.org

NOTES:
a. Measured at the discharge terminal point of the compressor package in accordance with ISO 1217, Annex E; acfm is actual cubic feet per minute at inlet conditions.
b. The operating pressure at which the Capacity and Electrical Consumption were measured for this data sheet.
c. No Load Power. In accordance with ISO 1217, Annex E, if measurement of no load power equals less than 1%, manufacturer may state "not significant" or "0" on the test report.
d. Tolerance is specified in ISO 1217, Annex E, as shown in table below:
NOTE: The terms "power" and "energy" are synonymous for purposes of this document.

Member:

COMPRESSED AIR AND GAS INSTITUTE CAGI

Volume Flow Rate at specified conditions		Volume Flow Rate	Specific Energy Consumption	No Load / Zero Flow Power
m^3 / min	#3 / min	%	%	
Below 0.5	Below 15	+/- 7	+/- 8	+/- 10%
0.5 to 1.5	15 to 50	+/- 6	+/- 7	
1.5 to 15	50 to 500	+/- 5	+/- 6	
Above 15	Above 500	+/- 4	+/- 5	

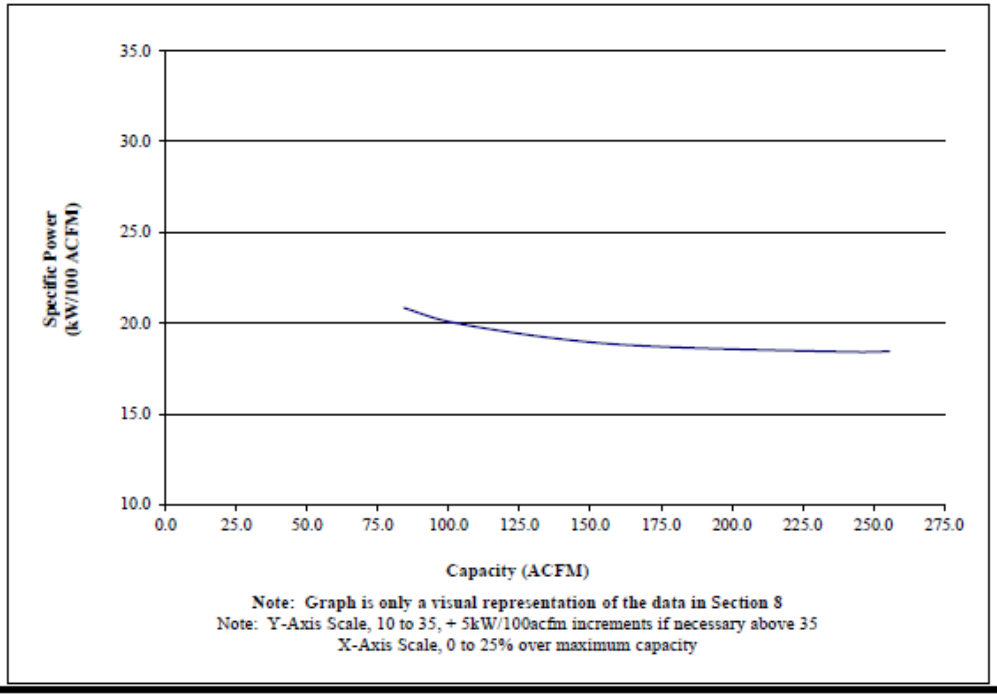
ROT 031

This form was developed by the Compressed Air and Gas Institute for the use of its members. CAGI has not independently verified the reported data.

Atlas Copco

Comparing VSD Compressor Efficiencies

- CAGI VSD Efficiency Curve

	Input Power (kW)		Capacity (acfm)[a,d]	Specific Power (kW/100 acfm)[d]
8*	47.2	Max	255.7	18.4
	44.8		243.6	18.4
	33.0		176.3	18.7
	26.6		139.1	19.1
	20.4		101.7	20.0
	17.6	Min	84.2	20.8
9*	Total Package Input Power at Zero Flow[c, d]		1.1	kW
10				

Note: Graph is only a visual representation of the data in Section 8
Note: Y-Axis Scale, 10 to 35, + 5kW/100acfm increments if necessary above 35
X-Axis Scale, 0 to 25% over maximum capacity

Atlas Copco

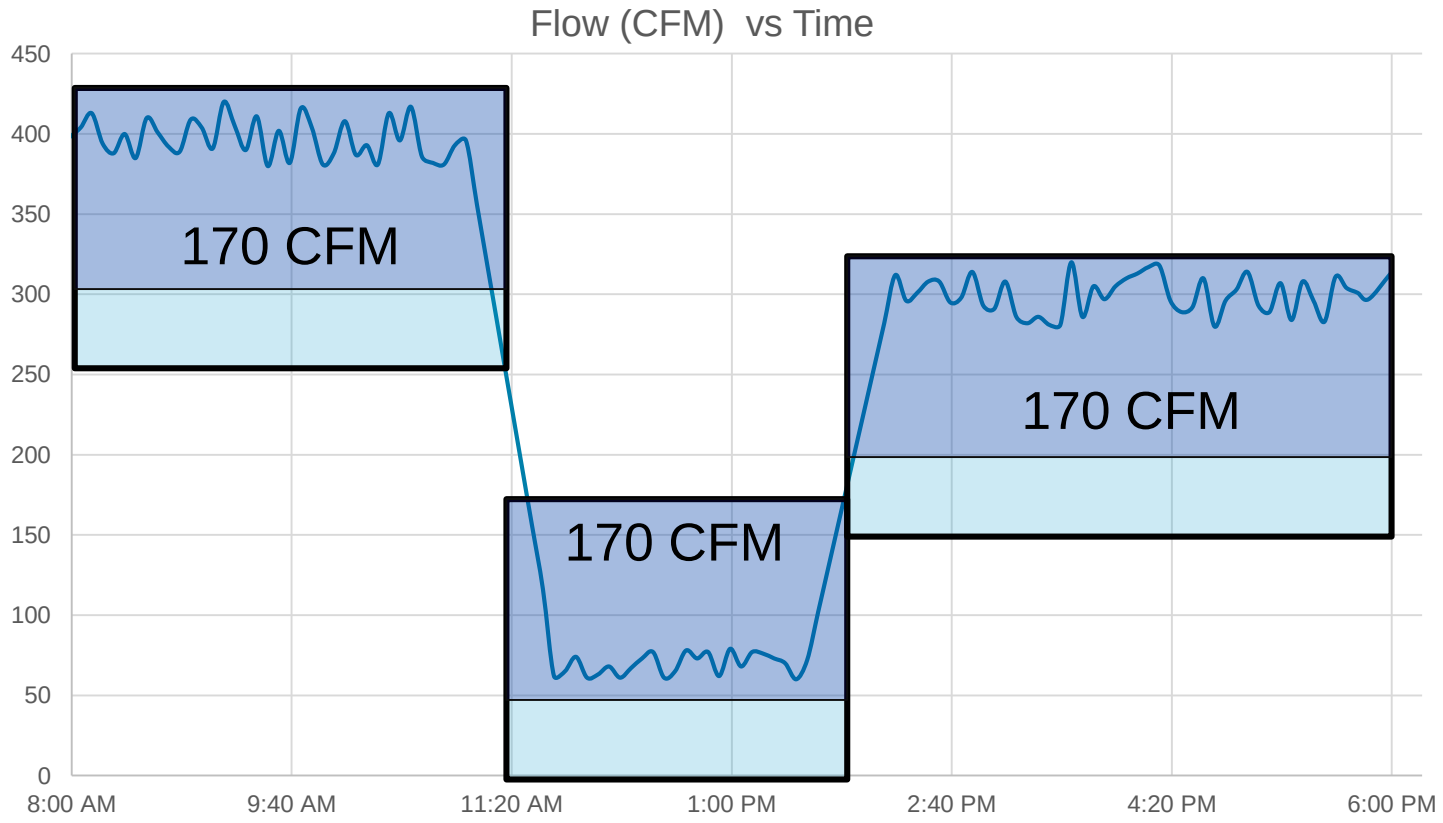
Which compressors to choose?

- Most efficient
- Widest turndown
- Flattest efficiency curve

- Will allow your system to run the most efficiently in the widest range of different flow demands and avoid falling into the control gap

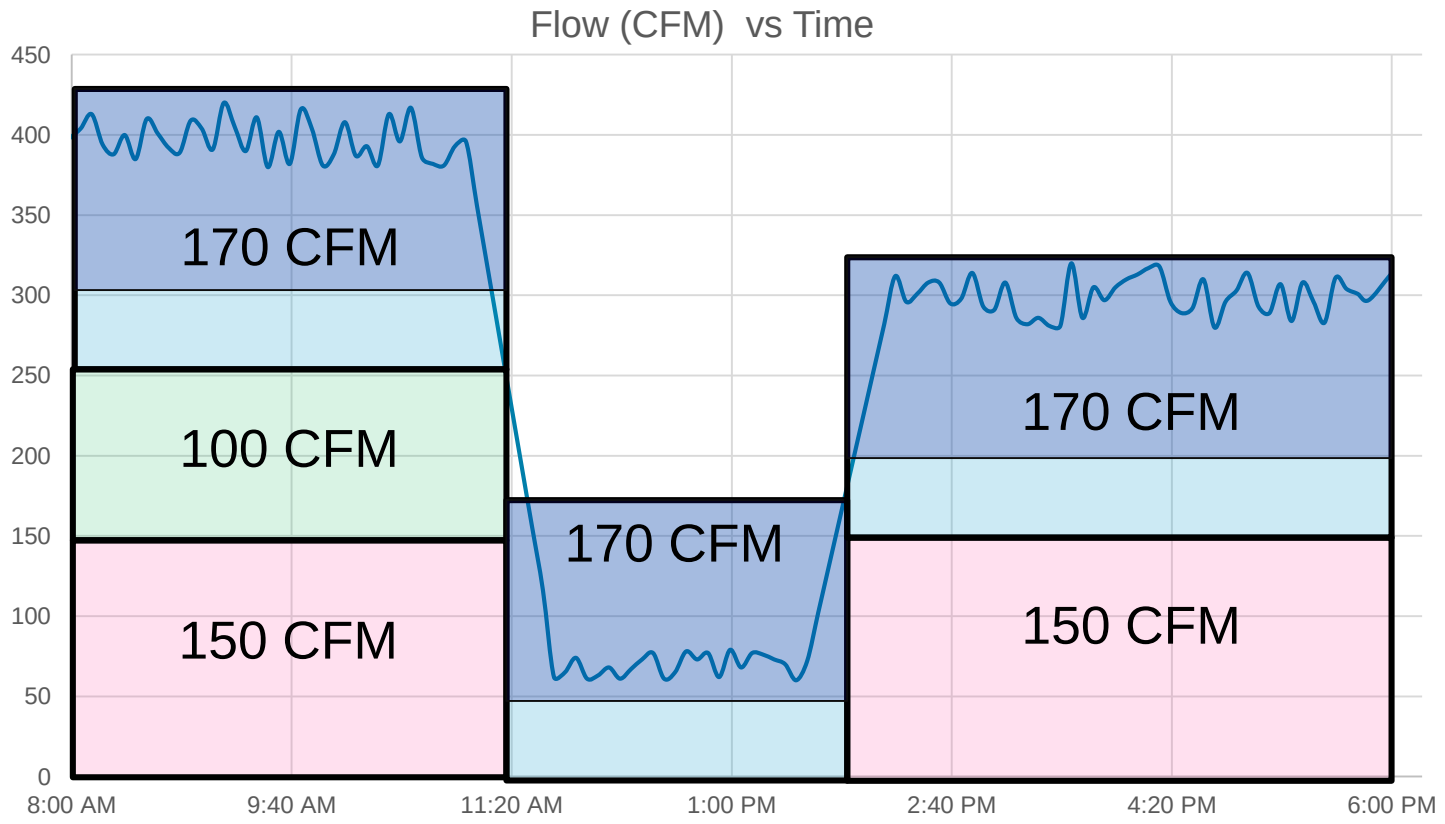
Multiple compressors with a single VSD

- If we chose VSD which can be turned down to 30%
- Use a 170 CFM VSD



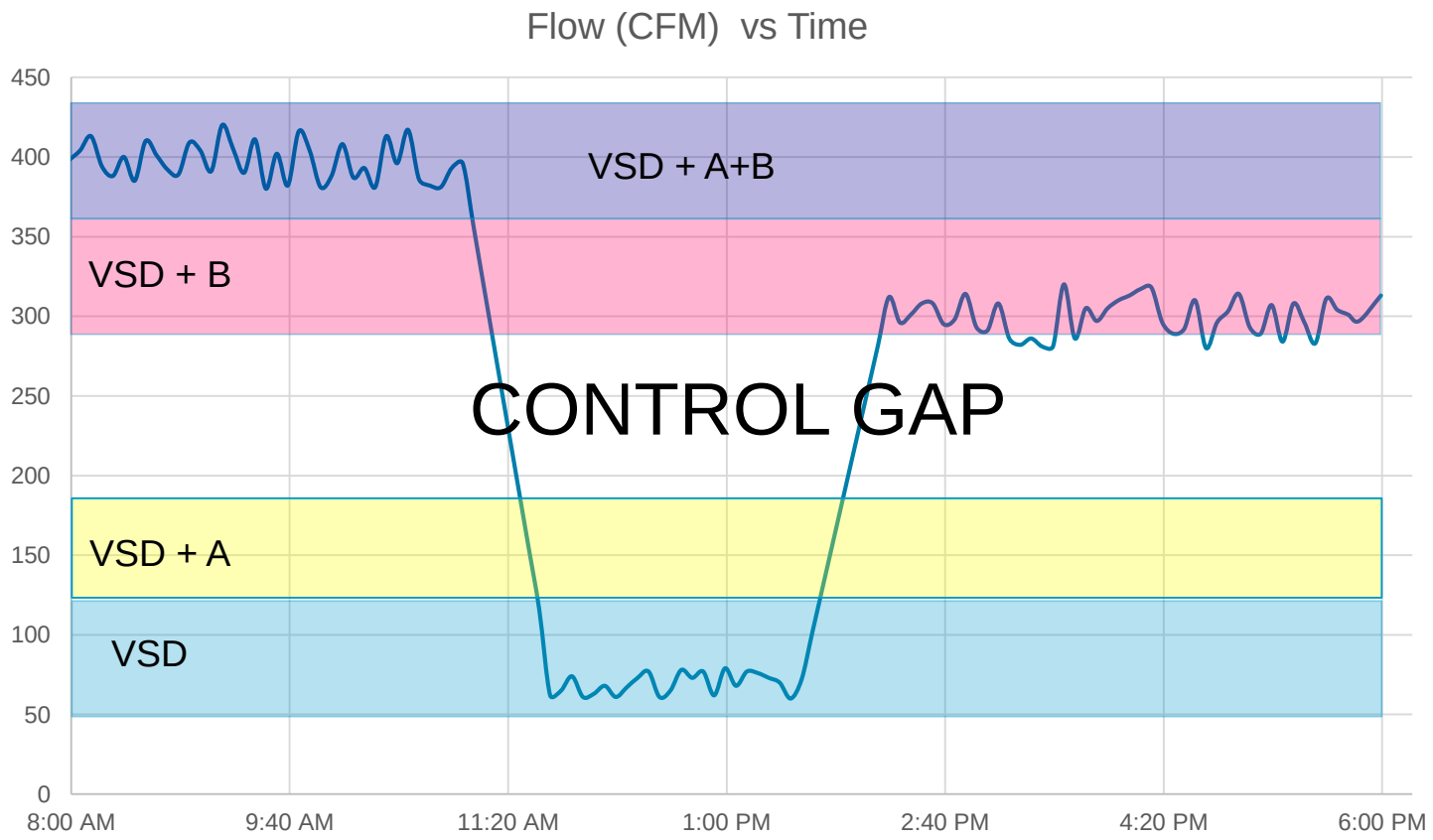
Multiple compressors with a single VSD

- 170 CFM VSD, 150 CFM Fixed Speed , 100 CFM Fixed Speed



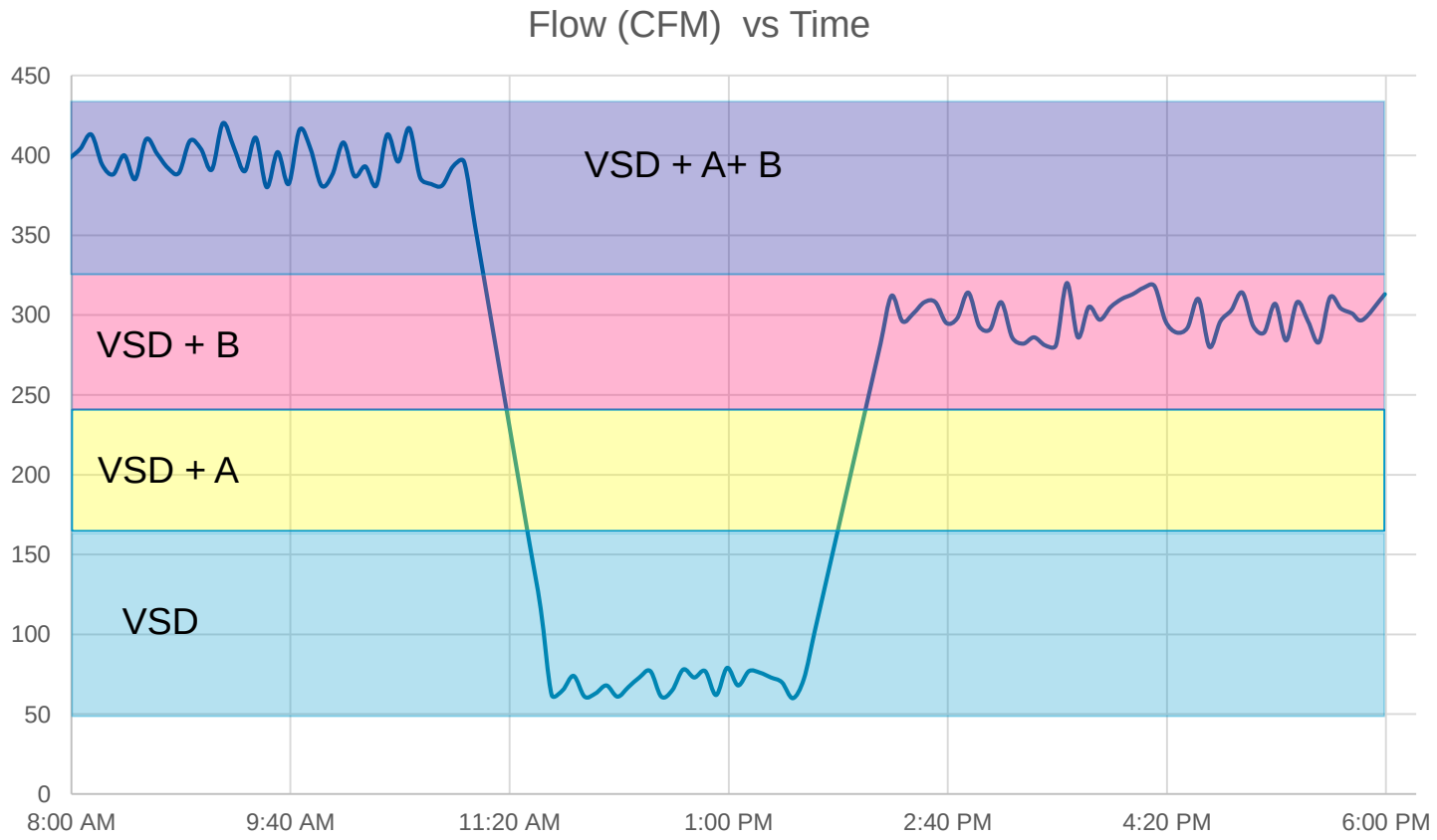
Control Gap – Multiple Compressors

- Previous example with 40% Minimum speed



Control Gap – Multiple Compressors

- New VSD with 30% Minimum speed
- No Control Gap



Thank you!

Steve Bruno

Product Marketing Manager

Oil Injected Screw Compressors 30kW – 90 kw and Controls

Atlas Copco Compressors LLC

803-817-7223

Steve.Bruno@us.atlascopco.com

www.atlascopco.us

COMMITTED TO SUSTAINABLE PRODUCTIVITY

COMPRESSED AIR
BEST PRACTICES
airbestpractices.com

How to Size VSD Air Compressors

Q&A

Please submit any questions through the Question Window on your GoToWebinar interface, directing them to Compressed Air Best Practices Magazine. Our panelists will do their best to address your questions, and will follow up with you on anything that goes unanswered during this session. **Thank you for attending!**

Sponsored by

Atlas Copco

For your free subscription, please visit www.airbestpractices.com/magazine/subscription.

COMPRESSED AIR
BEST PRACTICES
airbestpractices.com

Thank you for attending!

The recording and slides of this webinar will be made available to attendees via email later today.

PDH Certificates will be e-mailed to Attendees within two days.

Sponsored by

Atlas Copco

For your free subscription, please visit www.airbestpractices.com/magazine/subscription.

BEST PRACTICES

2018 EXPO SEPTEMBER 17-19 CHICAGO O'HARE, IL

COMPRESSED AIR / VACUUM / COOLING

CABPEXPO.COM

THE INAUGURAL 3-DAY CONFERENCE & EXPO!

IMPROVING PLANT PROFITABILITY THROUGH INDUSTRIAL UTILITY OPTIMIZATION

Industry self-provides the key industrial utilities of compressed air, vacuum, blower and cooling. BEST PRACTICES 2018 EXPO focuses on the significant opportunities presented by these inter-related utilities, **to reduce kW and water intensity – per unit of production.**

For more information and registration, please visit **www.cabpexpo.com.**

Date

September 17-19, 2018

Location

Chicago O'Hare Crowne Plaza Hotel

COMPRESSED AIR
BEST PRACTICES
airbestpractices.com

February 2018 Webinar:

5 Installation Tips for Flow and kW Meters

Tim Dugan, P.E.
Compression Engineering Corporation
Keynote Speaker

Sponsored by

VP INSTRUMENTS

Thursday, February 22, 2017 – 2:00 PM EST

Register for free at
www.airbestpractices.com/magazine/webinars