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When to Install a VSD Air Compressor

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

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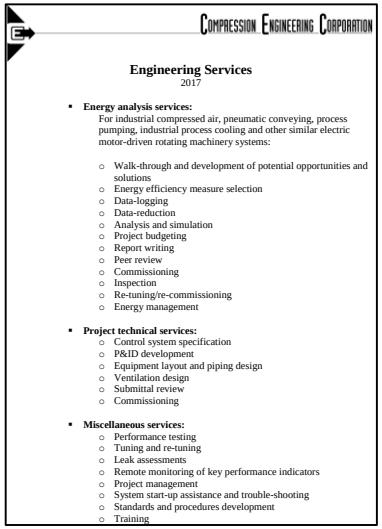
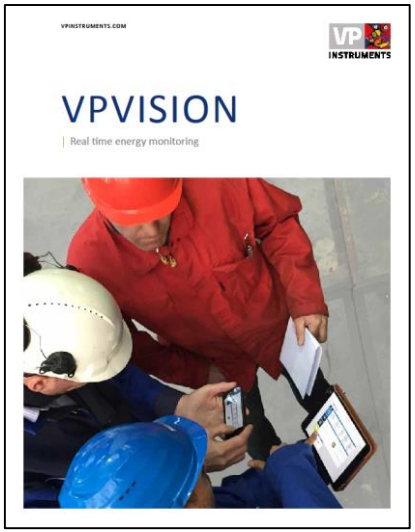
Handouts

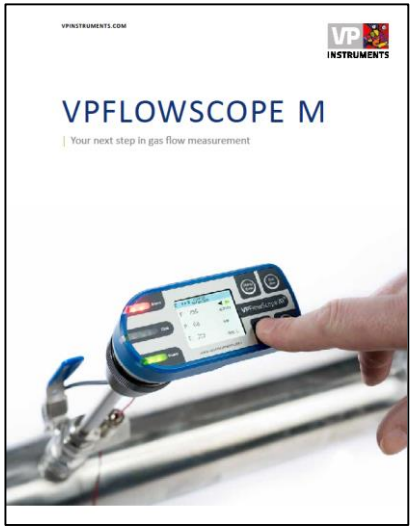


COMPRESSION ENGINEERING CORPORATION

Engineering Services
2017

- **Energy analysis services:**
  For industrial compressed air, 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





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

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When to Install a VSD Air Compressor

Introduction by Rod Smith, Publisher
Compressed Air Best Practices® Magazine

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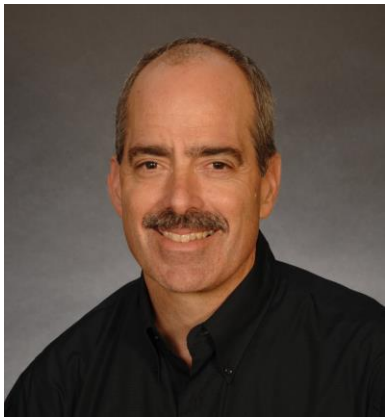

Tim Dugan P.E.,
Compression Engineering Corporation

- President and Principal Engineer of Compression Engineering Corporation

- Over 25 years of experience in the compressed air industry

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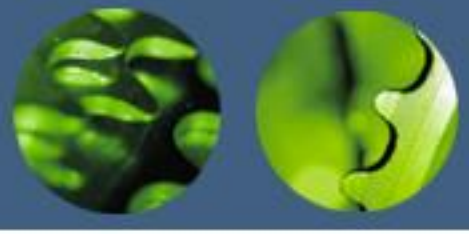
When to Install a VSD Air Compressor, Systems Issues

Tim Dugan
Compression Engineering Corp.

For Compressed Air Best Practices® Magazine
3-30-17

Outline

- Why Install a VSD Compressor?
- Best Practices for Integrating VSD Compressors Into Systems
- Best Practices for VSD Compressor Sizing
- Best Practices for Master Controls with VSD Compressors in System



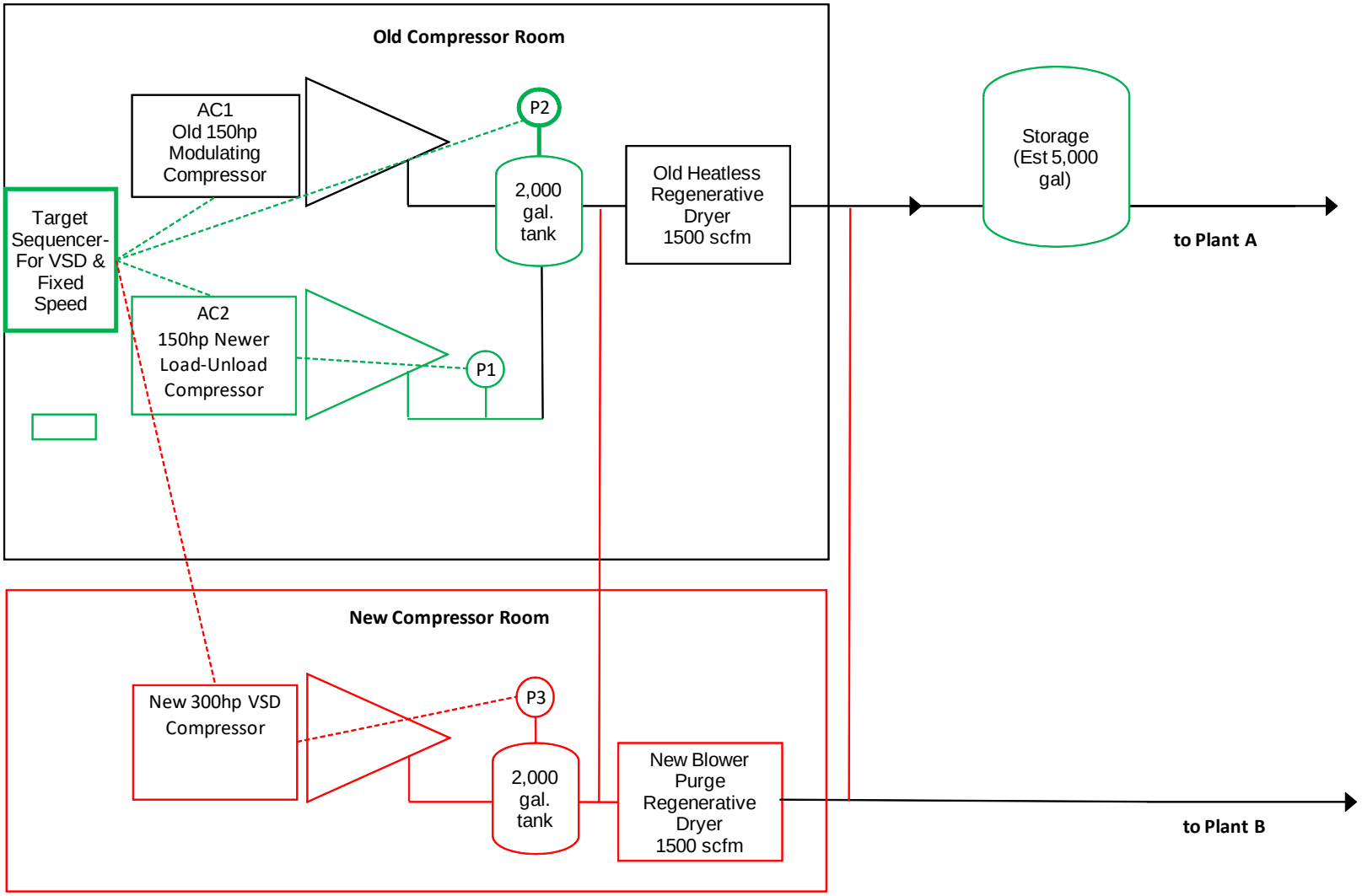
Why Install a VSD Compressor

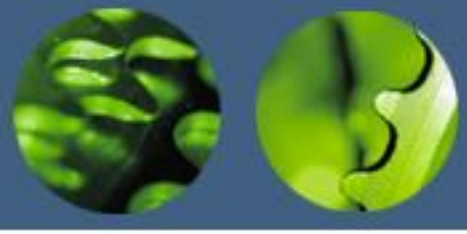
- All Systems Have Flow Variance
- All Systems Should have a “Trim” Compressor, to Follow the Typical Variance, and Others be Base-load
- Trim Compressor Technologies Include Variable Speed (VSD), Variable Displacement, and Load-unload.
- For Lubricated Screw Compressors, the Most Efficient Part-load Control is Variable Speed

Best Practices, System Design w- VSD

- Integrate All Compressors into Common Header
- Install a Master Control System for All Compressors
- Implement the Proper Algorithm, Based on Size, Location and Types of Compressors

Good Example of System w- VSD

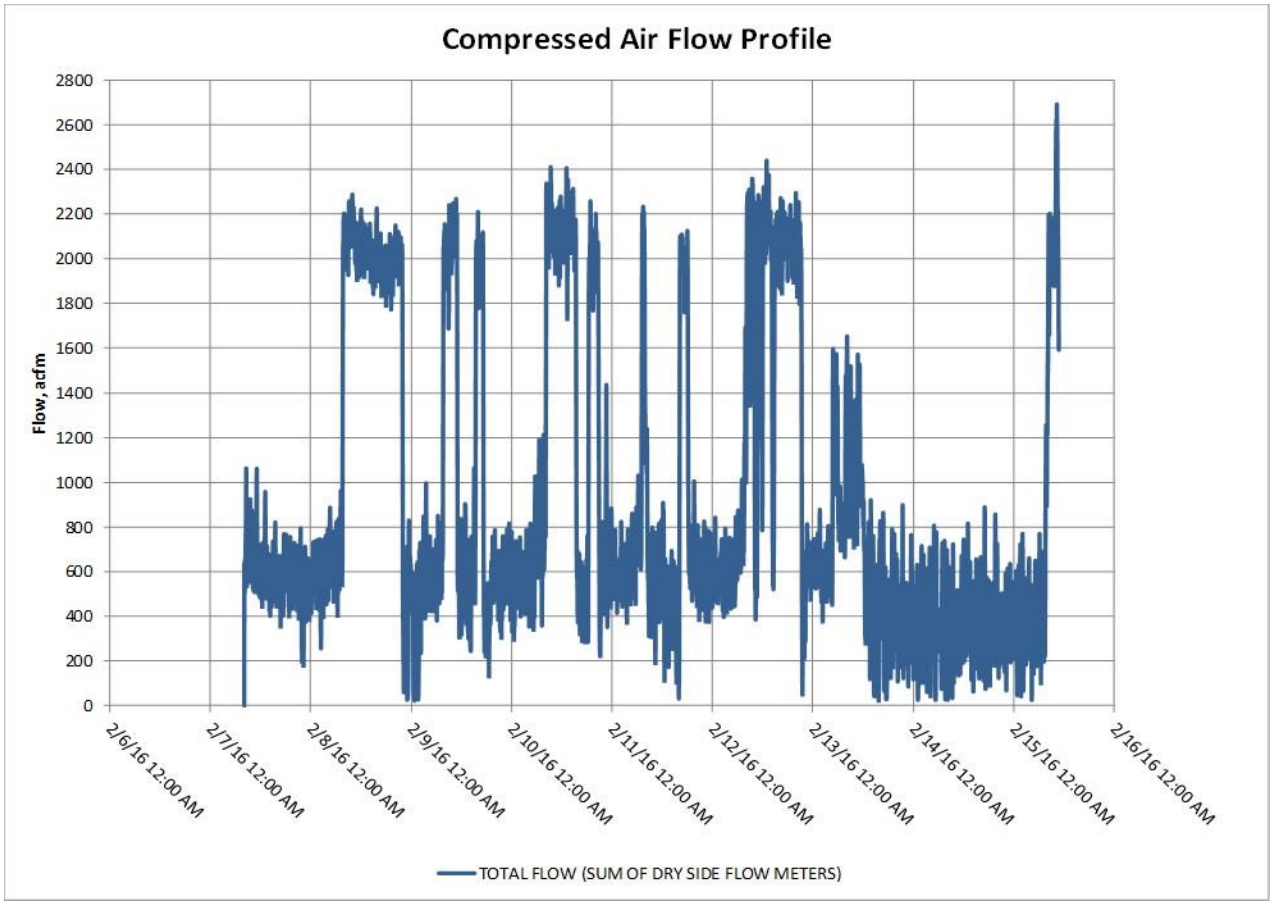




Best Practices, Sizing VSD Compressor

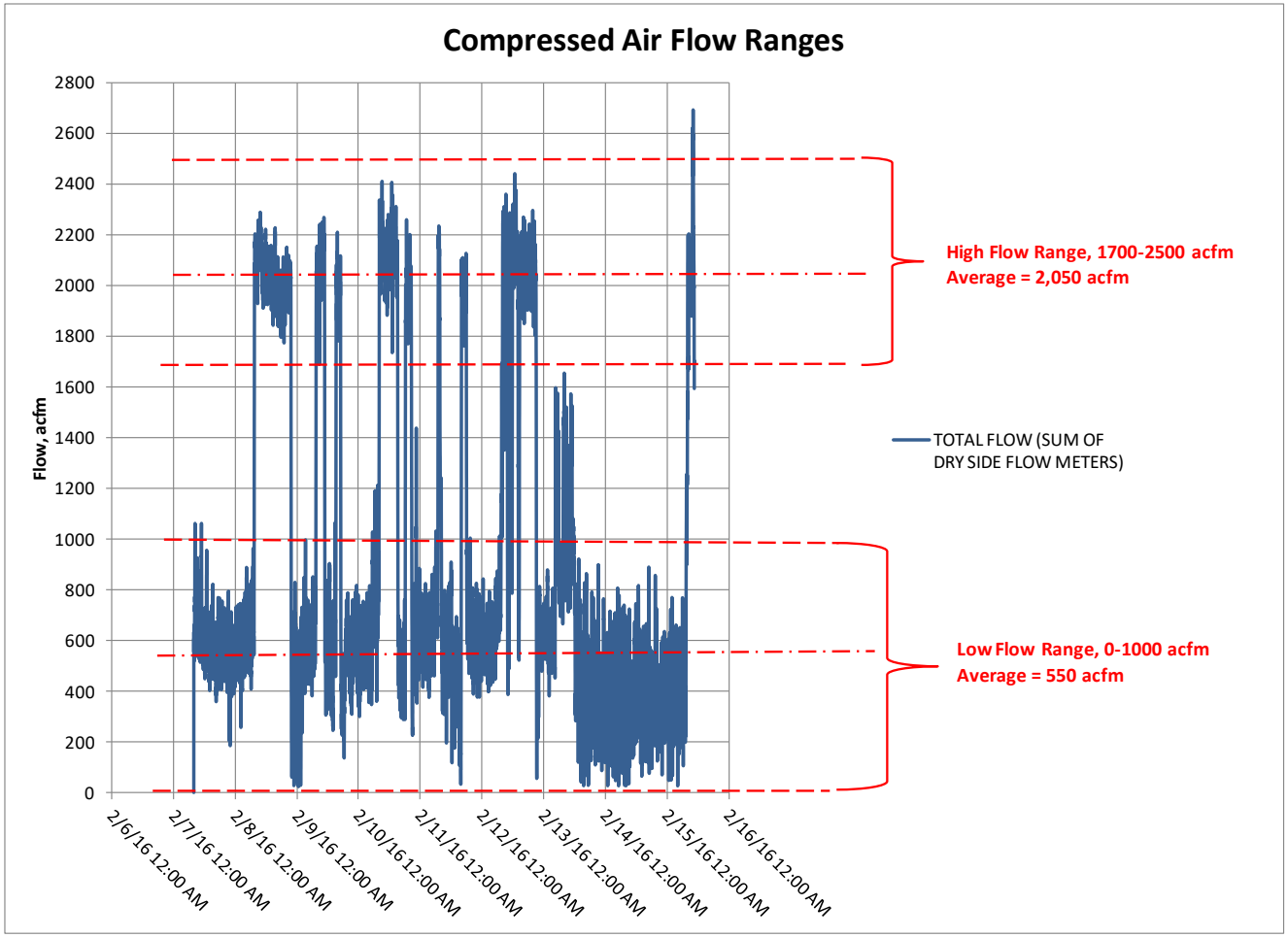
- Develop a Good Flow Profile
- Determine Flow Ranges for “Trim” Compressor(s)
- Size VSD & Base-load Compressor(s) From Variance & Base-load Size(s)

Develop a Good System Flow Profile



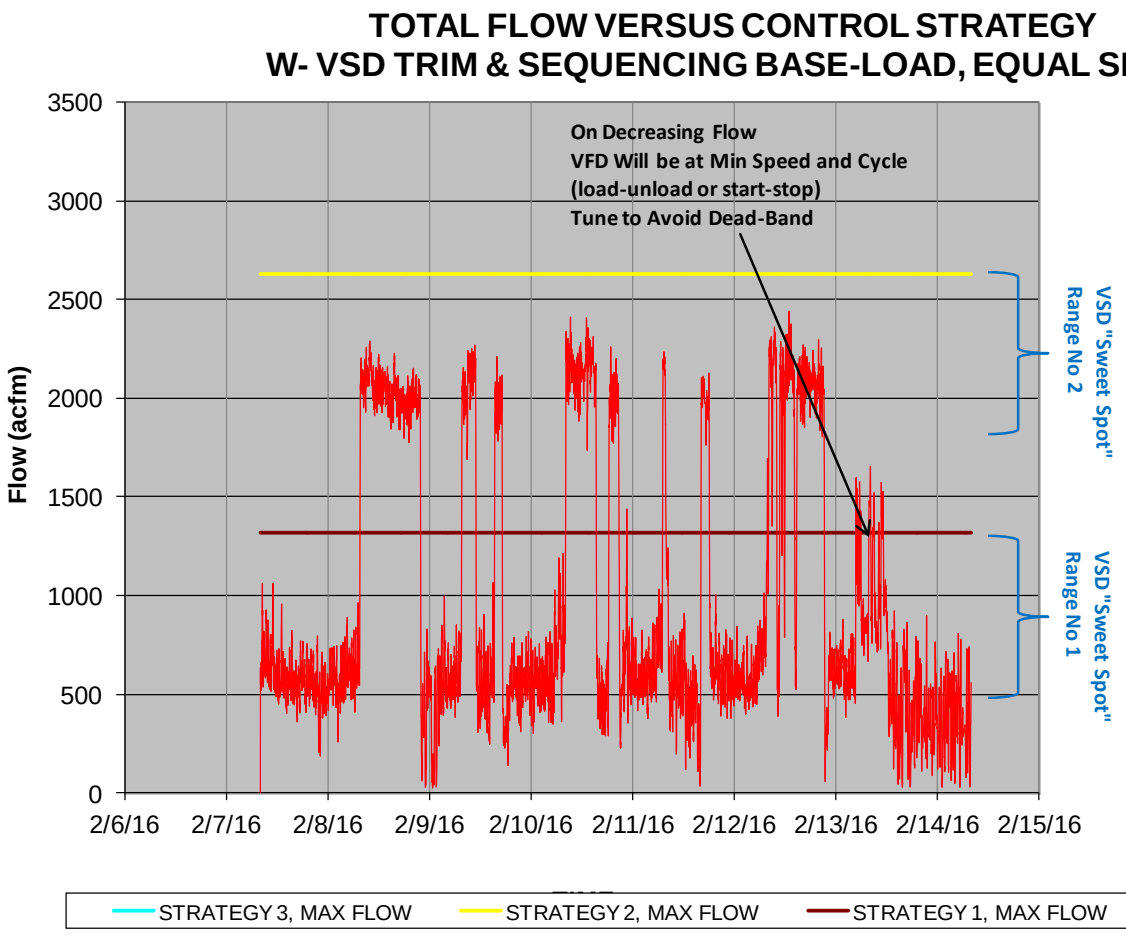
- Use Flow Meters if Possible
- Measure “System” Flow
- Or Calculate System Flow Correctly From Amps
- Convert to “acfm”
- Smooth Out “Noise”

Determine Flow Ranges for Trim



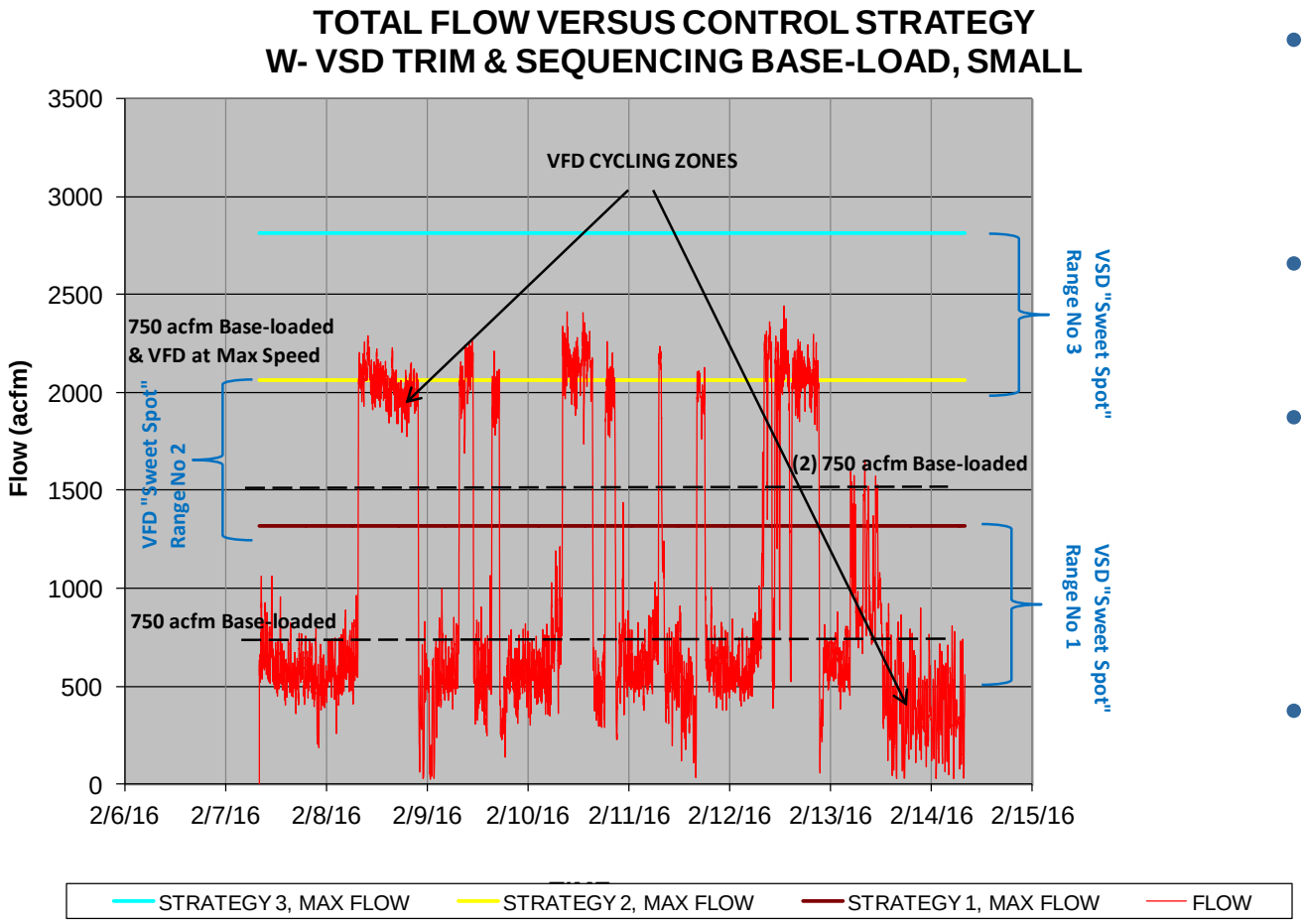
- Determine Variance in All "Modes"
- Look for Similar Min-Max Ranges
- Determine How Many Ranges to Map to

Size VSD Compressor Example 1: Equal Sizes



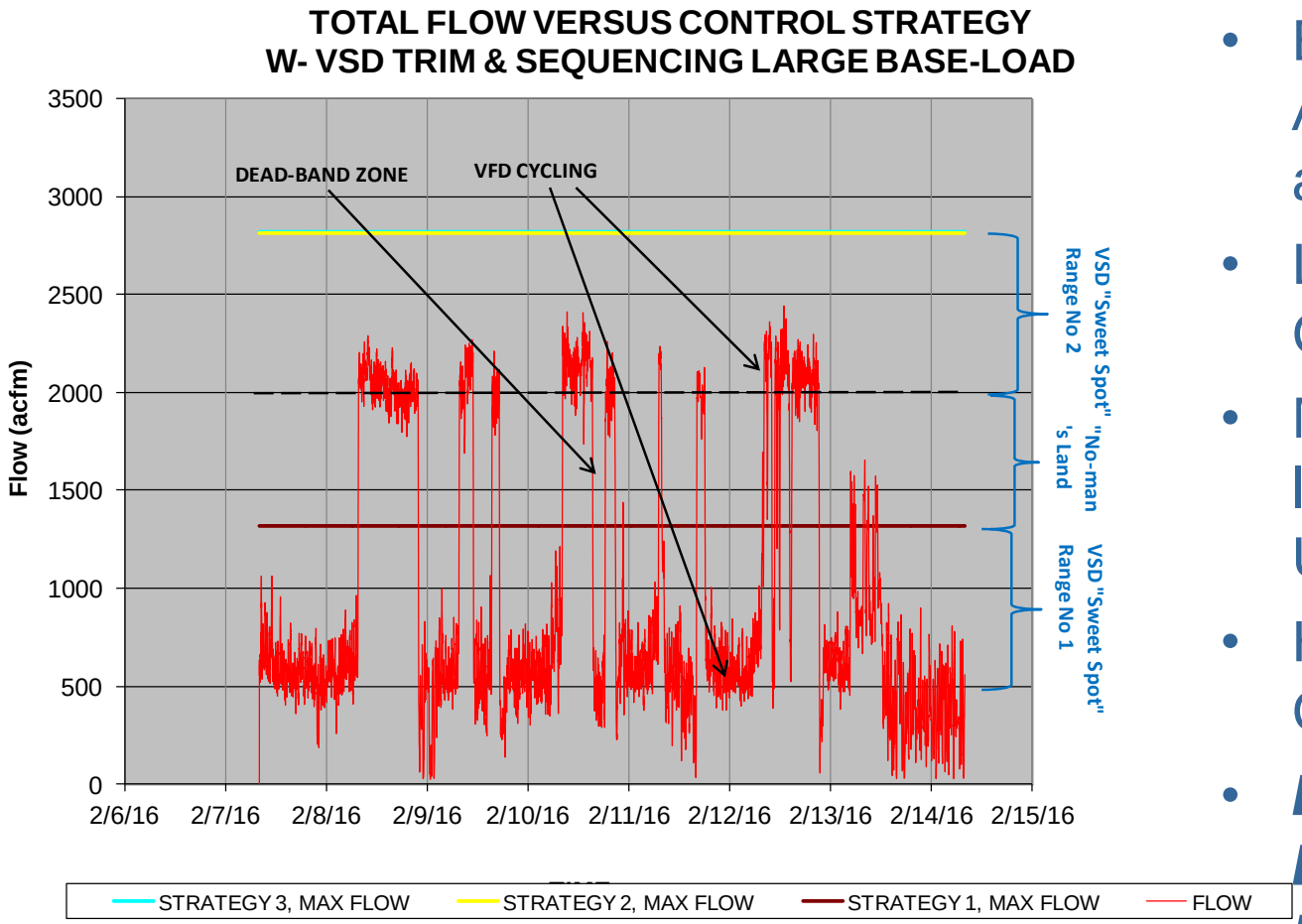
- Example 1: Assume Same Size Trim and Base, 1300 acfm/ea
- Low Flow: VSD Cycles
- High Flow, VSD in Sweet Spot
- Look Out for Mid Zone, 1300-1800 acfm, “Dead Band
- ***Equal OK for “2 Mode” Profile . BAD in Mid Range***

Size VSD Compressor Example 2

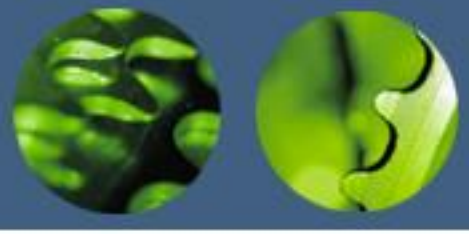


- Example 2: Assume (2) 750 acfm Base
- Low Flow, VSD Cycling
- High Flow, After 2nd Base Starts, VSD Swings Back, Cycling
- ***Small Base-load GOOD, Watch VSD Low Range***

Size VSD Compressor Example 3

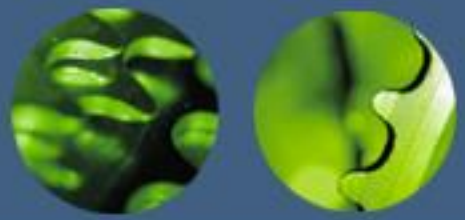


- Example 3: Assume (1) 2,000 acfm Base
- Low Flow, VSD Cycling
- Mid Flow, Base-load & VSD Cycle, Unstable
- High Flow, VSD Cycling
- ***Large Base-load BAD, Avoid Or Use Flow-based Controls***



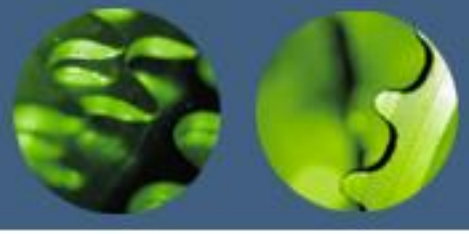
Summary – Sizing Criteria

- Ideally, Size VSD Compressor so its “Swing Range” is >= Largest Base-load Compressor Capacity, Usually about 1.5X BL acfm
- If not Possible, Consider 2+ VSD Compressors in a “Trim Set”



Integration and Master Control

- Common Header, Wet Side Preferably
- If Dry Side, Move VSD Pressure Sensing to Dry Side
- Use “Target” Algorithm if VSD Sized Right
- Use “Flow-based” Algorithm if VSD is Small
- Cluster Multiple VSDs as “Trim” if Needed
- Remote Set Point for VSD, in “Target”
- All Other Compressors are “Base-load”
- Have “Knobs” for Tuning



System Control Issues

- VSDs Are “Proportional Control” in Speed Range, and “Cycle” at Min Speed.
- Coordinate VSD and All Base-load Set Points w- Master Control, Avoid Local Control.
- All Compressors Must Sense Pressure at Same Point.
- Commission Well. Test and Tune Controls in Ranges Where Comps Shift.

Introduction to Sequencers

- Sequencers optimally stage multiple industrial compressors, running and loading only the minimum number required.

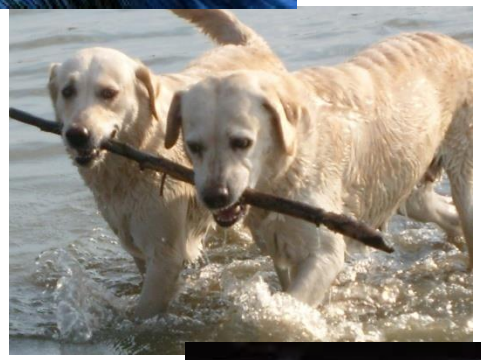
Target Algorithm

- Managing the running and loading of all compressors in one range surrounding a target pressure. This is done with either timers, rate-of-change, or other methods.

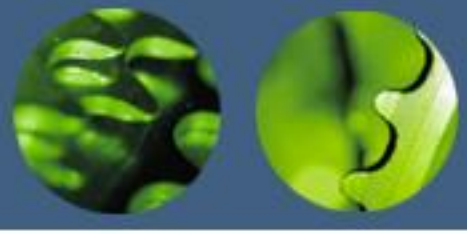
Custom Algorithms

- Flow-based

- Load-sharing



- Hybrid base-trim



Conclusions

- **System Design**
  - Common Header, Full Integration, Master Control, Commission Well
  - Simplify, Avoid PFCs Unless Master Controls Require
- **VSD Compressor Sizing**
  - Match to Flow Profile, VSD 1.5 x Base-load
  - Consider Multiple VSDs if Not Big Enough
- **Control Algorithm**
  - Target sequencer for VSD >1.5x BL
  - Flow-based or Load-sharing controls for smaller VSD

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About the Speaker

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

Steve Bruno, Atlas Copco

Atlas Copco

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Comparing VSD Compressor Efficiencies

Steve Bruno

Product Marketing Manager

Atlas Copco Compressors

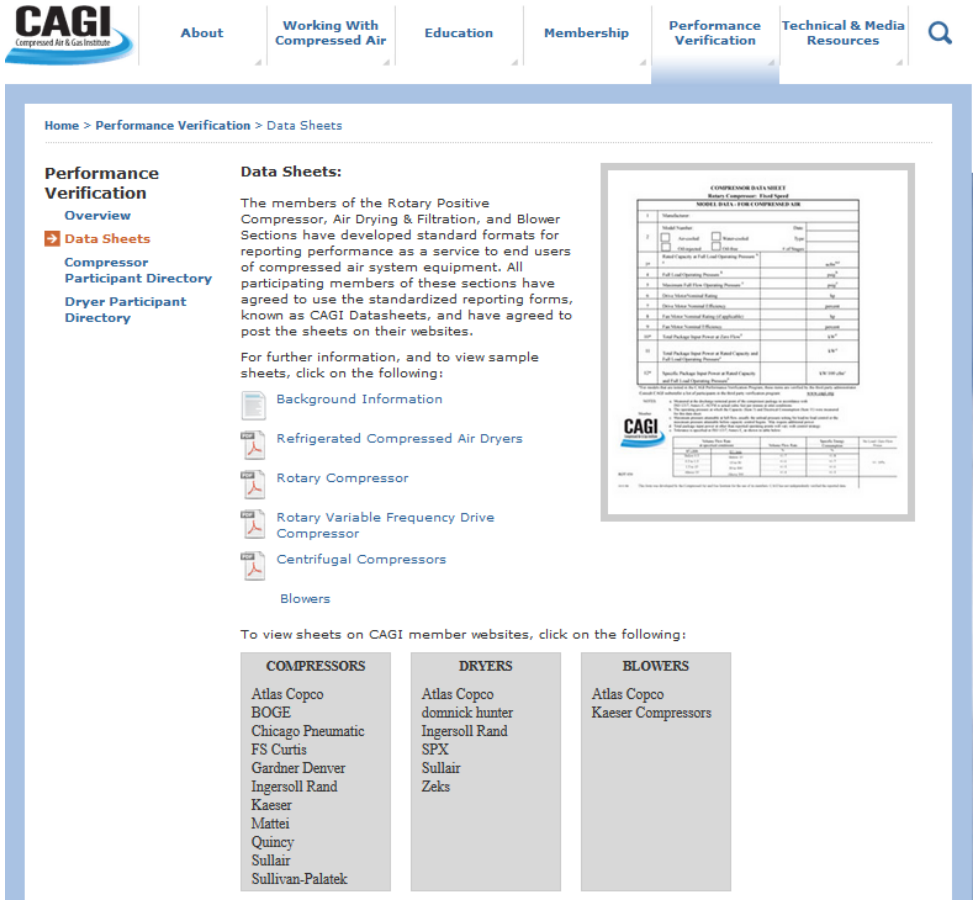
March 30, 2017

Agenda

- Comparing VSD Compressor Efficiencies
- Importance of a Flat Specific Power Curve
- Misconceptions of VSD compressors

Comparing VSD Compressor Efficiencies

- How efficient is your air compressor?
- WWW.CAGI.ORG



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Comparing VSD Compressor Efficiencies

- Sample CAGI sheet

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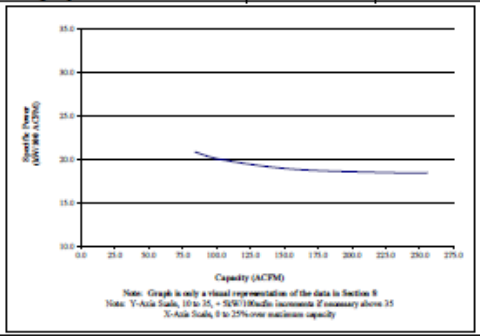
COMPRESSOR DATA SHEET
Rotary Compressor: Variable Frequency Drive

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				

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

*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:

CAGI Compressed Air and Gas Institute

Volume Flow Rate at specified conditions		Volume Flow Rate	Specific Energy Consumption	No Load / Zero Flow Power
m^3/min	cfm	%	%	
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.

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Comparing VSD Compressor Efficiencies

- Sample CAGI sheet

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

Comparing VSD Compressor Efficiencies

- Sample CAGI sheet

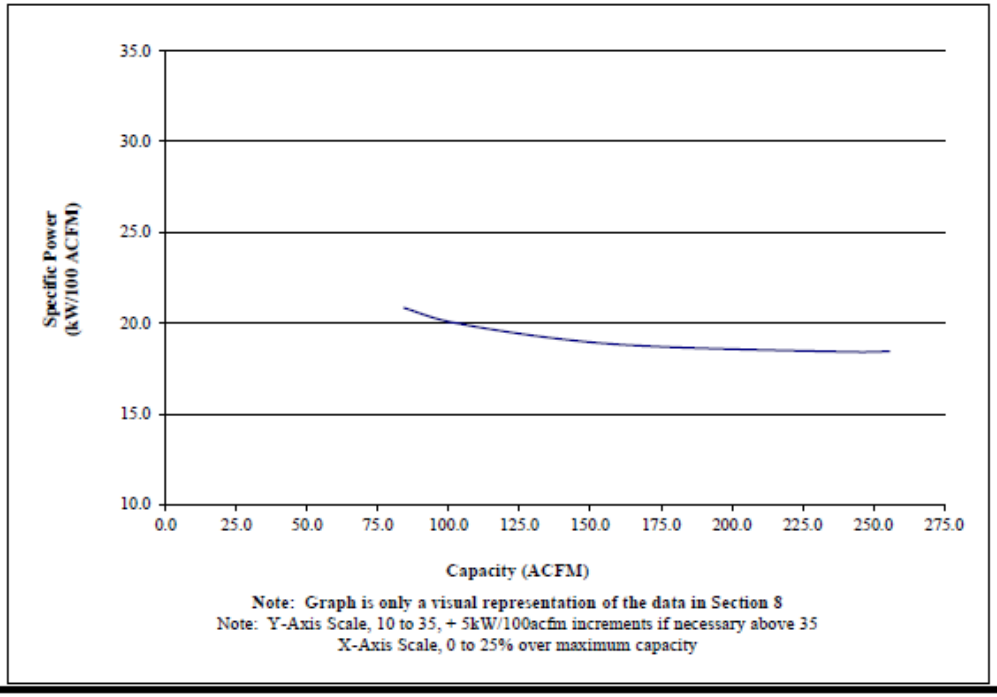
COMPRESSOR DATA SHEET

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

Comparing VSD Compressor Efficiencies

- Performance at rated PSI (125psi)

	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

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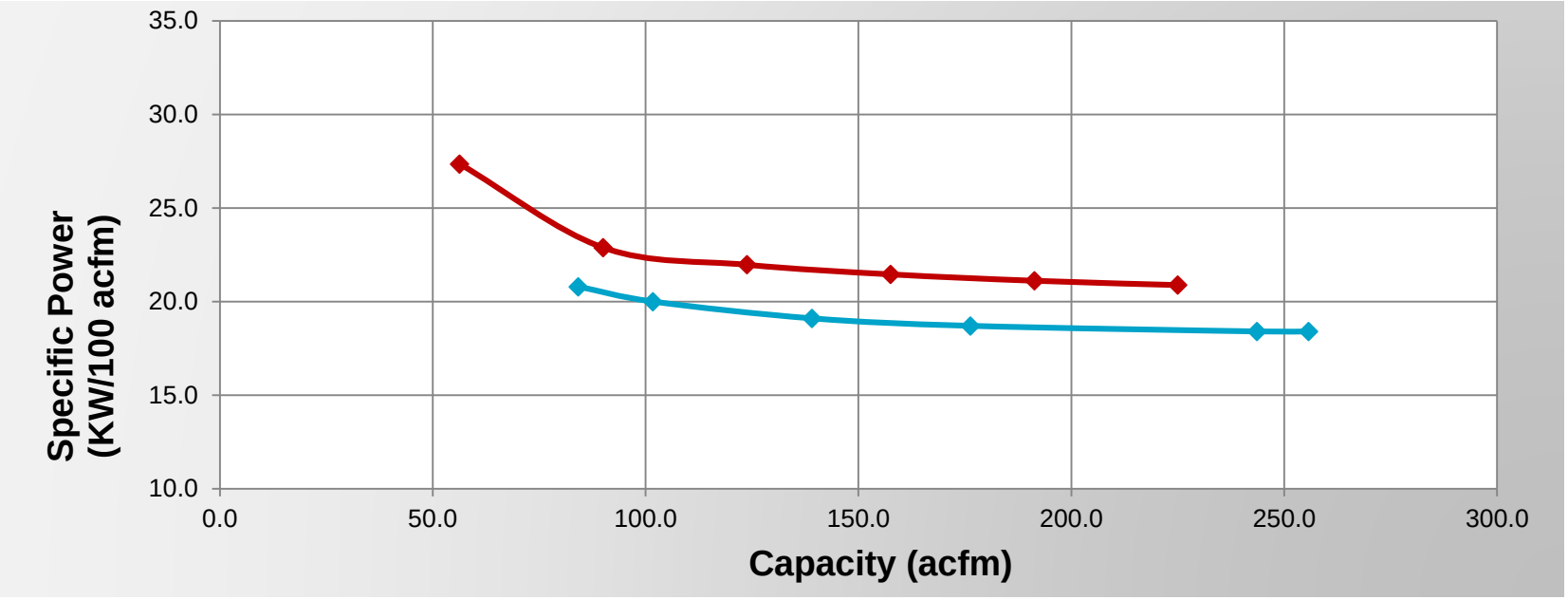
Comparing VSD Compressor Efficiencies

Compressor A			Compressor B		
Input Power (kW)	Capacity (acfm)	Specific Power (kW/100cfm)	Input Power (kW)	Capacity (acfm)	Specific Power (kW/100cfm)
17.6	84.2	*20.8*	15.4	56.3	*27.4*
20.4	101.7	*20.0*	20.6	90.0	*22.9*
26.6	139.1	*19.1*	27.2	123.8	*22.0*
33.0	176.3	*18.7*	33.8	157.5	*21.5*
44.8	243.6	*18.4*	40.4	191.3	*21.1*
47.2	255.7	*18.4*	47.0	225.0	*20.9*



Comparing VSD Compressor Efficiencies

- How much money will I save?
  - At 200 CFM;
    - 2.4 kw/100 CFM improvement for 6000hrs will save ~ $3,000
  - At 150 CFM;
    - 2.5 kw/100 CFM improvement for 6000hrs will save ~ $2,300

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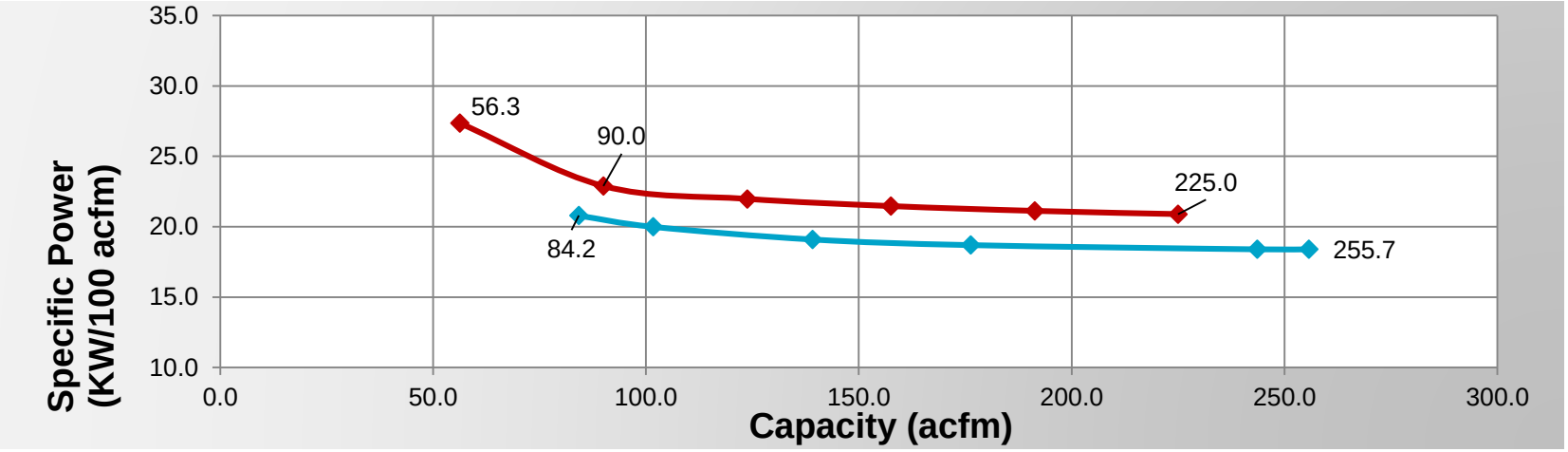
Importance of a Flat Specific Power Curve

- Each VSD CAGI Sheet will show the efficiency of the compressor at various speeds.
- You'll want the compressor to have the maximum efficiency at the speed you will be using it and having
- A flat curve allows for maximum efficiency throughout the entire range.



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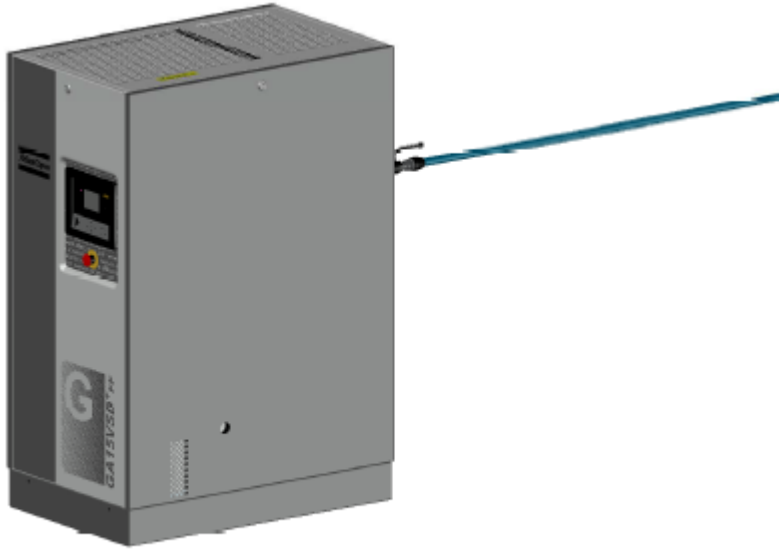
Misconceptions of VSD compressors

Not needing any storage downstream from a VSD

Misconceptions of VSD compressors

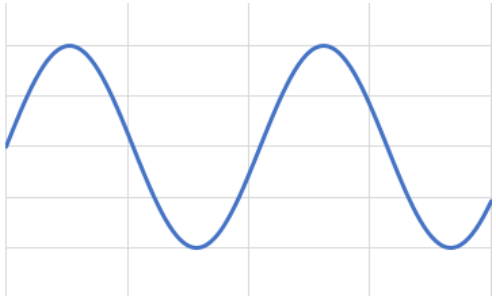
Not needing any storage downstream from a VSD

- VSDs can mirror demand if changes are very slow
- System pressure will be remain stable

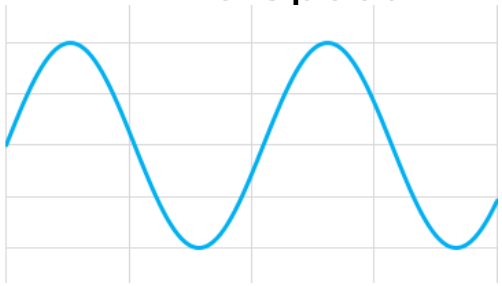


Atlas Copco VSD Compressor - No Receiver

System Demand



Drive Speed



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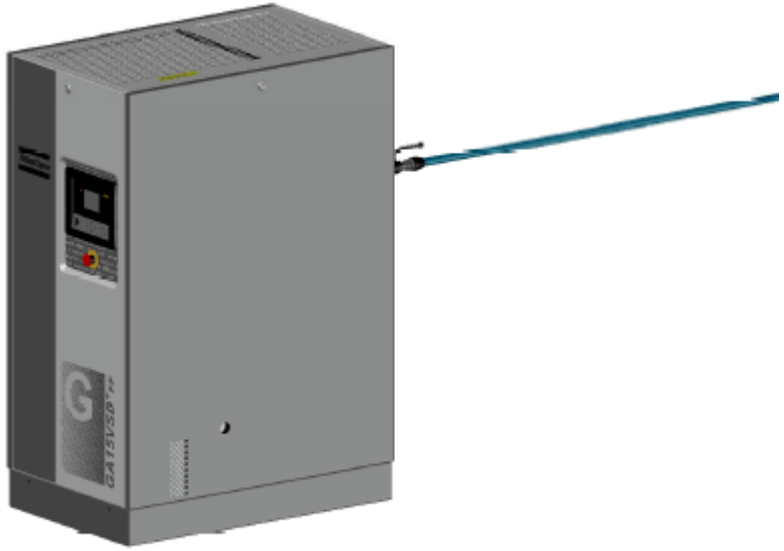
Misconceptions of VSD compressors

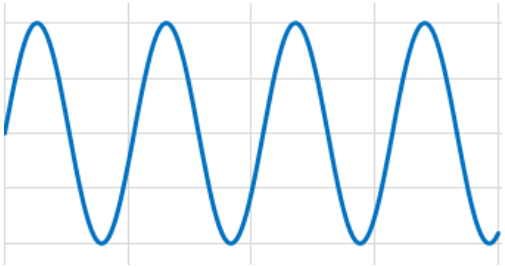
Not needing any storage downstream from a VSD

- VSDs cannot react instantaneously to rapid changes in demand
- System pressure will vary widely

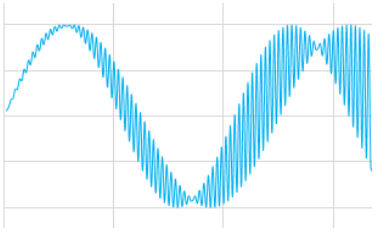


Atlas Copco VSD Compressor - No Receiver

System Demand



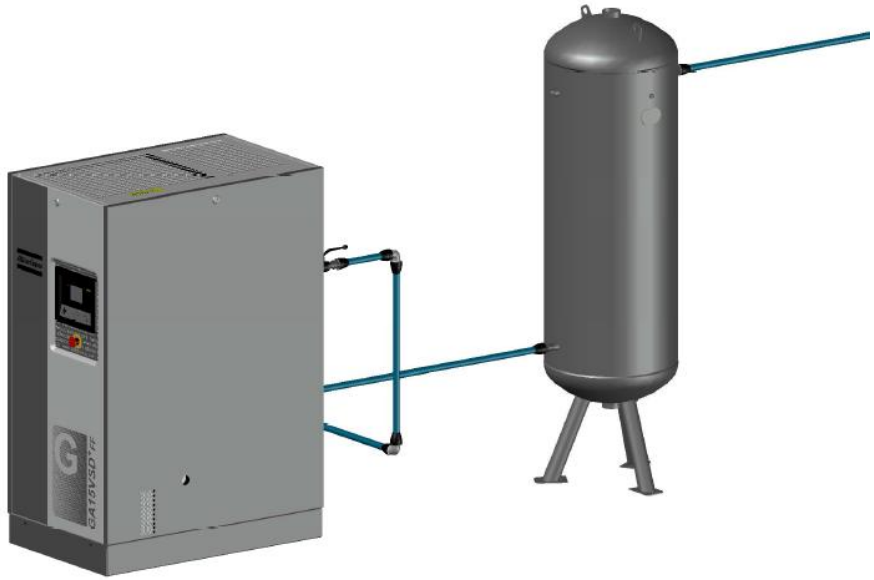
Drive Speed



Misconceptions of VSD compressors

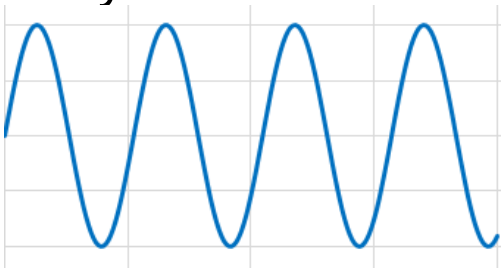
Not needing any storage downstream from a VSD

- Installing a receiver will dampen the effect of system demand
- System pressure will remain steady

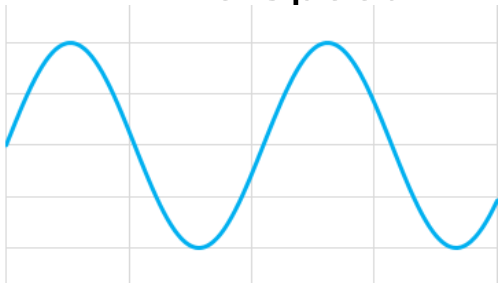


Atlas Copco VSD Compressor with a Receiver

System Demand

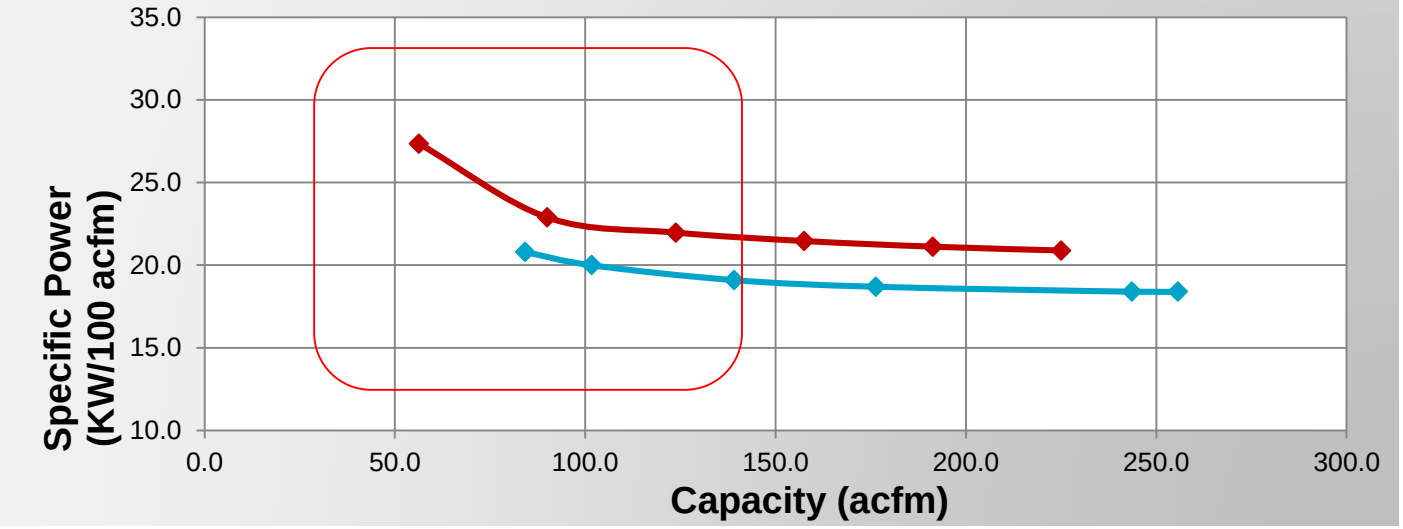


Drive Speed



Misconceptions of VSD compressors

- Oversizing a compressor
  - Most common reason for failures of VSD compressors
  - Compressor oil does not heat up
  - Condensate is not removed from oil
  - Oil's ability to cool, seal and lubricate the airend is diminished
  - Lower speed = lower motor cooling = motor overheating
  - Wasting money



Misconceptions of VSD compressors

Don’t size a compressor on what you hope to grow into.

Buy for what you know that you’ll need.

Thank you!

Steve Bruno

Product Marketing Manager

Oil Injected Screw Compressors 30kW – 90 kw and Controls

Atlas Copco Compressors LLC

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About the Speaker

•CEO of VPInstruments

Pascal van Putten, VPInstruments

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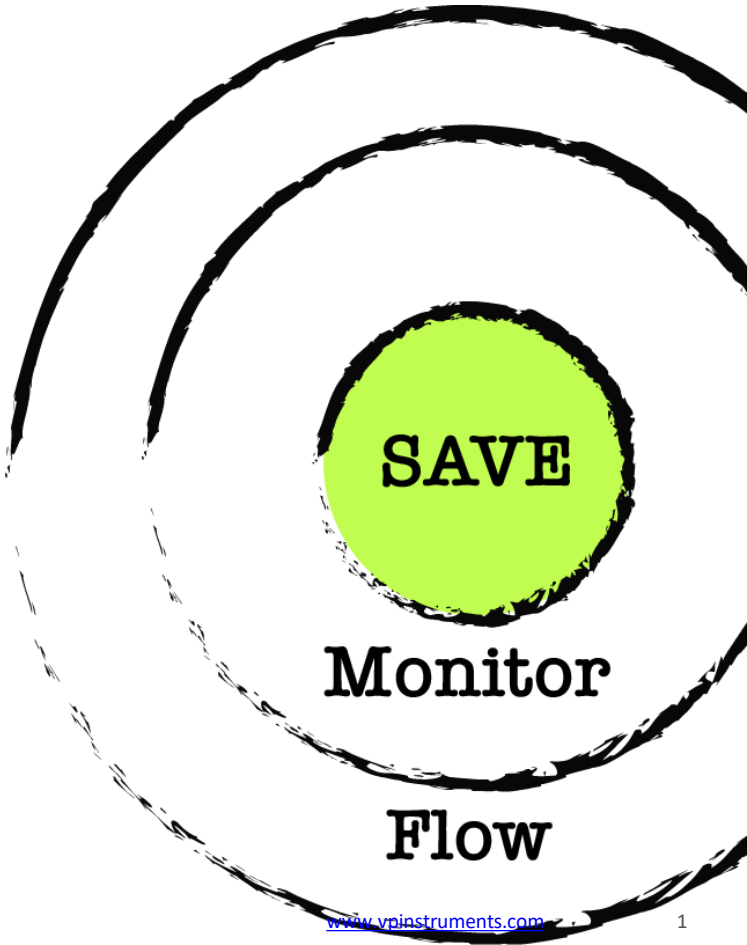
Why flow measurement?

The air consumption fingerprint

Pascal van Putten, CEO
VPInstruments



Compressed Air Best Practices® Magazine

Webinar March 30

Contents

VPInstruments

We provide easy insight in energy flows™

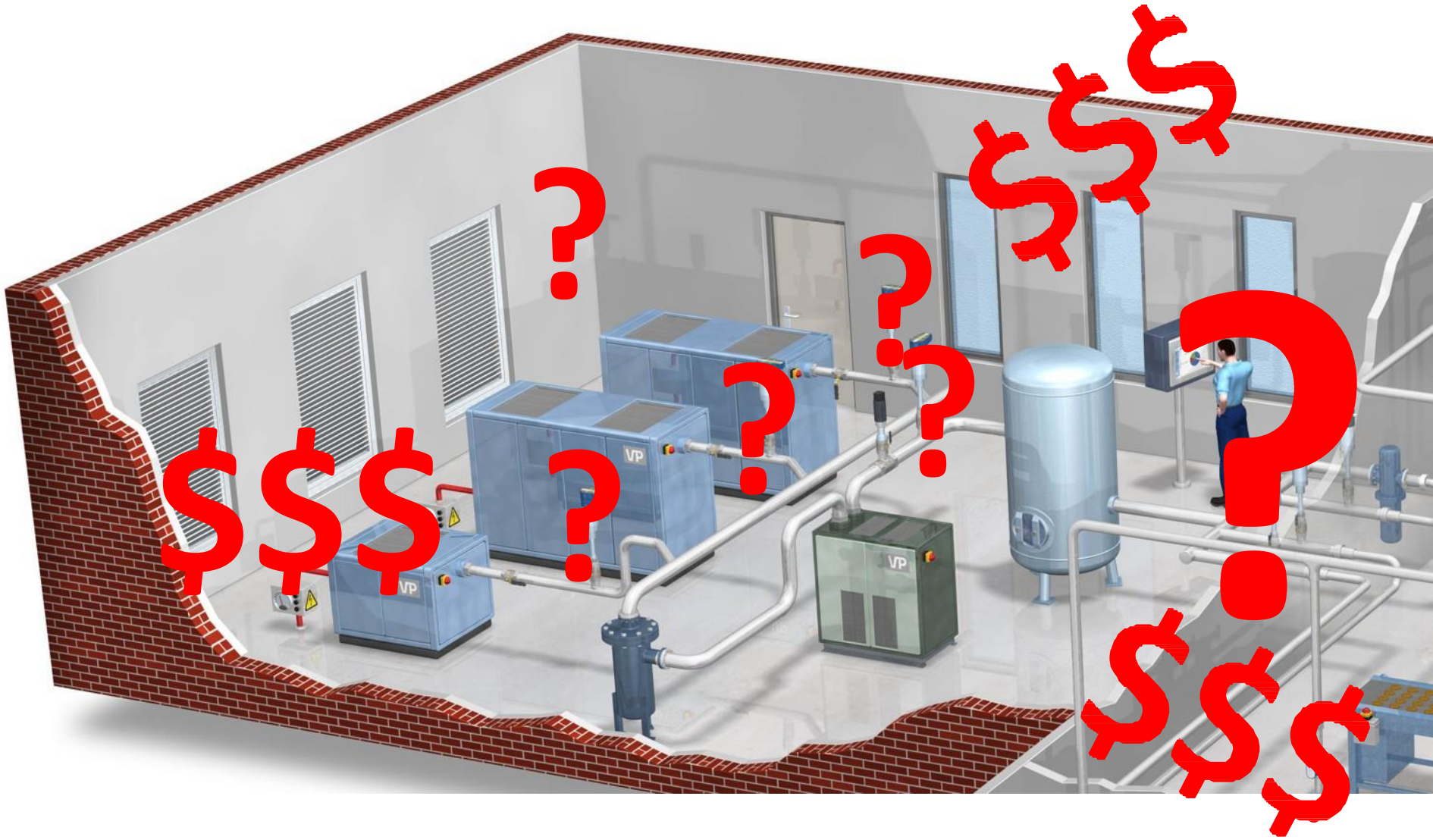
We believe that with our easy to use products and monitoring software, we can help our customers to discover where, when and how much energy they can save.

Why install a flow meter?

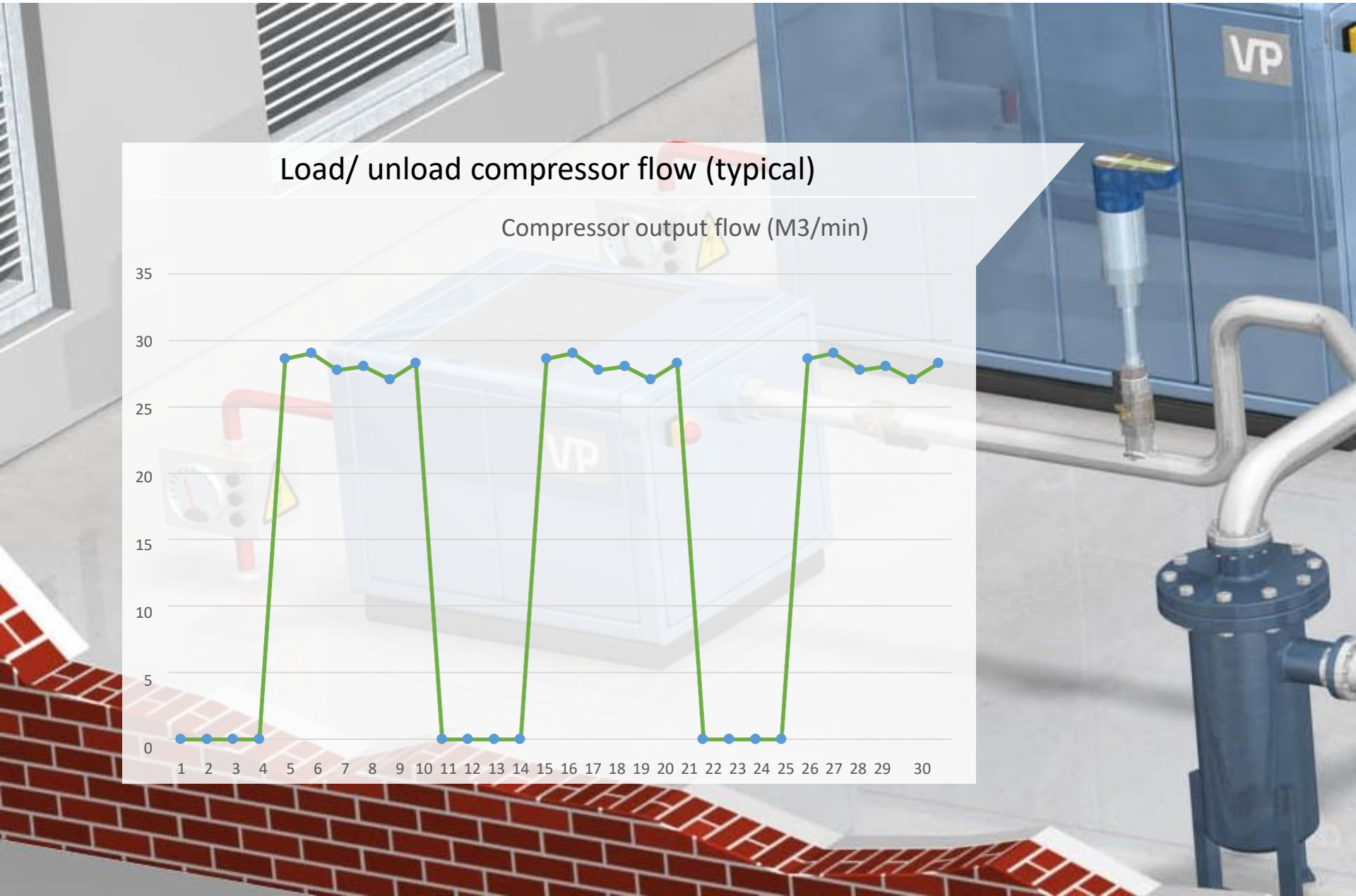
Keep your factory in shape!

- Make the right choices based on **facts**
- **Reduce** leakage and associated energy costs
- Eliminate **excessive demand**
- Allocate **costs**
- Measure flow, pressure and temperature together

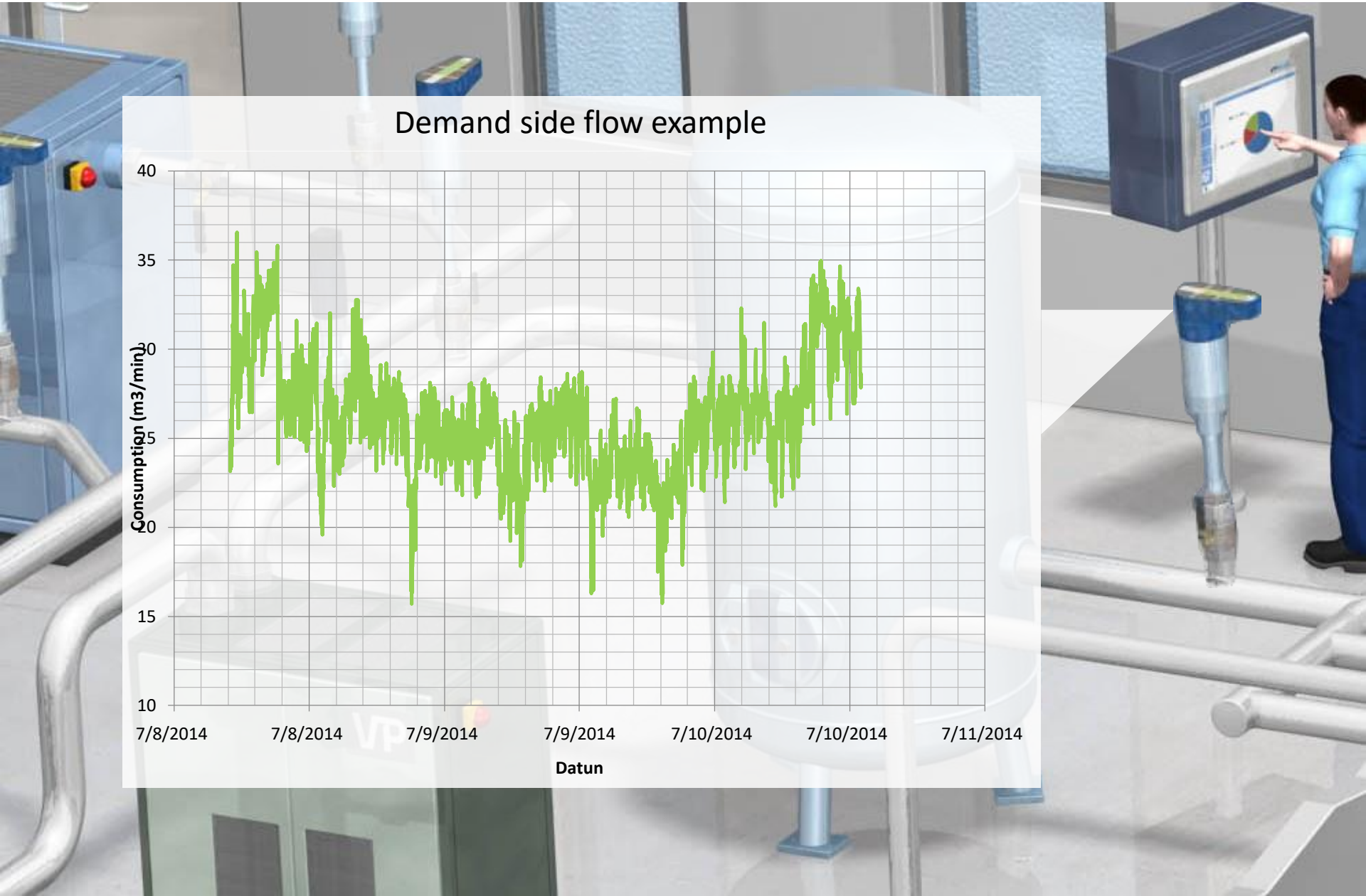
Where to install a flow meter?



Where to install a flow meter?



Where to install a flow meter?



Where to install a flow meter

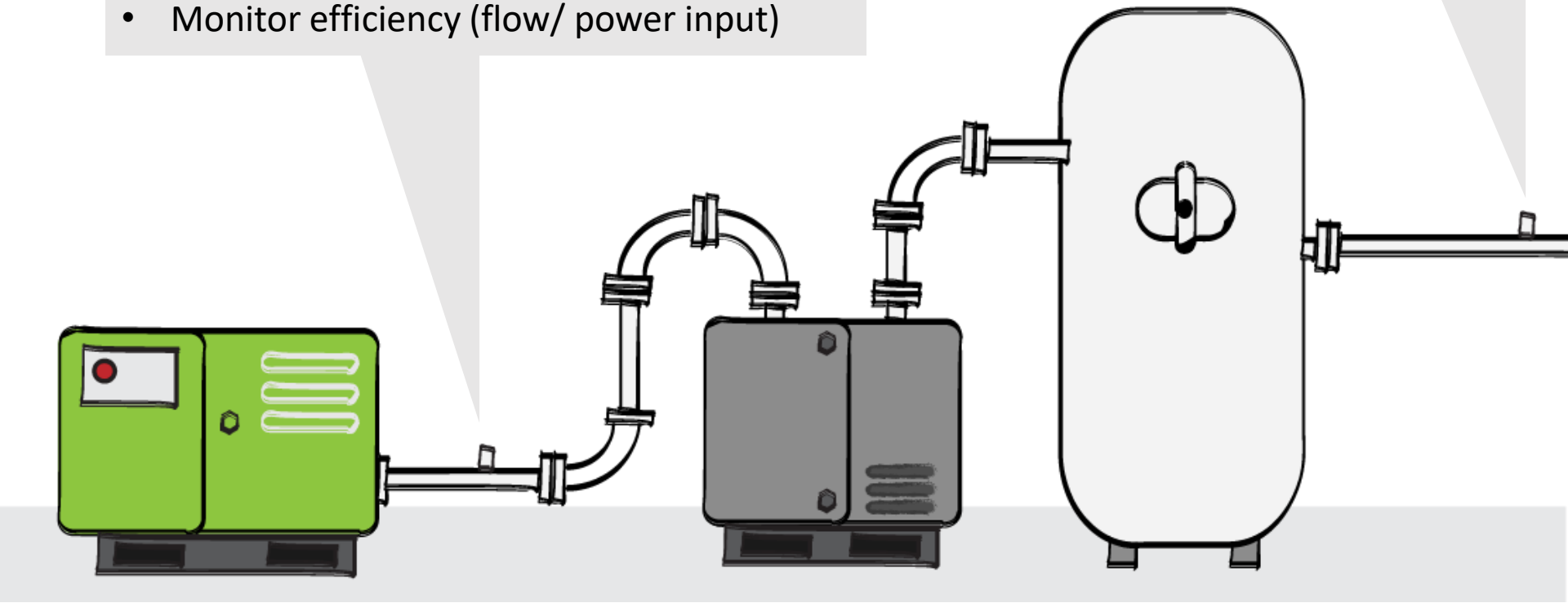
What's your goal?

After receiver:

- Trend the entire demand side
- Alarm on excessive flows
- Allocate costs
- Determine leakage baseload

Compressor discharge:

- Trend compressor performance over time
- Monitor efficiency (flow/ power input)



Where to install a flow meter

Common challenges

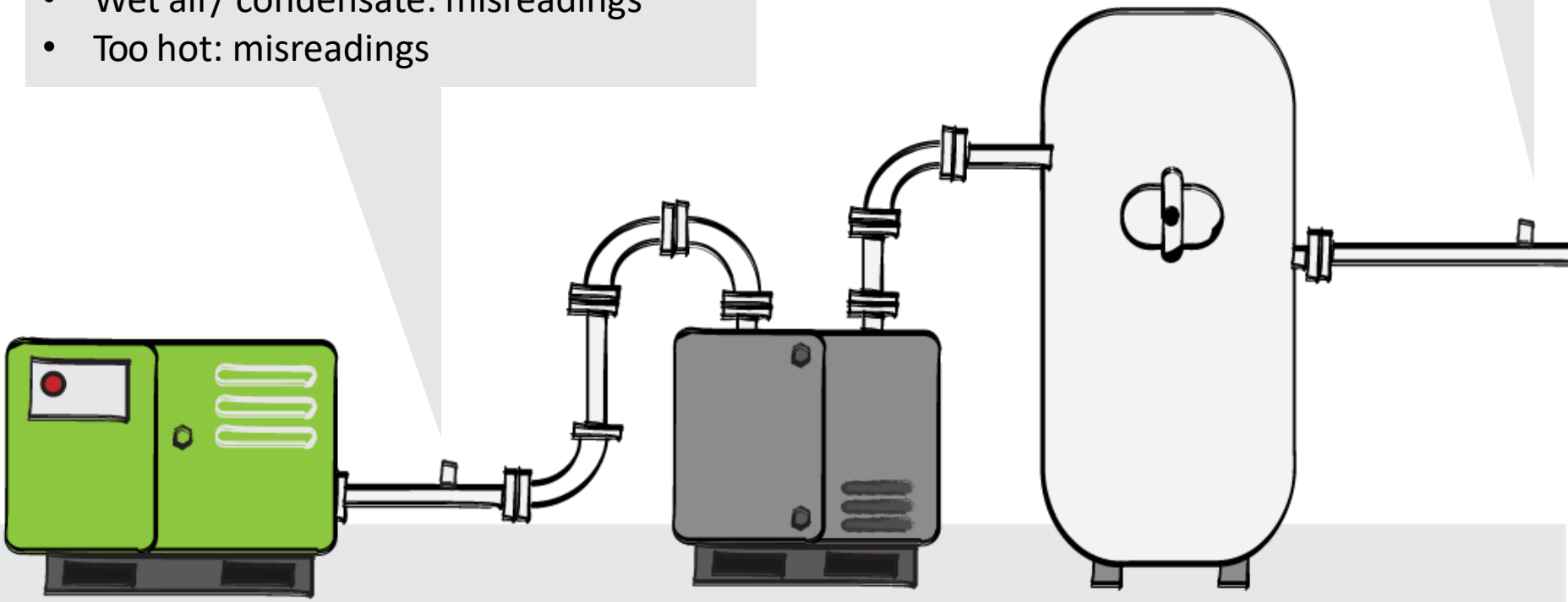
After receiver:

- Short pipe: flow profile issues
- Reverse flow: use bi-directional
- Oversized/undersized pipes

Compressor discharge:

- Short pipe: flow profile issues
- Undersized pipes
- Wet air/ condensate: misreadings
- Too hot: misreadings

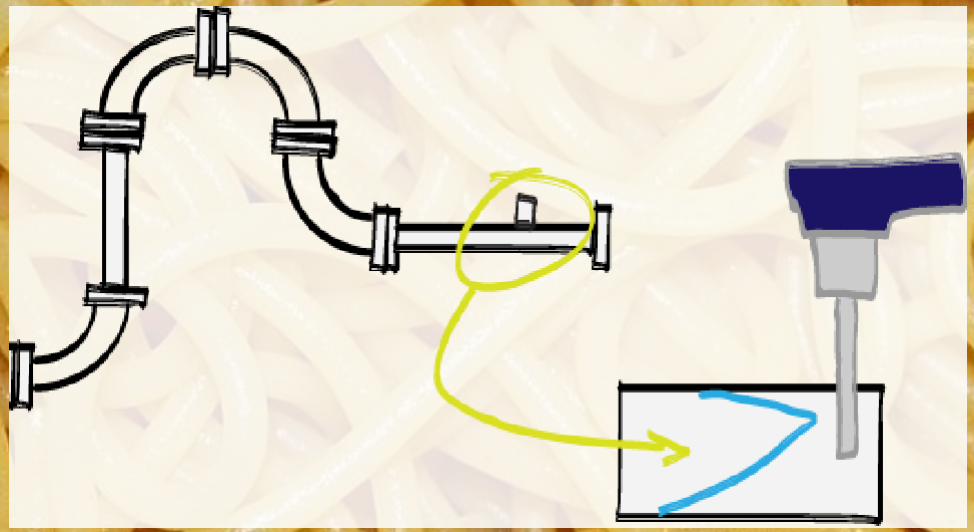
After the receiver is the best place for demand profile recording



Challenges

Common challenges top 3:

1.



Pipe “spaghetti”
Short meter run:

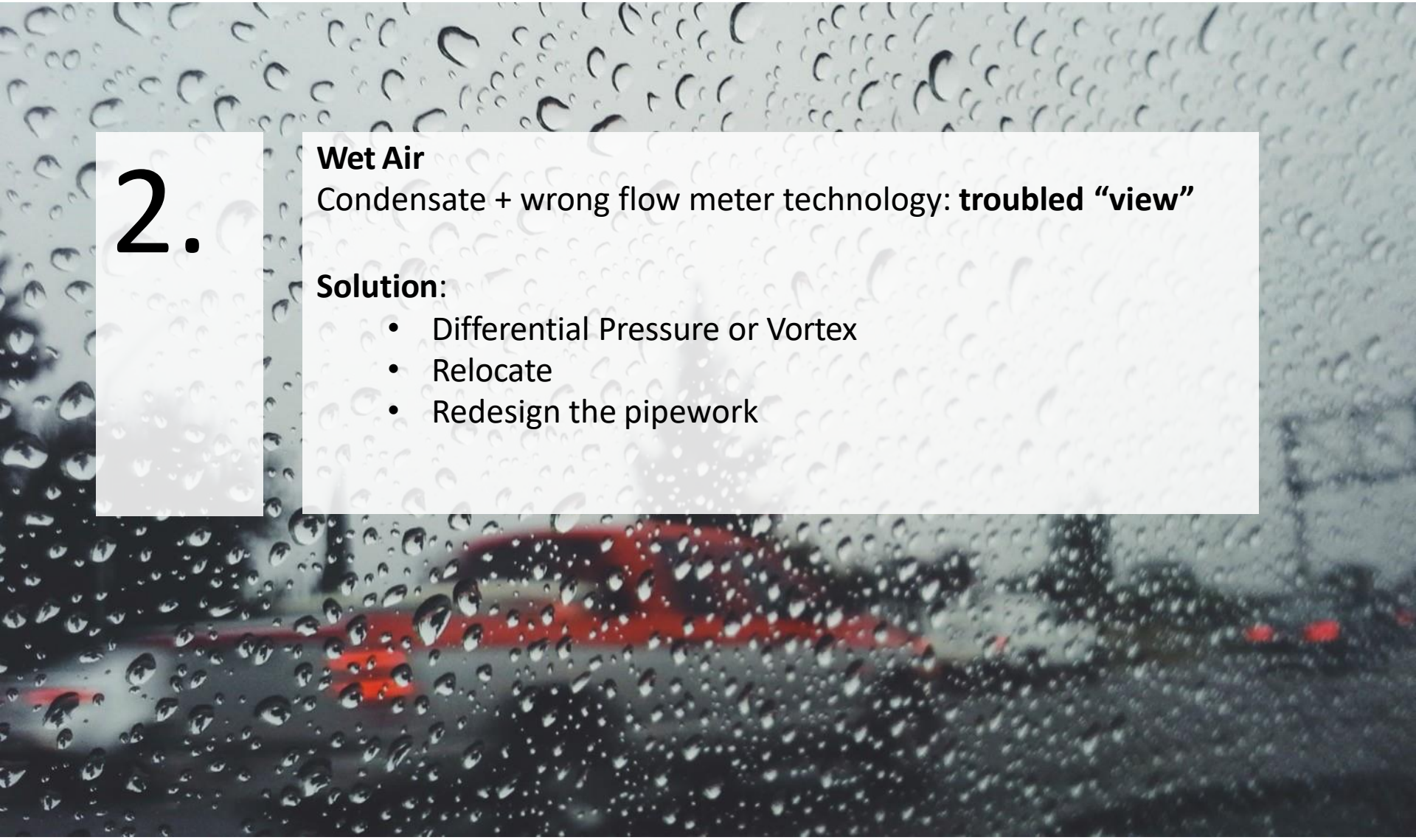
- Swirl
- Distorted flow profile

Solution:

- Relocate
- Change pipework
- Conditioners (Pressure loss)

Challenges

Common challenges top 3:



2.

Wet Air

Condensate + wrong flow meter technology: **troubled “view”**

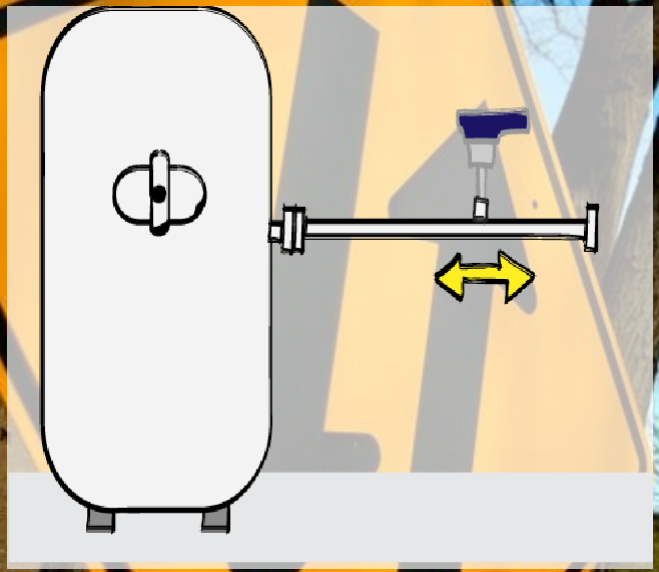
Solution:

- Differential Pressure or Vortex
- Relocate
- Redesign the pipework

Challenges

Common challenges top 3:

3.



Reverse flow (multiple receivers)

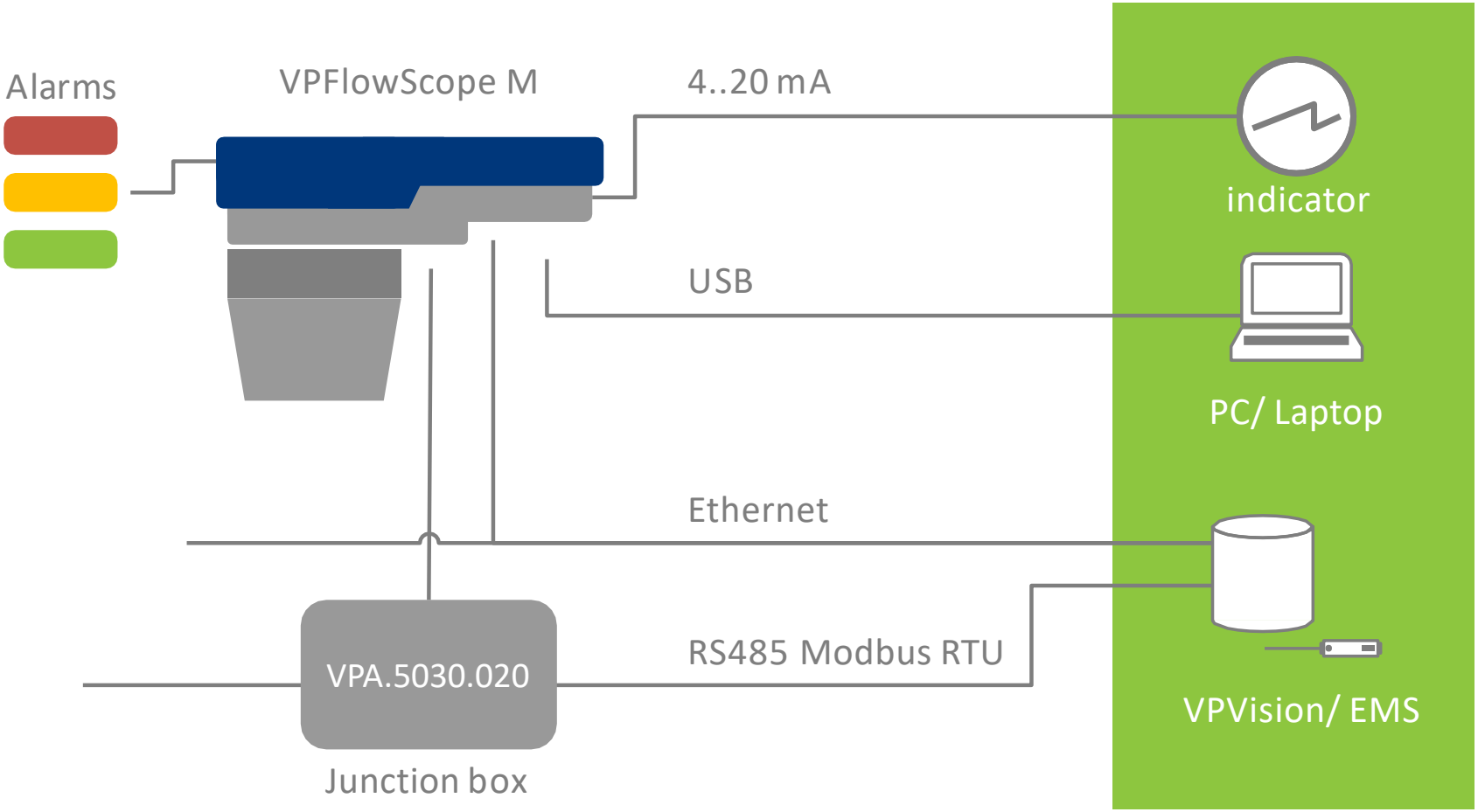
- Mistaken for consumption
- Wrong accounting
- Wrong compressor sizing

Solution:

- Bi-directional flow meter

How to capture the data

From data logging to real time monitoring



How to capture the data

From data logging to real time monitoring

Quick scan/ audits:

- Integrated display and data logger
- PC Software/ spreadsheet

Permanent:

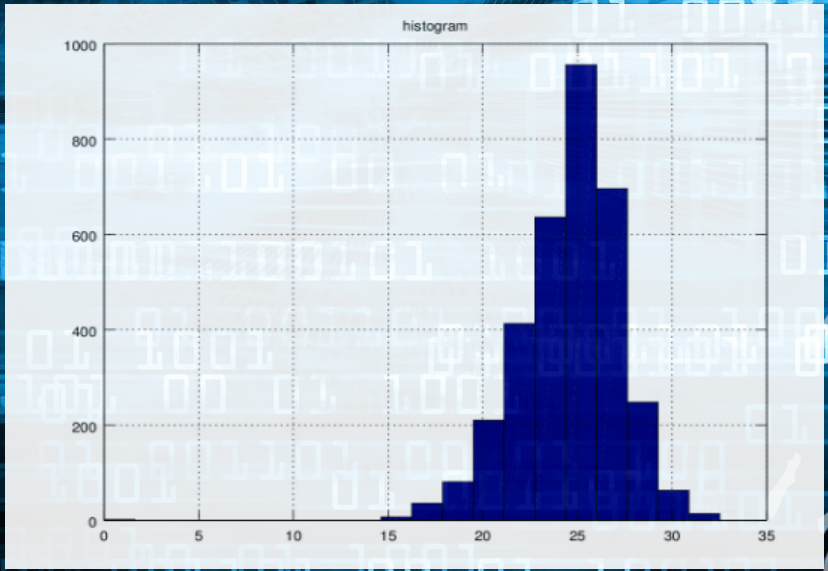
- “Old school”: 4 ... 20 mA/ pulse to DCS or BMS
- Advanced: Modbus RS485
- Industry 4.0: Ethernet or Wi-Fi

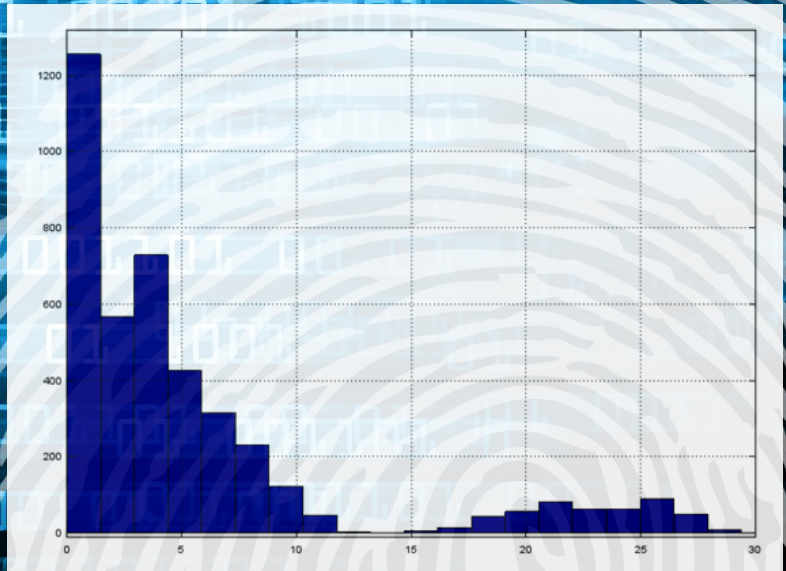
What's your factory fingerprint?

Histograms: Another look at consumption data

Air compressors, production departments & pneumatic devices leave unique "fingerprints"

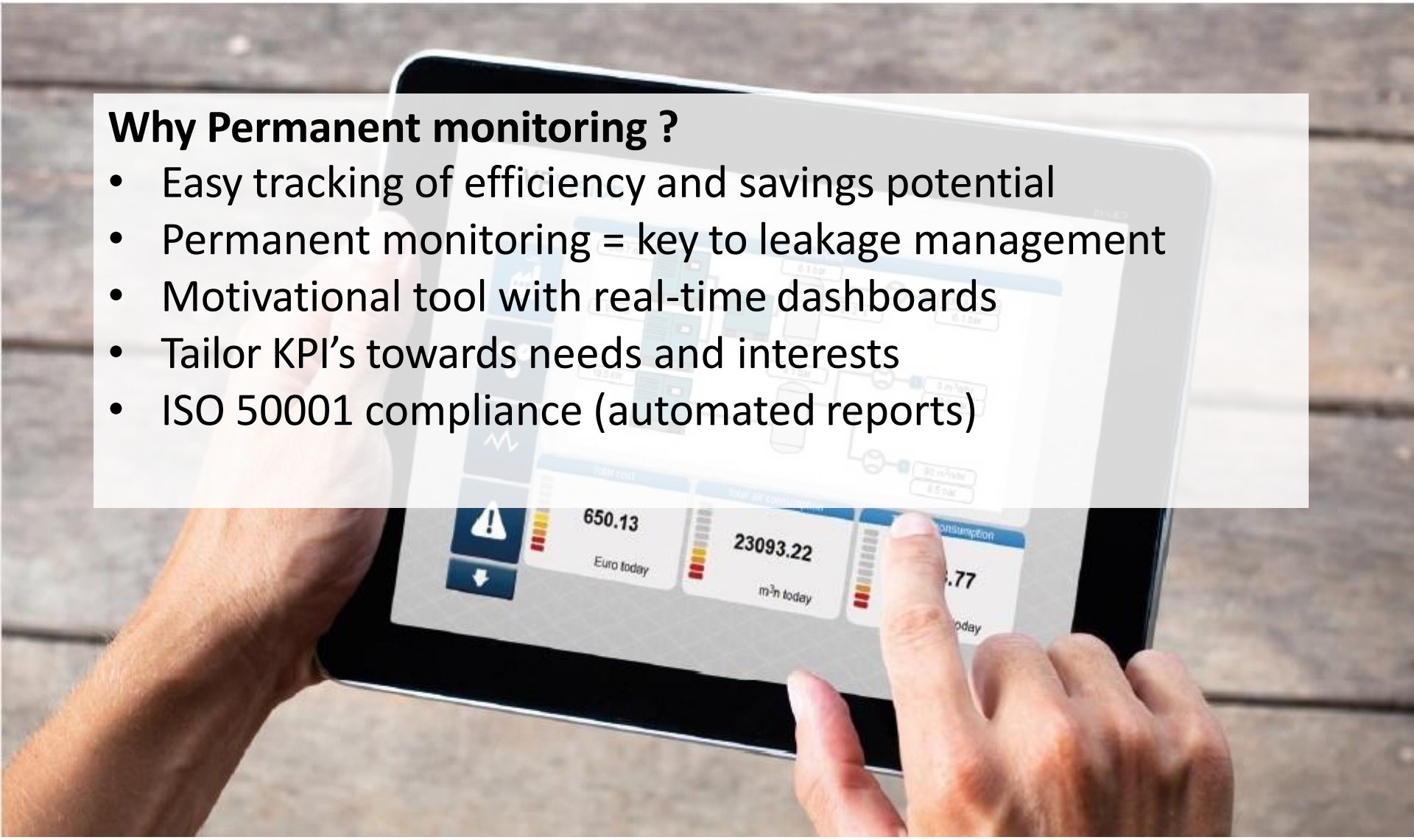
- Histogram is a powerful way to visualize
- Application: Compressor sizing, leak detection





Permanent energy monitoring software

Provides real-time insight, alarms and reports



Why Permanent monitoring ?

- Easy tracking of efficiency and savings potential
- Permanent monitoring = key to leakage management
- Motivational tool with real-time dashboards
- Tailor KPI's towards needs and interests
- ISO 50001 compliance (automated reports)

Tips & conclusions

- Define your goal, then decide on equipment
- Location of flow meter is very important
- Analyze and visualize data: KPIs, graphs and alarms → tailor it to specific needs
- Histogram: ”fingerprint” of factory or proces

Try online histogram software yourself:

http://www.shodor.org/interactivate/activities/Histogram/

https://plot.ly/create/histogram/

Thank you!

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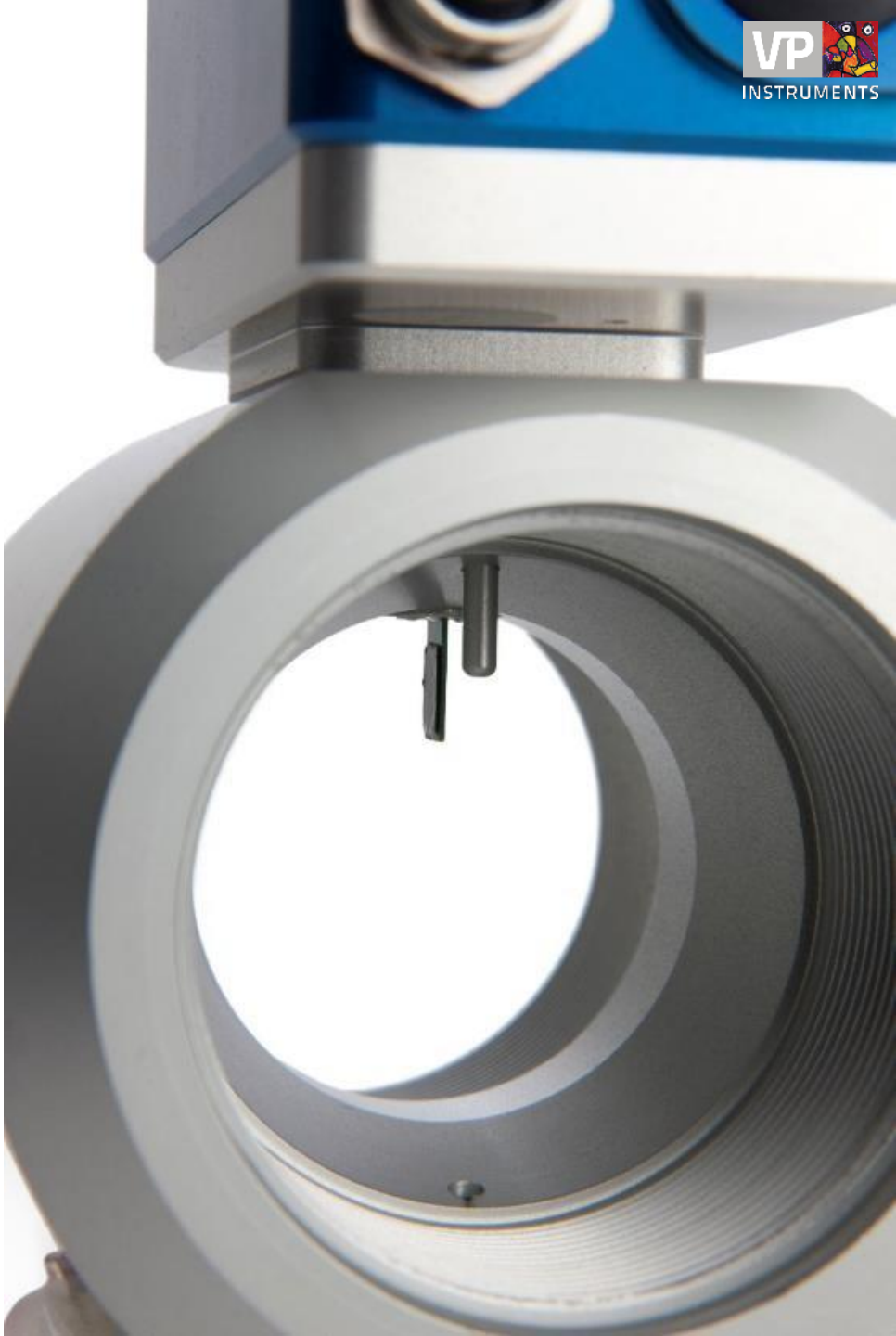

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When to Install a VSD Air Compressor

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