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Integrating Aeration Blowers with Most-Open-Valve

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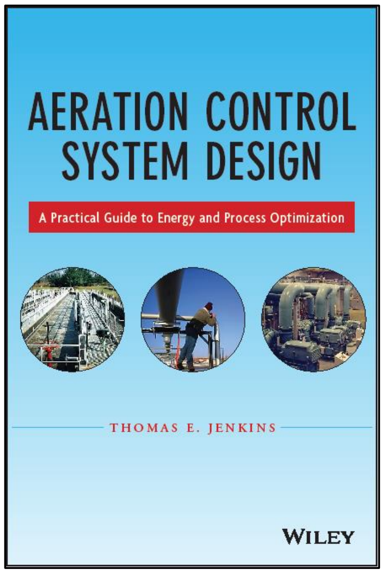

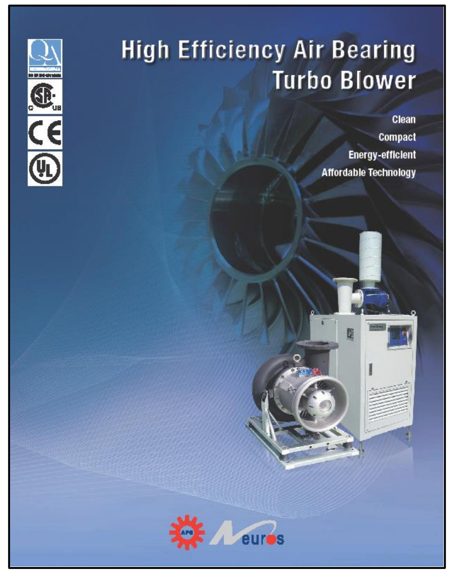

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Integrating Aeration Blowers with Most-Open-Valve

Introduction by Rod Smith, Publisher

Blower & Vacuum Best Practices Magazine

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About the Speaker

Tom Jenkins P.E.
JenTech Inc

- President of JenTech Inc.
- Over 30 years of experience with aeration blowers and blower controls

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Integrating Blowers & Most-Open-Valve Control

October 26, 2017
1:00 PM CST

Thomas E. Jenkins
President, JenTech Inc.
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Topics

- The benefit of Most-Open-Valve (MOV) control
- Air flow control basics
- Pressure based systems and MOV
- Flow based systems and MOV
- Effects of blower and control type on MOV benefits

MOV Benefits

- MOV isn't part of blower control or DO/aeration control
  - Must integrate with both
- MOV is a method for reducing system pressure requirements
- **The benefit of MOV is reduction of power required**

MOV Benefits

- Blower power is a function of several parameters:

$$P_{wa} = \frac{Q_s \cdot T_i}{\eta_{wa} \cdot 3131.6} \cdot \left[\left(\frac{p_d}{p_i} \right)^{\frac{k-1}{k}} - 1 \right]$$

$$\frac{k-1}{k} \approx 0.283$$

P_{wa} = wire-to-air power, kW
η_{wa} = wire to air efficiency, decimal (includes blower , motor, and VFD)
T_i = inlet air temperature, °R
p_d, p_i = discharge and inlet pressure, psia
k = ratio of heat capacity = C_p/C_v, dimensionless
Q_s = flow rate, SCFM

Air Flow Control Basics

- Efficiency is determined by the blower system design
  - It varies within the operating range
- Temperature, inlet pressure, and k are outside the operator’s control
- Flow rate is dictated by process demand
  - Especially with automatic DO control
- Discharge pressure is a function of air flow and system resistance to flow

Air Flow Control Basics

- Discharge pressure is a function of air flow and system resistance to flow

$$p_{total} = d \cdot 0.433 + k_f \cdot Q_s^2$$

p_{total} = total discharge pressure, psig
d = depth of water at top of diffuser, feet
(Note that depth varies for some applications, SBR, AD, EQ)
k_f = constant of proportionality for friction, psi/SCFM^2
Q_s = flow rate, SCFM

- k_f includes cumulative effects of friction in pipe, diffusers, and air flow control valves

Air Flow Control Basics

- k_f for valves is usually expressed as C_v

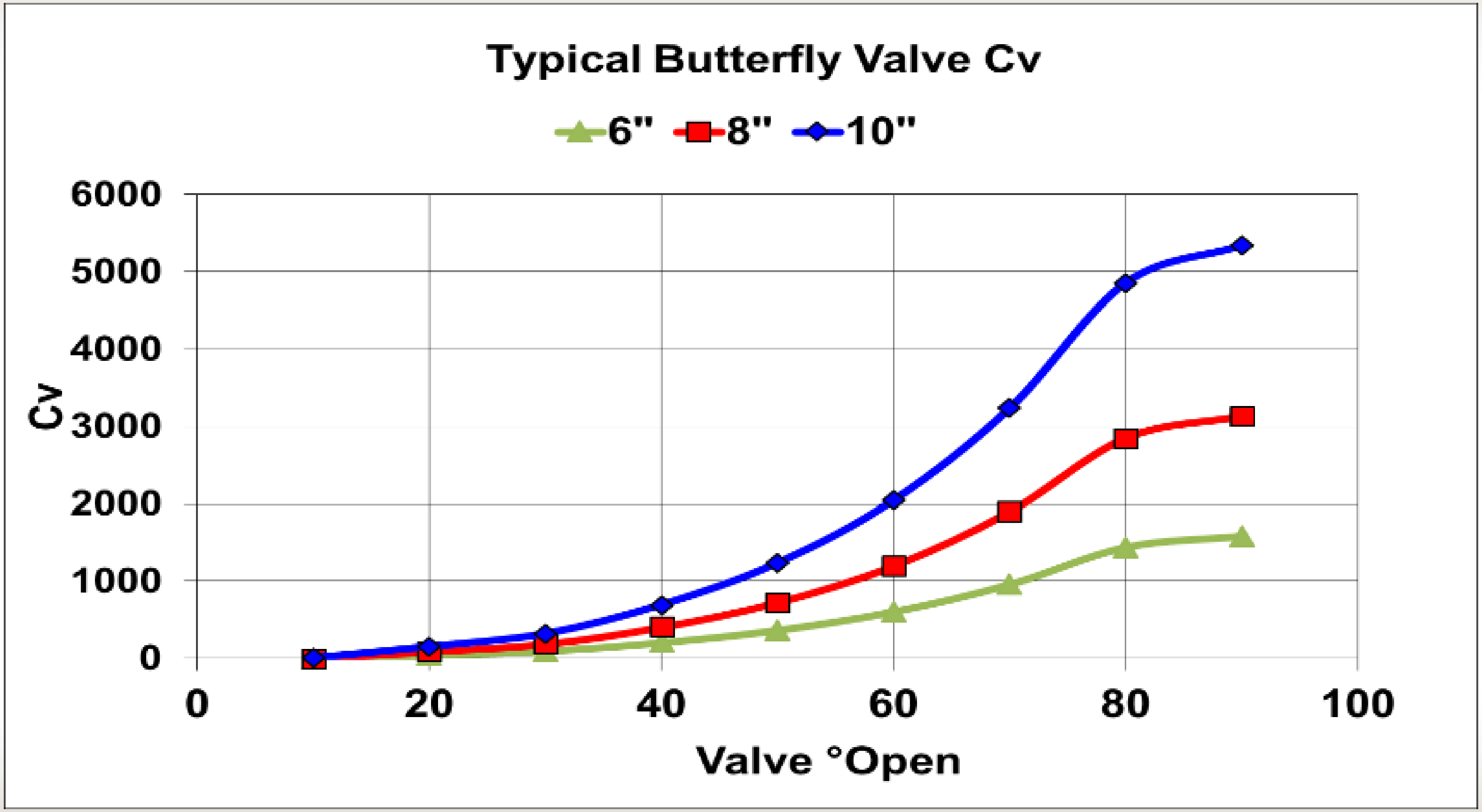
$$\Delta p_v = \left(\frac{Q_s}{22.66 \cdot C_v}\right)^2 \cdot \frac{SG \cdot T_u}{p_u}$$

Where:

Δp_v	= pressure drop across the valve, psi
Q_s	= air flow rate, SCFM
C_v	= valve flow coefficient from manufacturer's data, dimensionless
SG	= specific gravity, dimensionless, = 1.0 for air
T_u	= upstream absolute air temperature, °R
p_u	= upstream absolute air pressure, psia

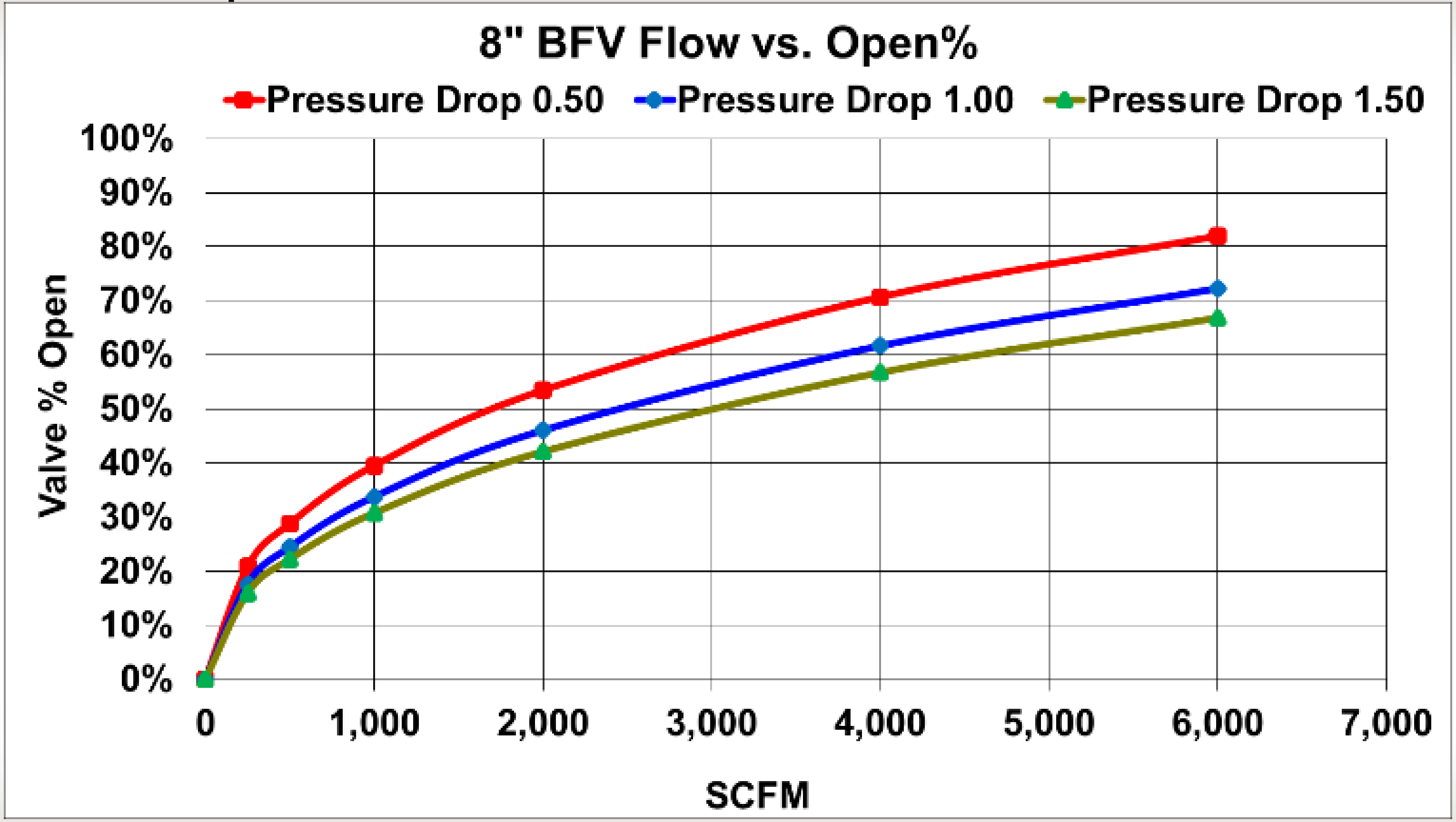
Air Flow Control Basics

- C_v varies with amount of throttling and is a function of valve position

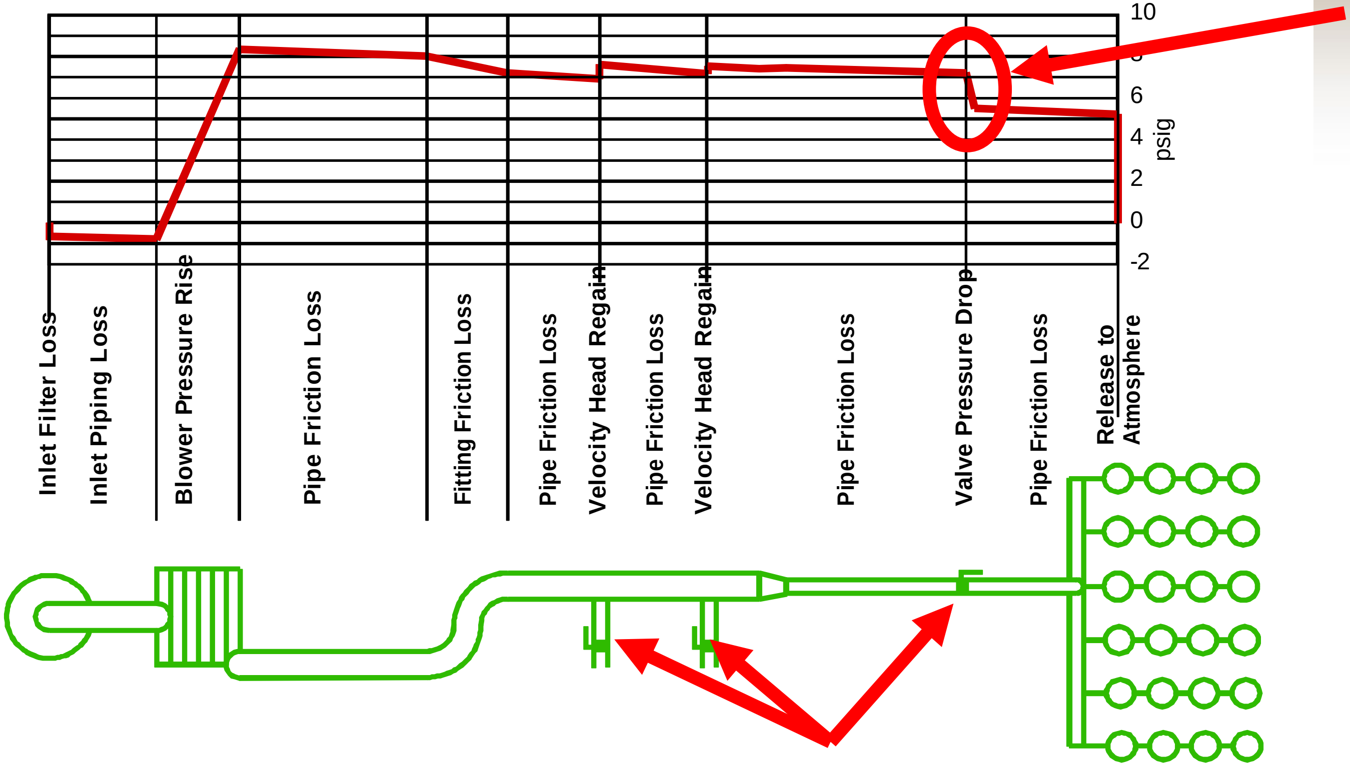


Air Flow Control Basics

- For a given valve the relationship between flow and position is non-linear



Air Flow Control Basics

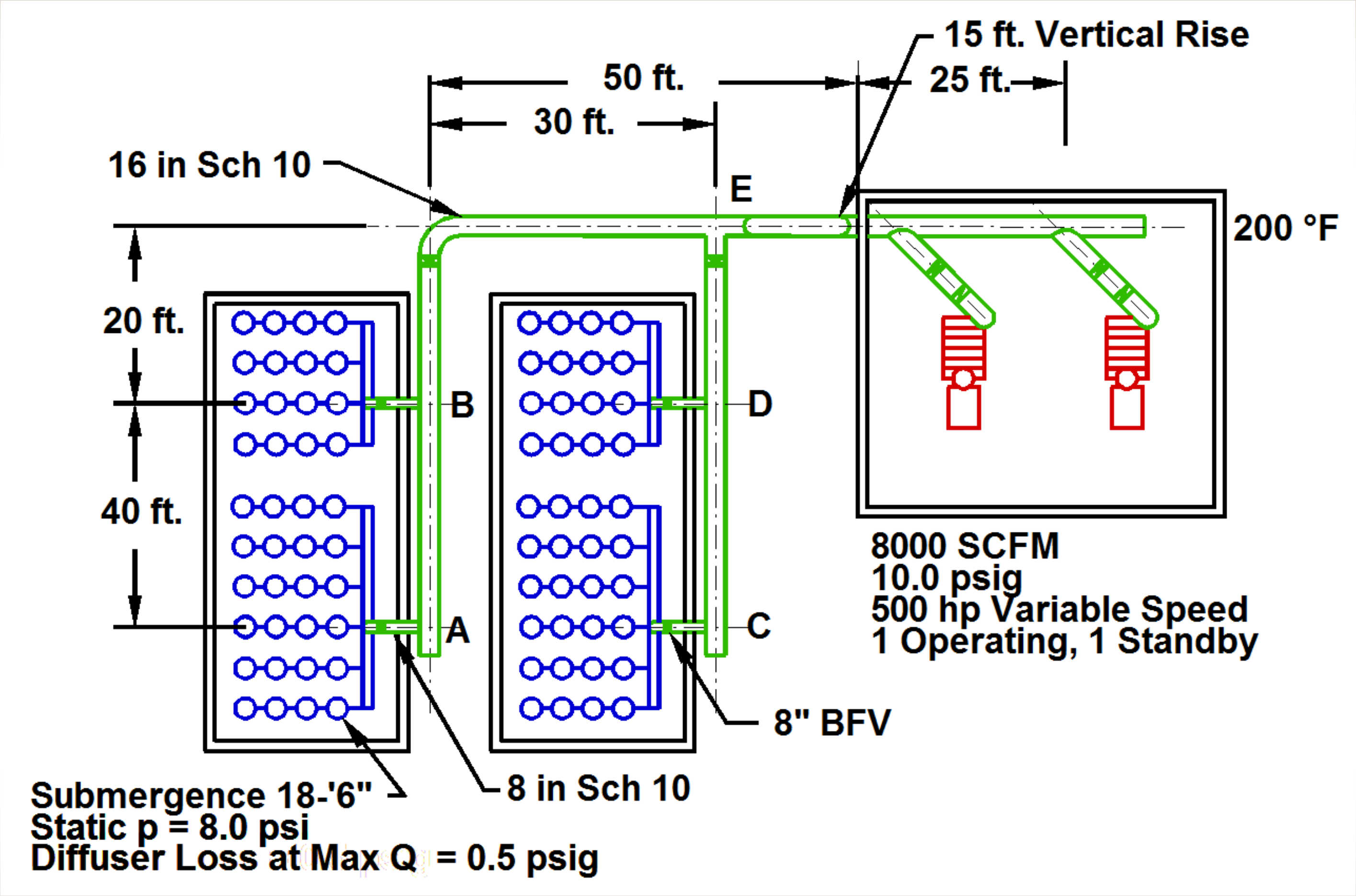


This is the pressure drop MOV is intended to minimize.

The pressure drop at all valves is close to identical. Valve position changes the flow rate that creates this pressure drop.[10]

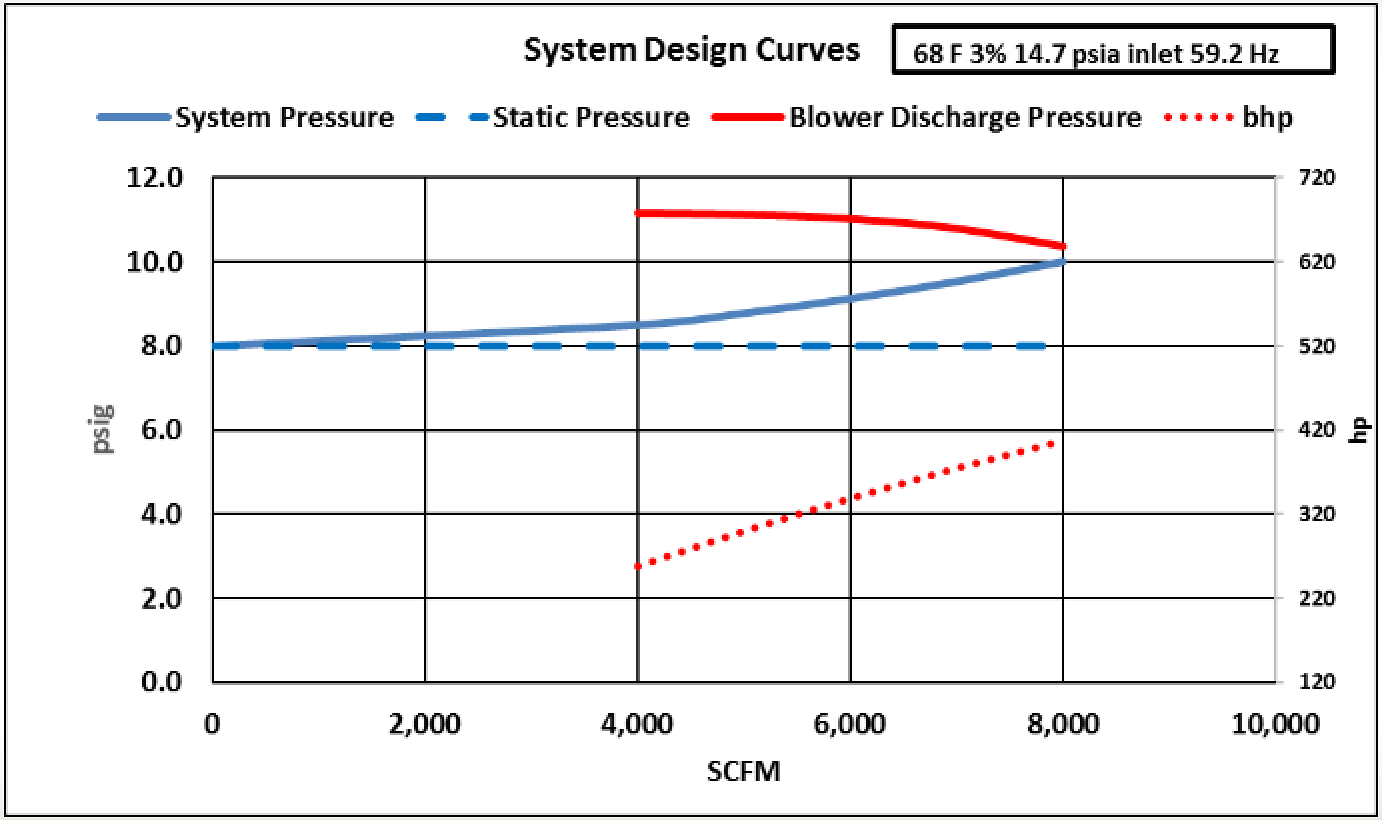
Air Flow Control Basics

- Example aeration piping system



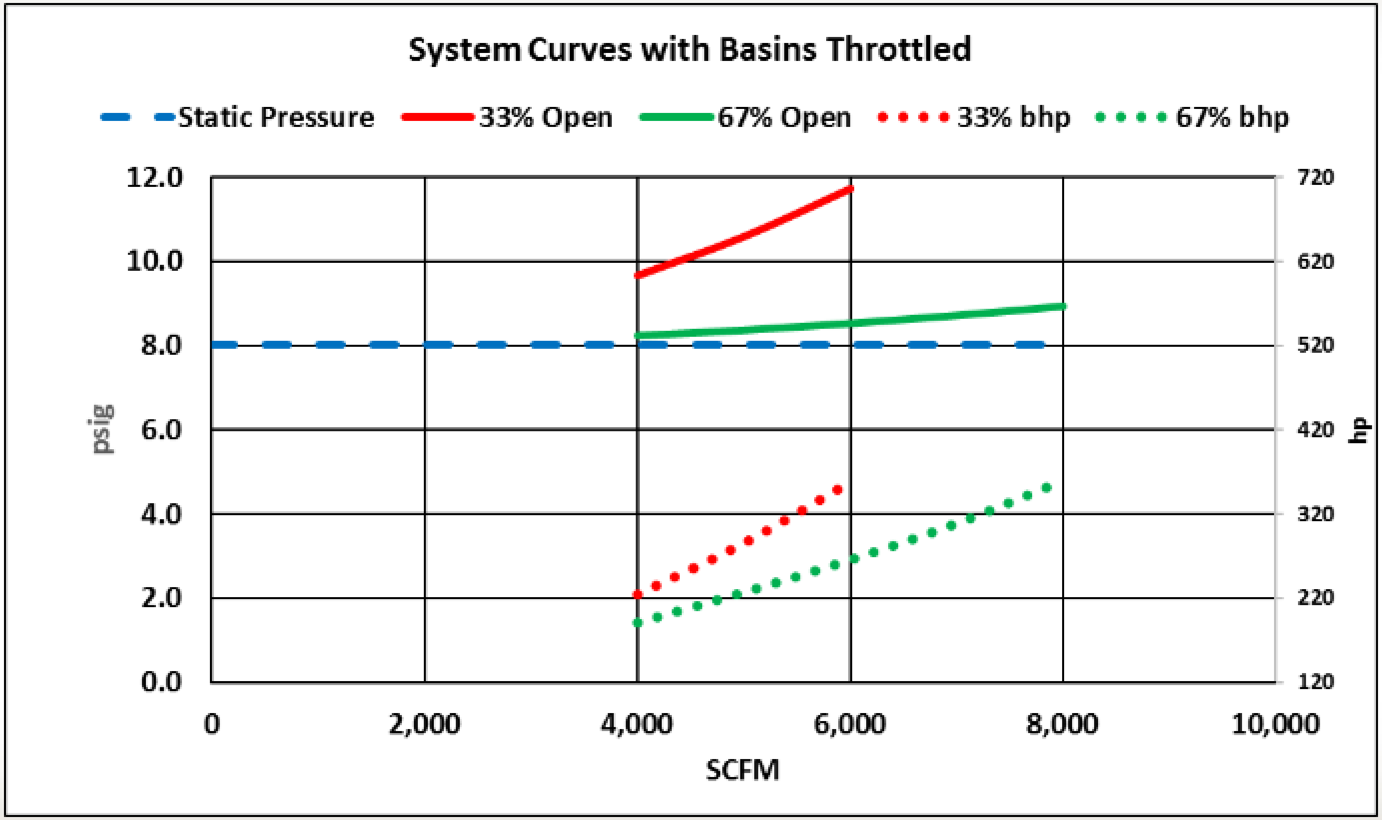
Air Flow Control Basics

- If you put the total pressure demands together you get a "system curve"



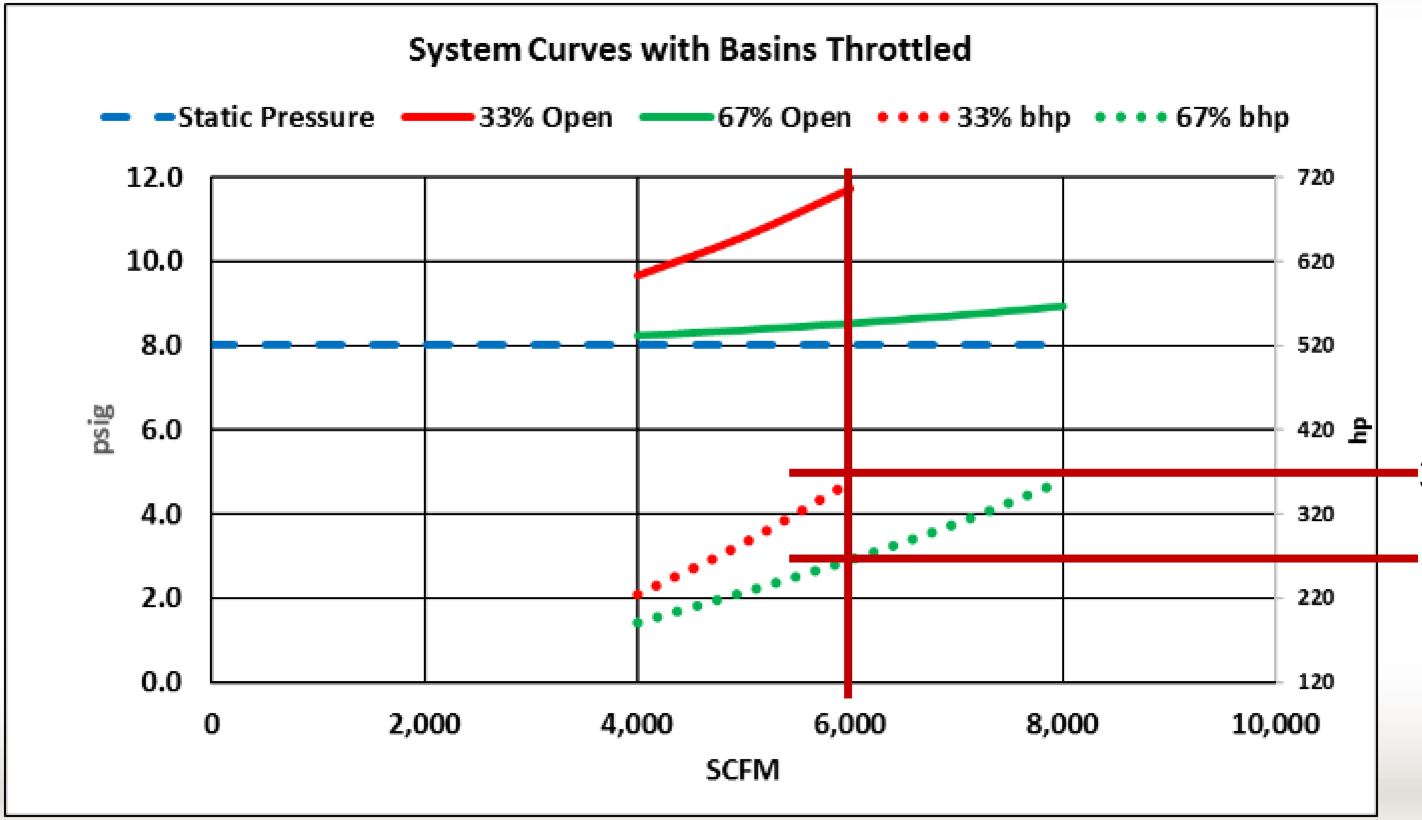
Air Flow Control Basics

- Throttling the basin valves will generate changes in the system curve



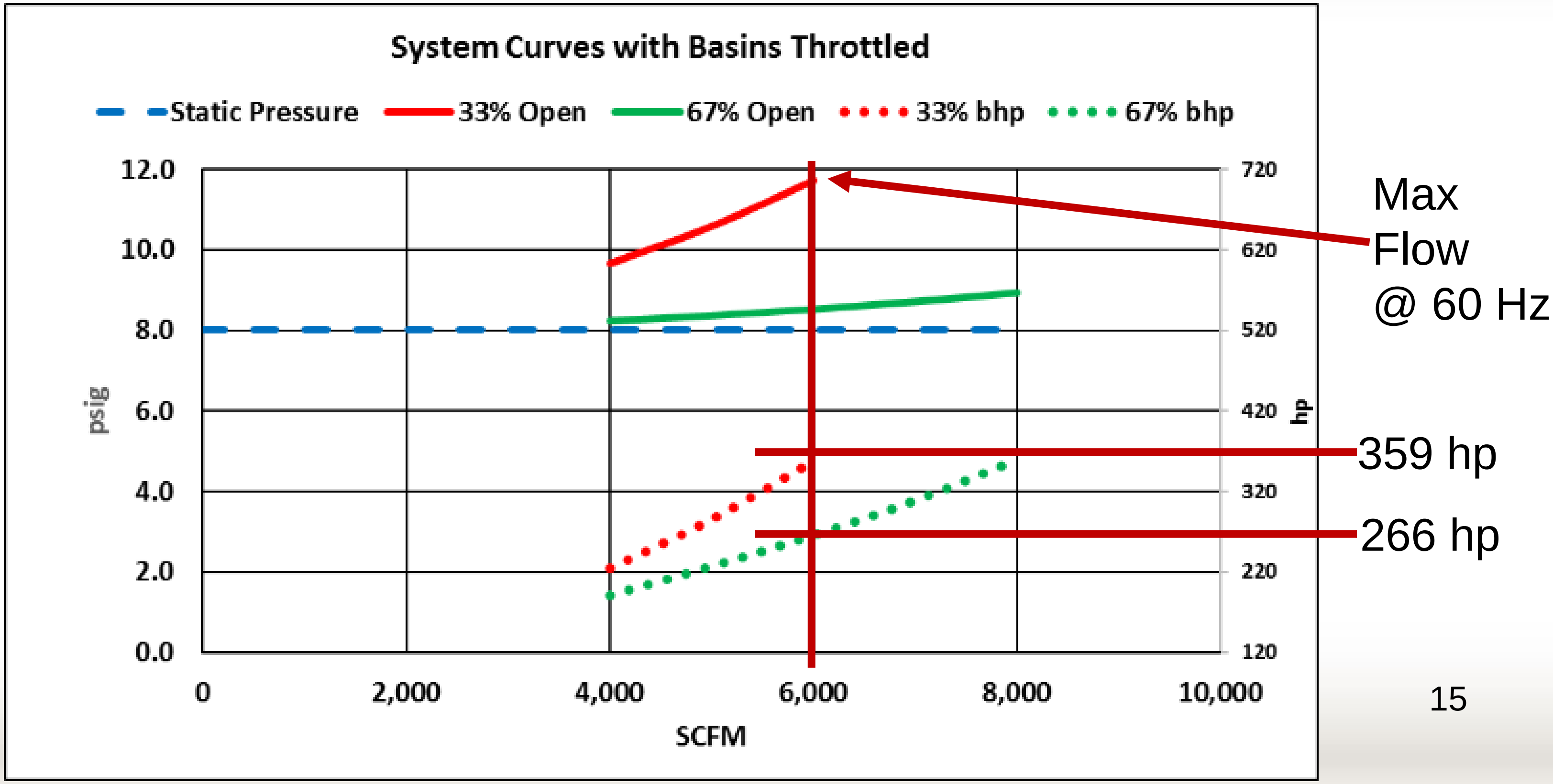
Air Flow Control Basics

- Throttling the basin valves will generate changes in the system curve
- These affect blower power vs. system air flow



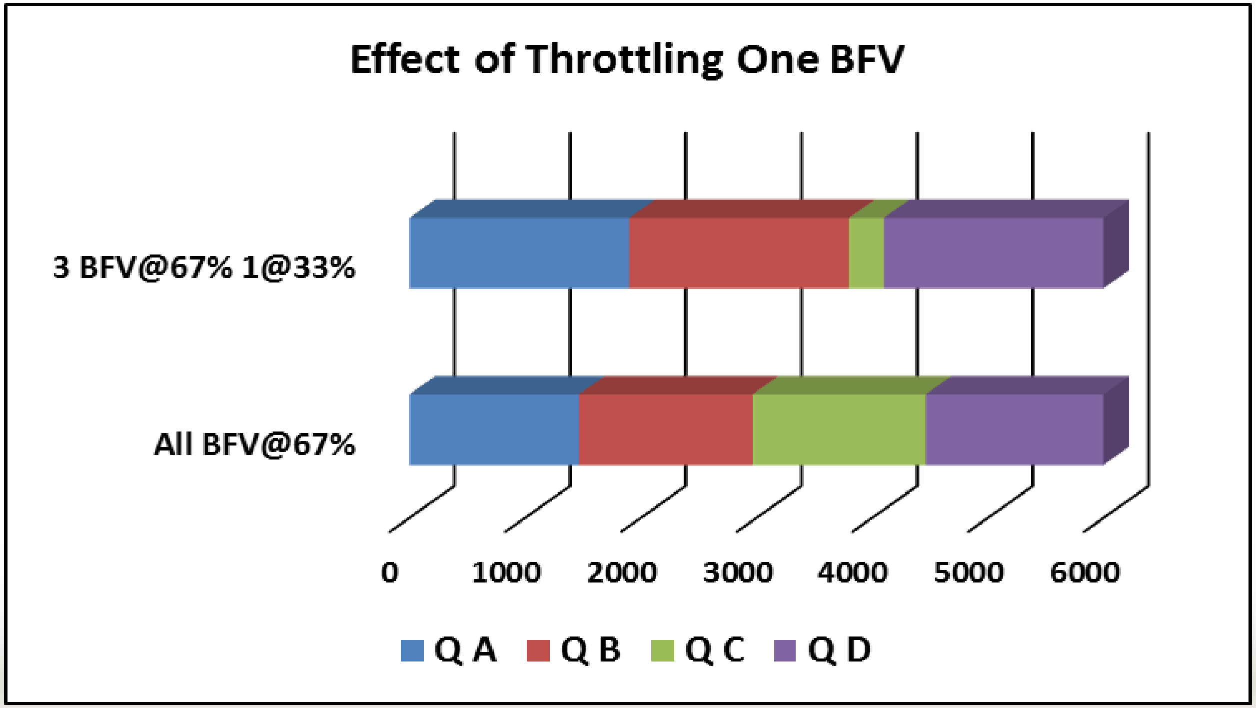
Air Flow Control Basics

- Throttling the basin valves will generate changes in the system curve
- These affect blower operating range



Air Flow Control Basics

- Changing one valve affects flow in other basins
- Changing one valve affects system pressure
- Example – throttle BFV at point C from 67% to 33% open, modulate the blower to maintain 6,000 CFM



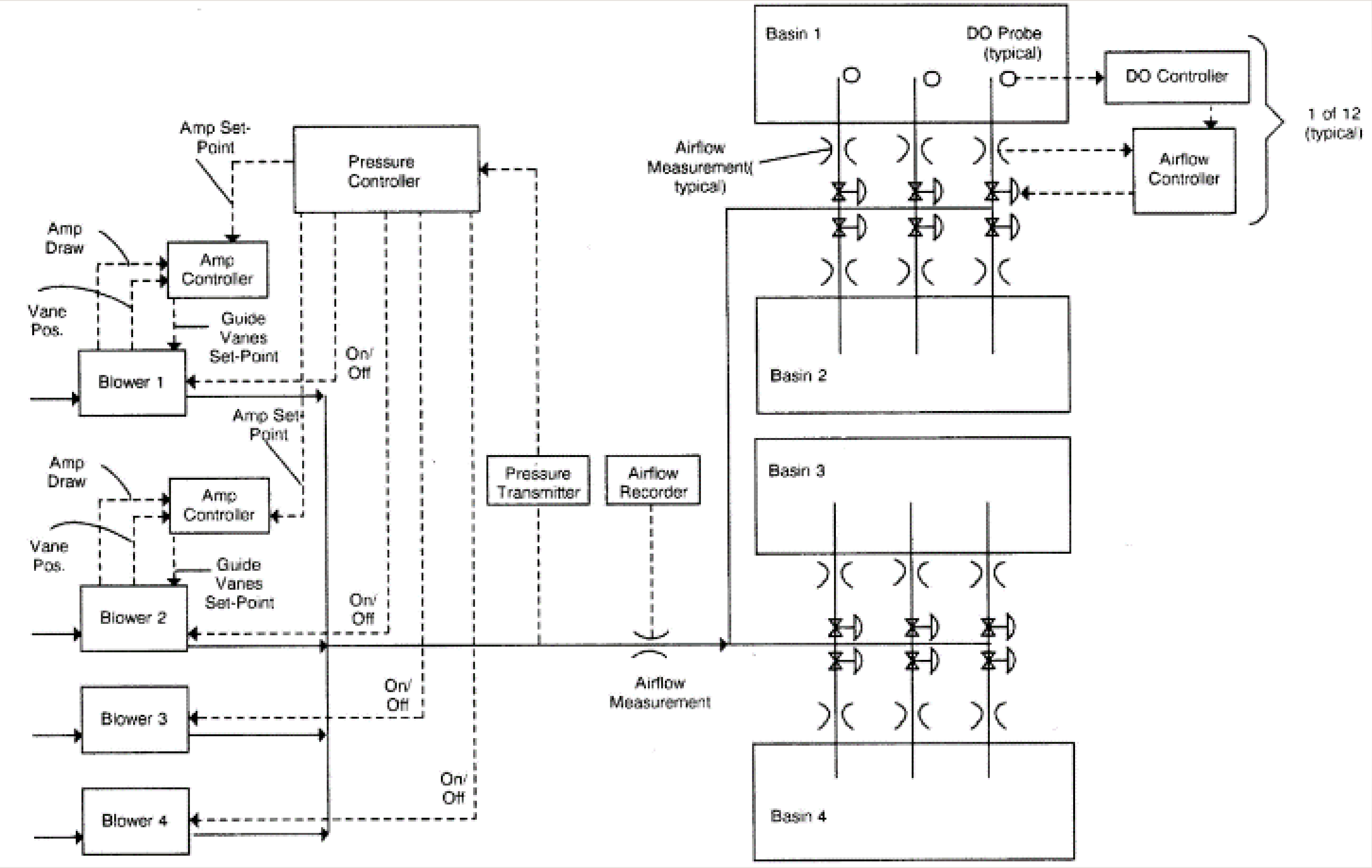
Pressure Increase = 0.05 psi

Pressure Based Systems

- The traditional response to this phenomenon was to maintain a constant system pressure
- The theory is that by maintaining a constant system pressure, changes in valve position and flow at one location wouldn't change air flow at other locations
- When pressure changed because of valve movement the total blower air flow would be increased or decreased
- In previous example if blowers are modulated to maintain 9.6 psig pressure
  - Total air flow drops to 4,800 SCFM
  - BFV C position goes to 34% open

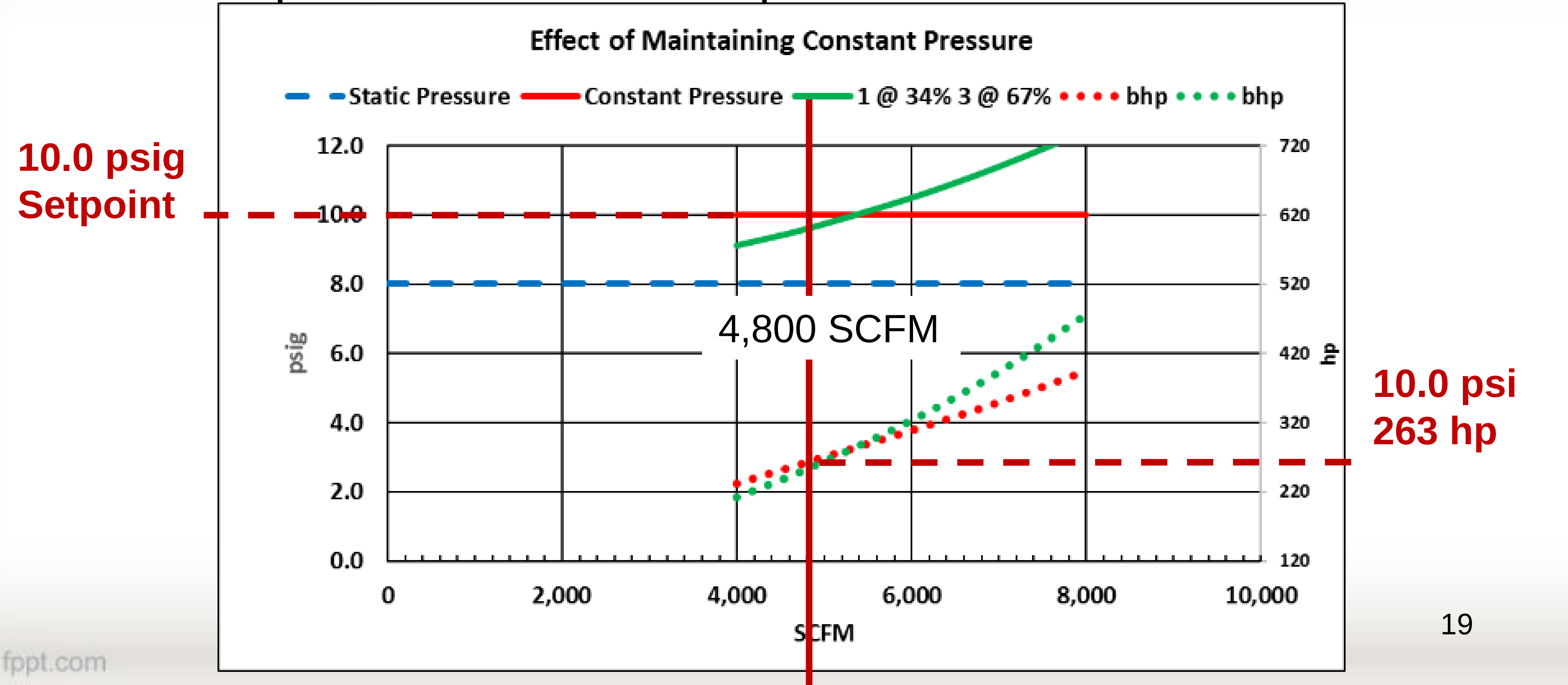
Pressure Based Systems

- From EPA Fine Pore Aeration Systems, EPA/625/1-89/023 © **1989**



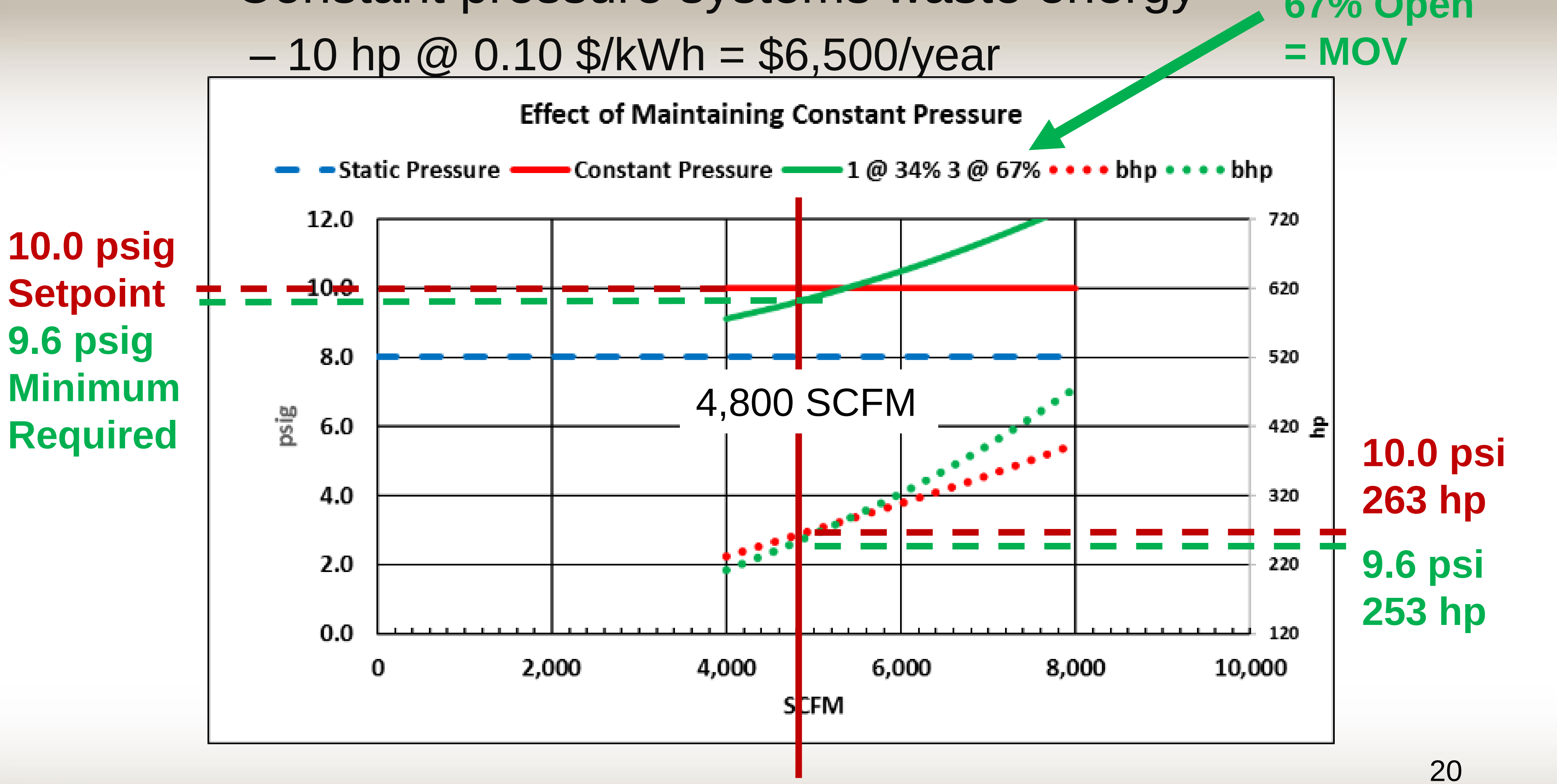
Pressure Based Systems

- Constant pressure systems waste energy
- To maintain 10 psi requires 3 BFVs at 34% open, 1 BFV at 17% open



Pressure Based Systems

- Constant pressure systems waste energy
  - 10 hp @ 0.10 $/kWh = $6,500/year



Pressure Based Systems

- MOV systems were developed (circa late 1980's) to minimize wasted energy
- The logic is intended to minimize pressure by keeping at least one valve at a set maximum open position (Typically **not** 100% Open)
- Pressure based systems function by modifying the pressure control setpoint if valves approach position limits
- These systems were developed to accommodate independent single loop PID controllers
- These system can result in unstable control and hunting

Pressure Based Systems

- If the valve that is at maximum position (the most open valve) is MORE than 75% open, the pressure setpoint will be periodically increased by 0.05 psig
- The pressure control loop forces the blower output air flow higher, which forces the basin flow control valves to move to a less open position to restore air flow to setpoint
- The back pressure increases and causes the pressure control loop to decrease blower air flow
- The logic goes through several iterations. At the new point of equilibrium the basin air flow is the same, but with valves less open

(underlined values are typical)

Pressure Based Systems

- If the valve that is at maximum position (the most open valve) is LESS than 30% open, the pressure setpoint will be periodically decreased by 0.05 psig
- The pressure control forces the blower output air flow lower, which forces the basin flow control valves to move to a more open position to restore air flow to setpoint
- The back pressure decreases and causes the pressure control loop to increase blower air flow
- The logic goes through several iterations. At the new point of equilibrium the basin air flow is the same, but with valves more open

(underlined values are typical)

Flow Based Systems

- Some newer DO control systems use process flow demand to directly control blower total air flow rate
- System pressure rises and falls based on restriction
- MOV logic maintains one valve at max open position to minimize restriction
- The Most Open Valve is not allowed to close until another valve reaches maximum position
- Flow setpoints are based on proportion of each basin’s actual flow rate to total process demand
- Flow based systems are generally more stable than pressure based systems

Flow Based Systems

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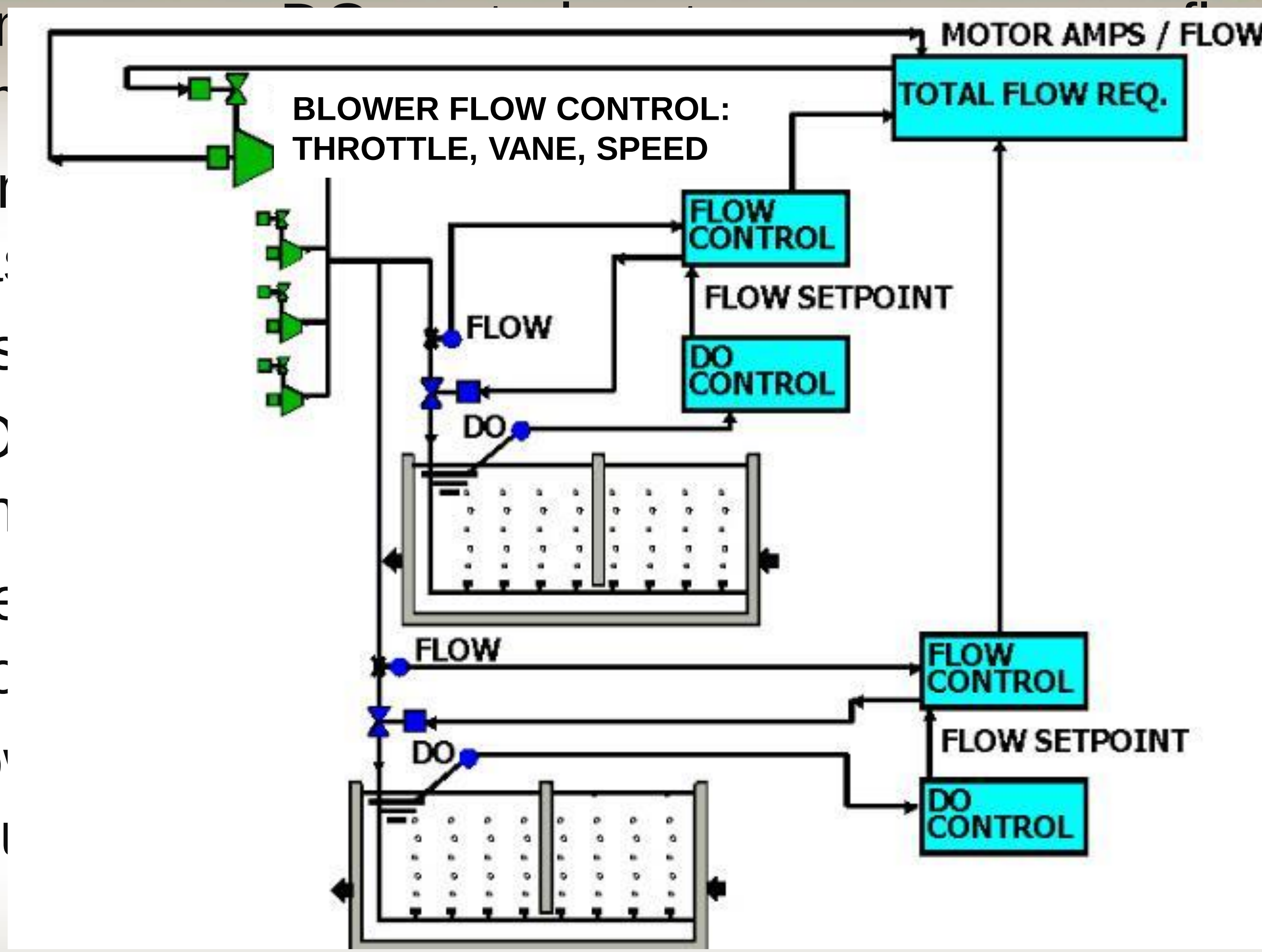
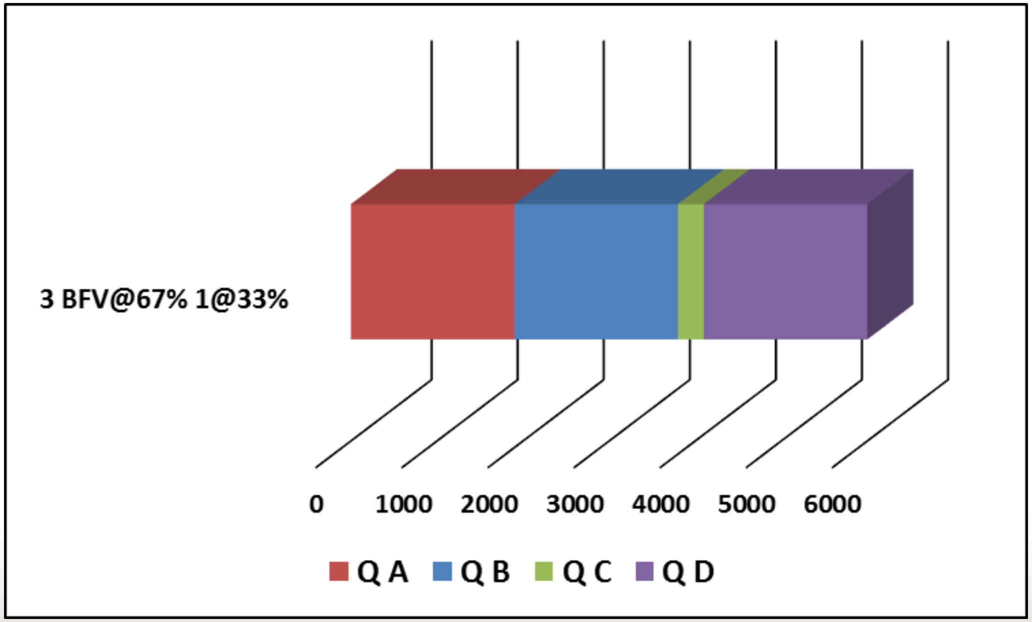


Flow Based Systems

- In this example if the air flow to Grid A, B, and D needs to be reduced I have two choices:
  1) Close the three BFVs at A, B, and D, increasing restriction
  2) Open the BFV at C, decreasing restriction



Flow Based Systems

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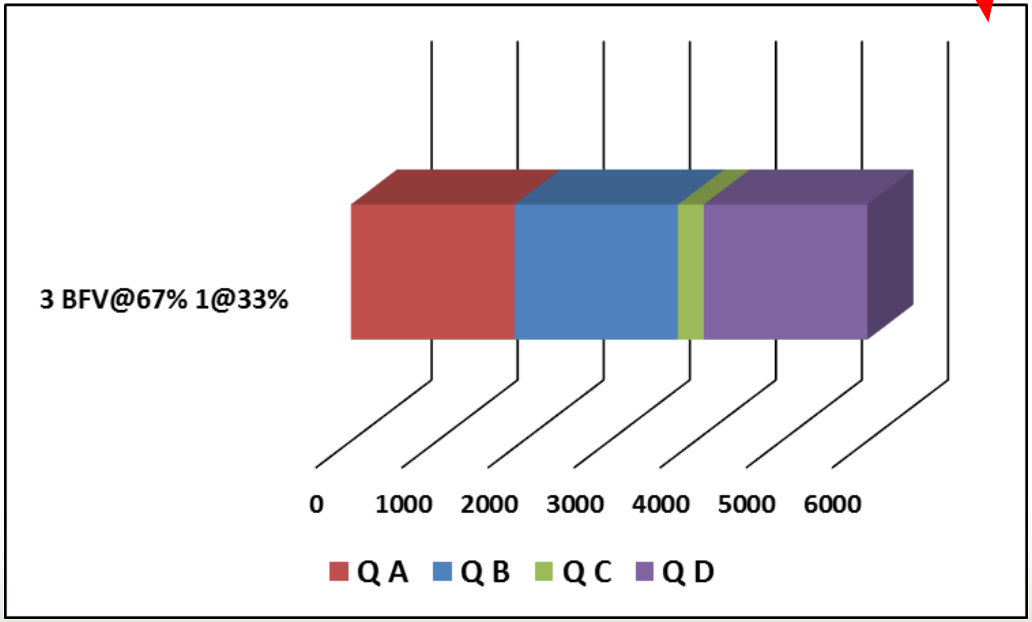
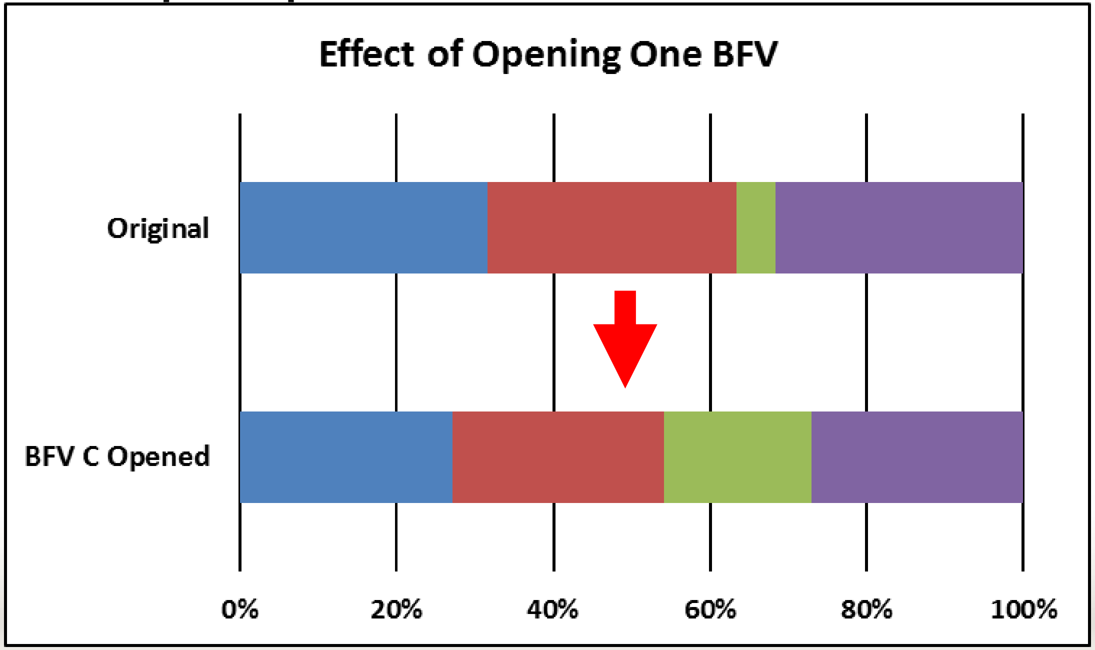


Flow Based Systems

- The blower is modulated to meet the total process air flow demand
- The basin BFVs are adjusted to meet new proportions
- The most open valve stays at max until another valve gets to max open position



Blower Control and MOV Benefits

- The type of blower and the control method used can decrease the benefit of MOV control
- Blower modulation increases and decreases flow for all types of blowers
- The system restriction dictates the discharge pressure
- Blower power is a function of:
  - Flow rate: set by process demand
  - Pressure ratio of discharge to inlet pressure: set by system restriction
  - Blower efficiency: varies with flow rate for any blower
  - Properties of inlet air: beyond control

(See Slide #4)

Blower Control and MOV Benefits

- Throttled blowers derive the least benefit from MOV
- This control is usually applied to multistage centrifugal blowers
- The pressure ratio for a given flow rate doesn't change
  - Throttling creates pressure drop at the inlet
  - Flow rate changes until the discharge pressure matches system pressure at that flow
  - Total pressure ratio is a function of blower characteristic curve: flow vs. pressure
  - Total pressure rise at a given flow is constant at constant speed, constant temperature

Blower Control and MOV Benefits

- Throttled blowers derive the least benefit from MOV
- This control is usually applied to multistage centrifugal blo
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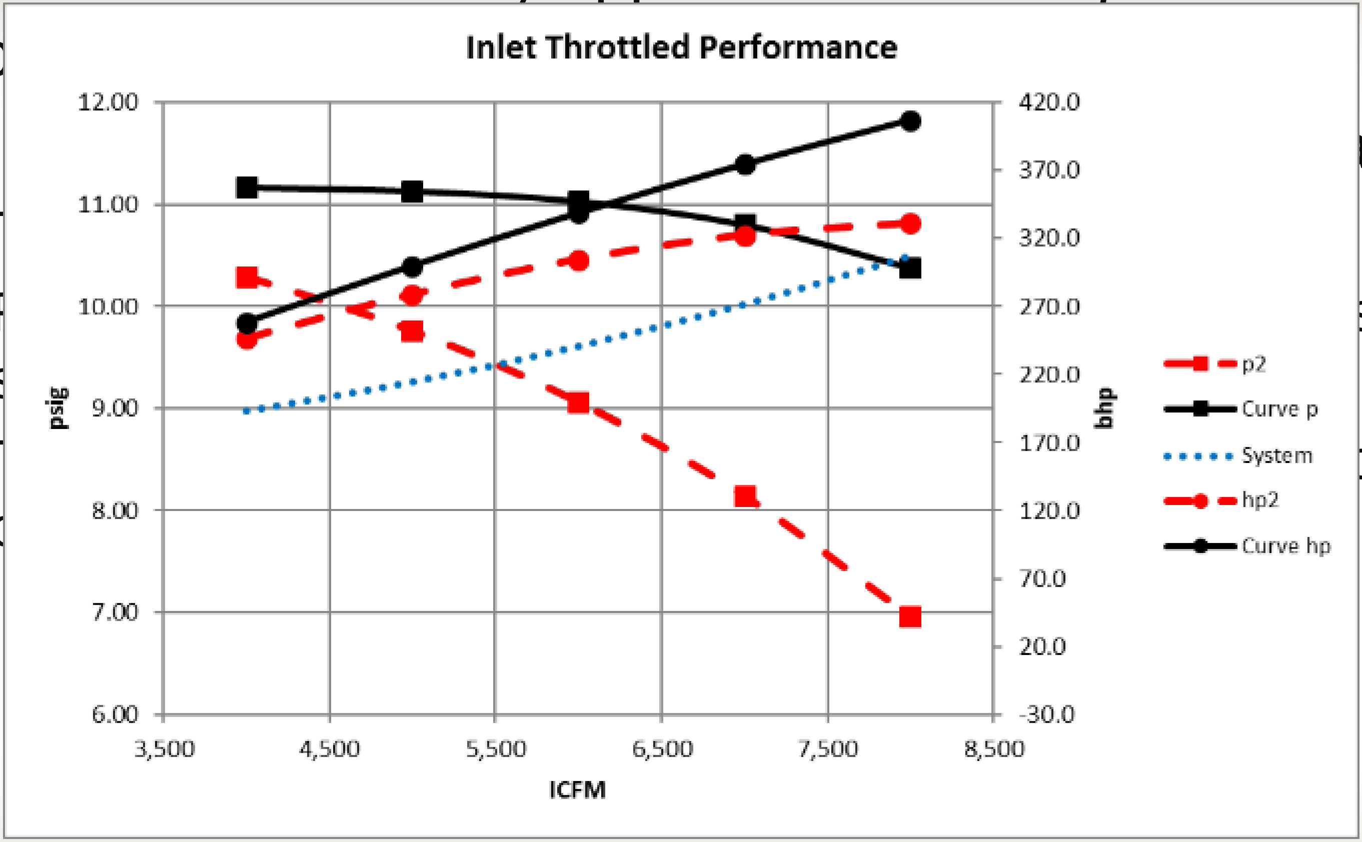

Blower Control and MOV Benefits

- Variable speed centrifugal blowers derive maximum benefit from MOV
- Both flow and pressure ratio of centrifugal blowers change with speed change
- This applies to variable speed for:
  - Multistage centrifugal blowers
  - Geared single stage centrifugal blowers
  - Gearless single stage centrifugal blowers (Turbo blowers)

Blower Control and MOV Benefits

- Variable speed centrifugal blowers derive maximum benefit from MOV
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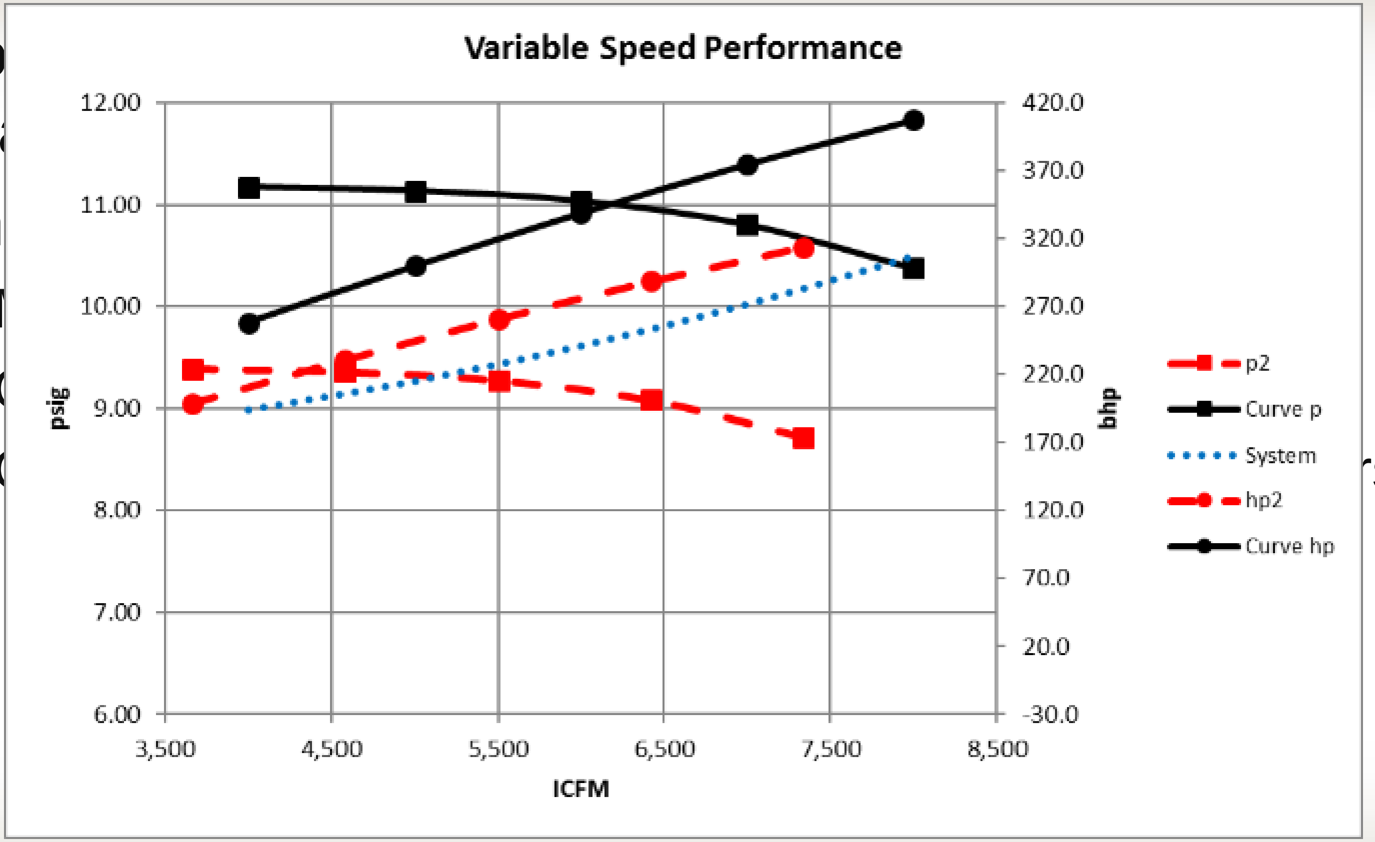

Blower Control and MOV Benefits

- Guide vanes are often used to control large geared centrifugal blowers
  - Inlet guide vanes (IGV) or variable discharge diffuser vanes (DDV) or both
- Guide vanes change flow vs. pressure ratio characteristics
- Guide vanes also produce pressure drop like throttling
  - Especially significant at low flow rates
- Benefit of guide vane controlled blowers from MOV is intermediate between throttling and variable speed

Blower Control and MOV Benefits

- Variable speed positive displacement (PD) blowers derive maximum benefit from MOV
- Flow of PD blowers changes directly with speed change regardless of pressure ratio
- Pressure ratio inherently changes to match system pressure required

Blower Control and MOV Benefits

- Variable speed positive displacement (PD) blowers derive maximum benefit from MOV
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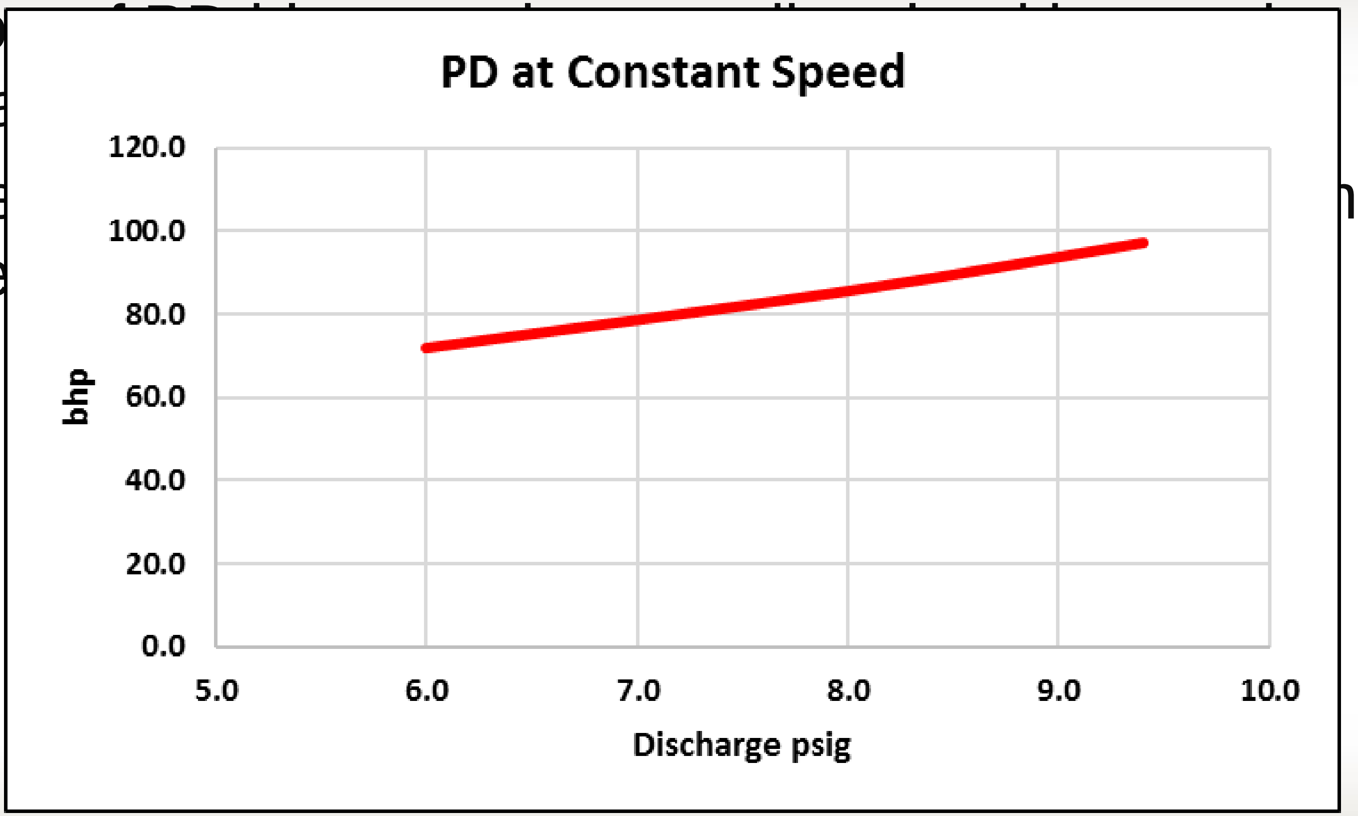
- Pre
  pre



Summary

- MOV control can reduce aeration system power requirements
- The MOV logic must be configured to match aeration and blower control strategies
- Blower and blower modulation method can be selected to optimize savings

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About the Speaker

Omar Hammoud
APG-Neuros

- CEO and President of APG-Neuros

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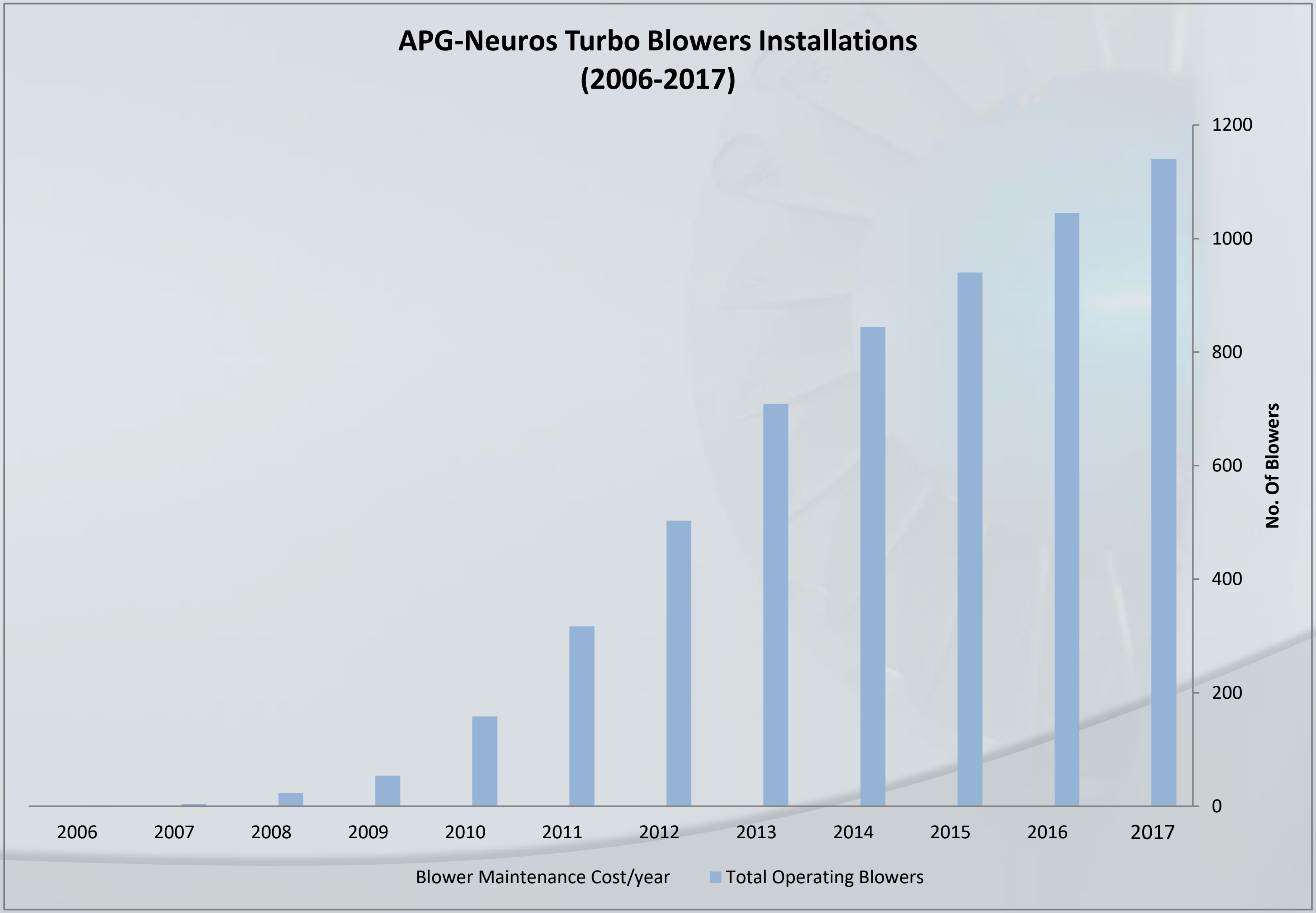
October 26, 2017

High Efficiency Turbo Blowers

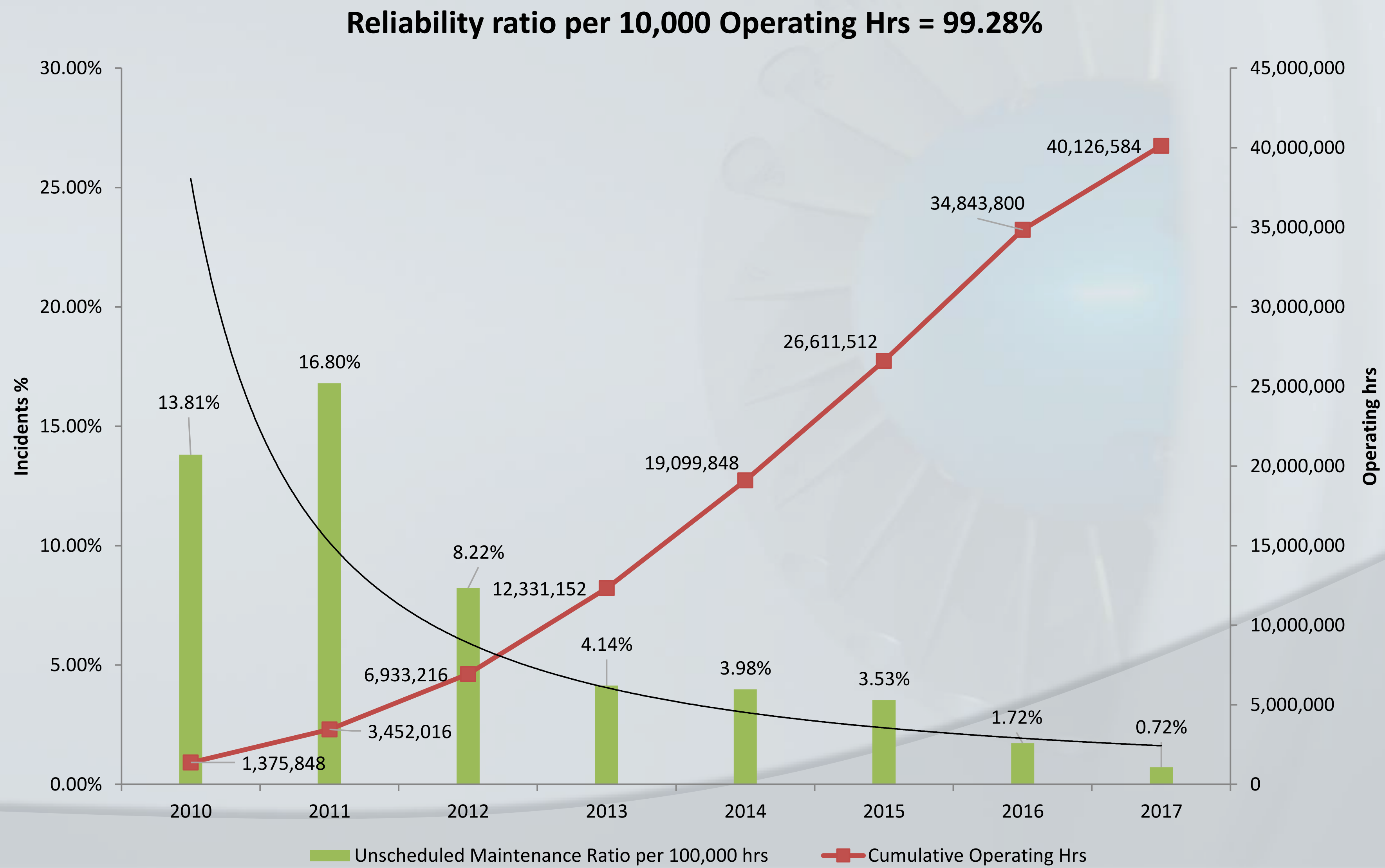
Omar Hammoud
CEO and President - APGN Inc.
Email: ohammoud@apg-neuros.com

APG-Neuros

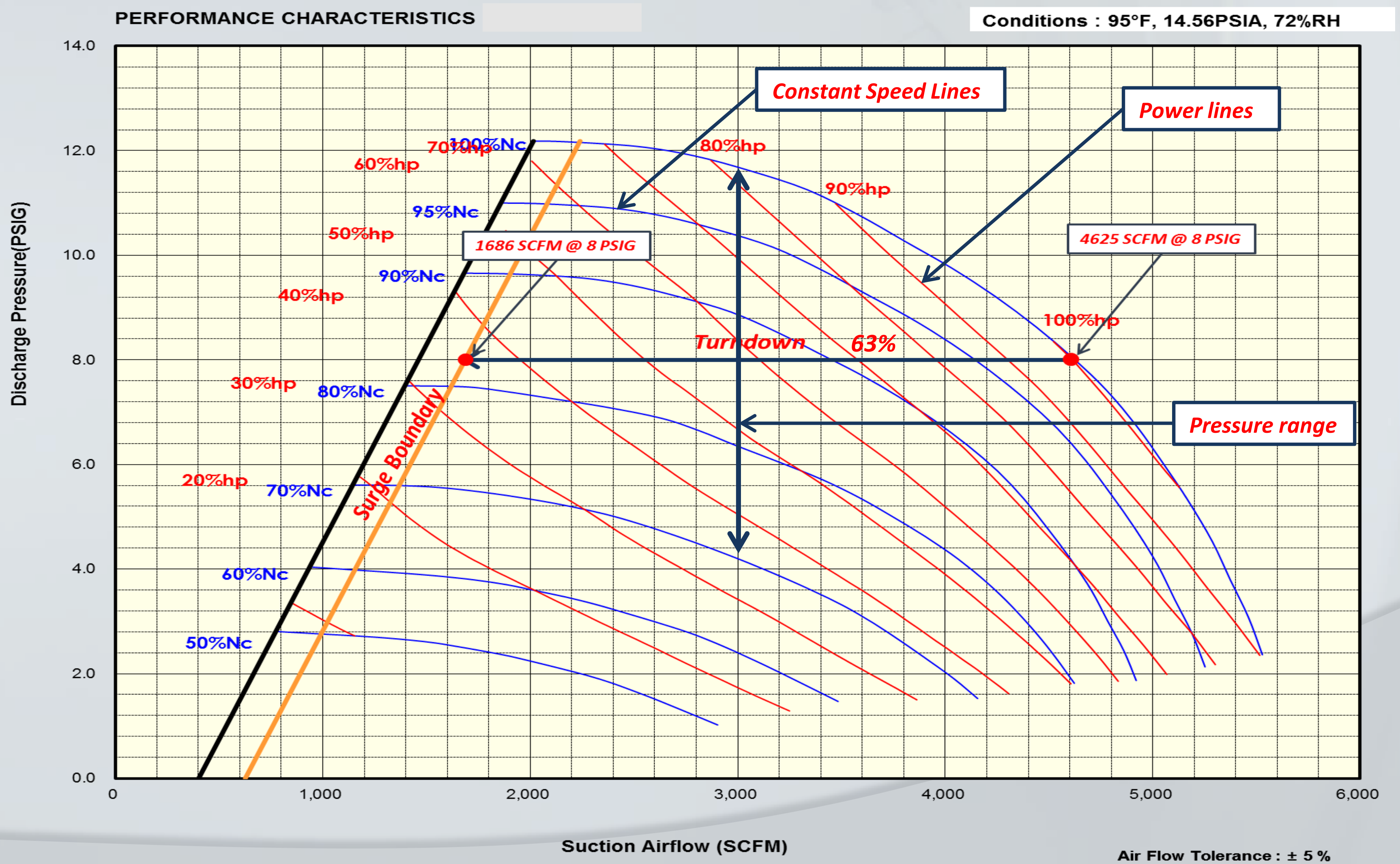


APG-Neuros Turbo Blowers Installations
(2006-2017)
1200
1000
800
600
400
200
0
No. Of Blowers
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Blower Maintenance Cost/year
Total Operating Blowers

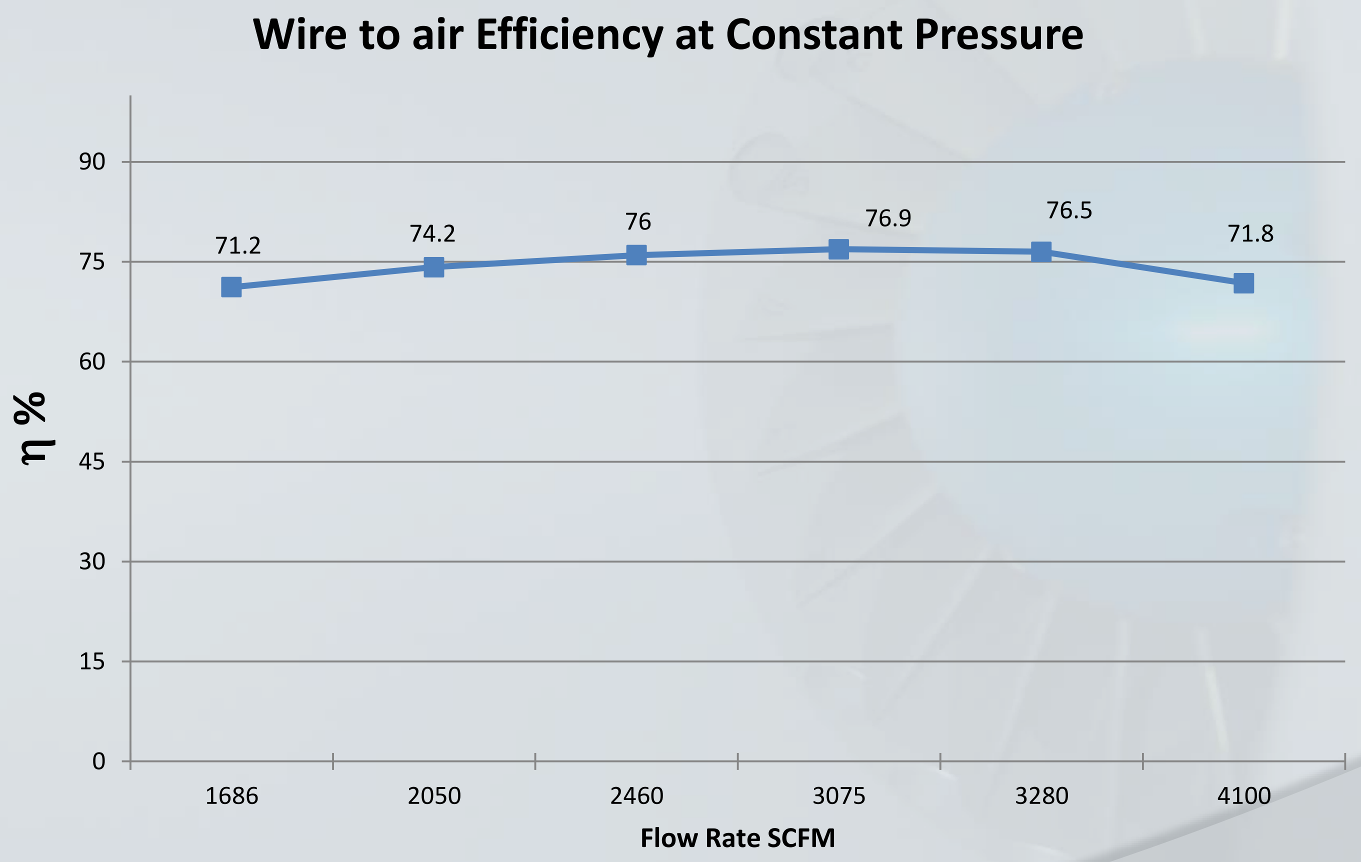
APG-Neuros Reliability



Performance Curve



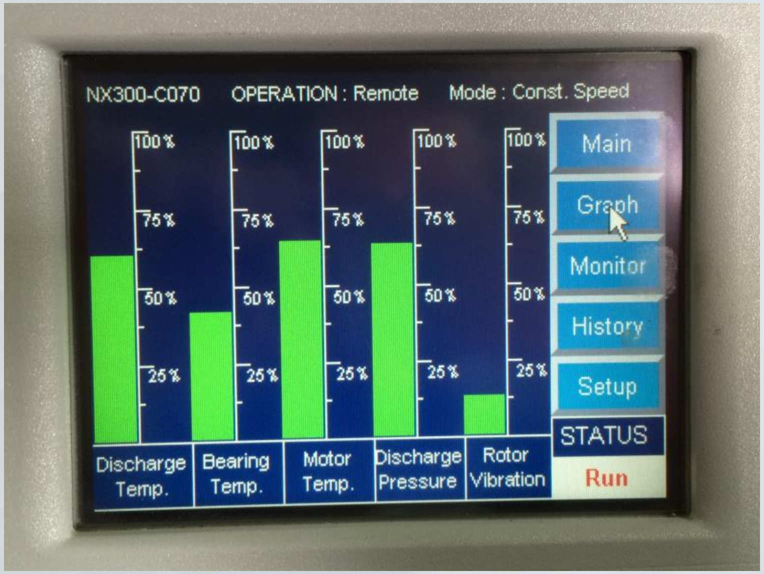
High Efficiency Over the Whole Flow range



PLC based control

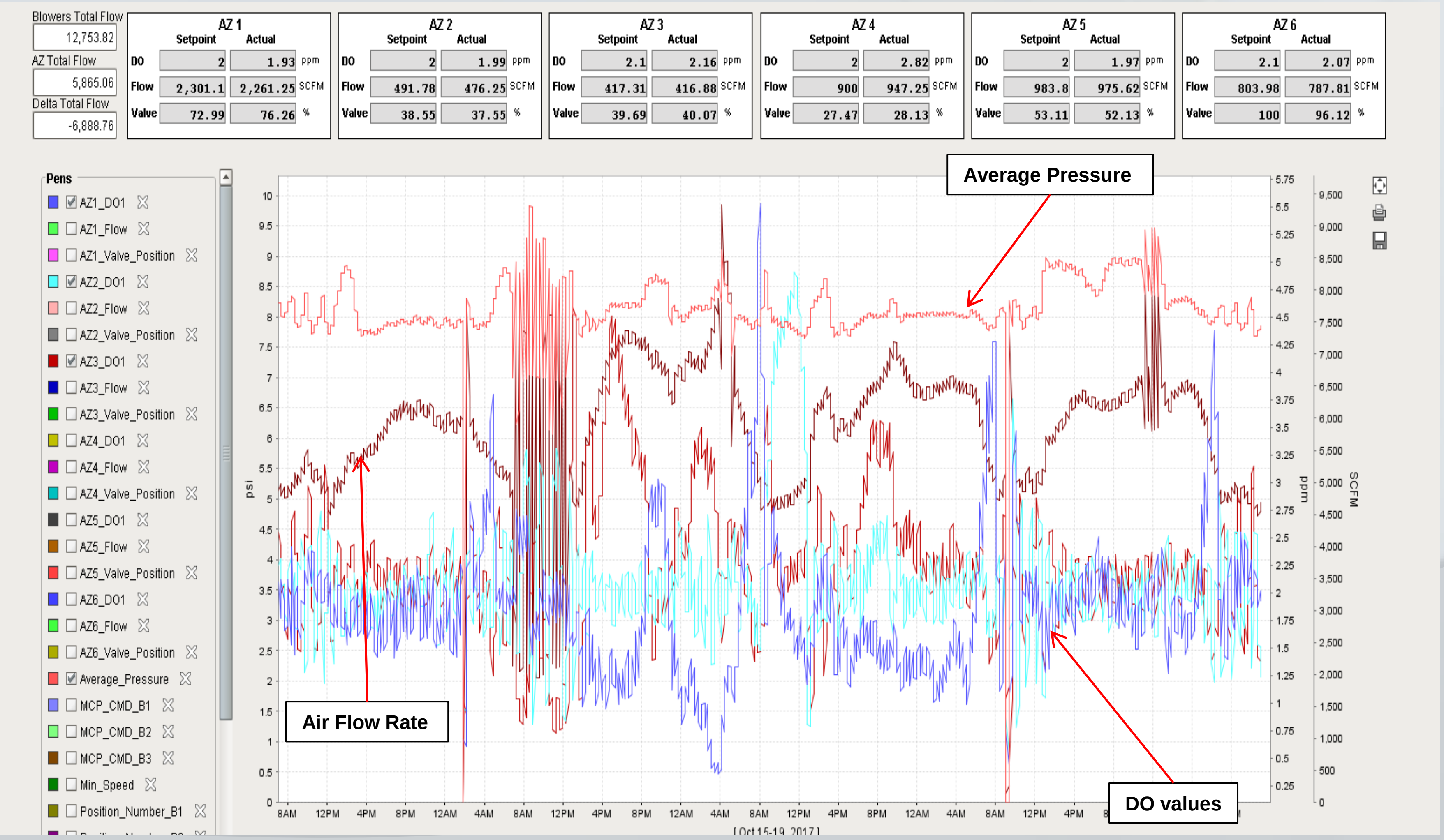
Integrated PLC for advance Control in the Blower (LCP)

- Advanced monitoring and control capability
- Blower PLC has 4 control modes;
  - Speed Control
  - Pressure Control
  - Flow Control
  - Dissolved Oxygen Control



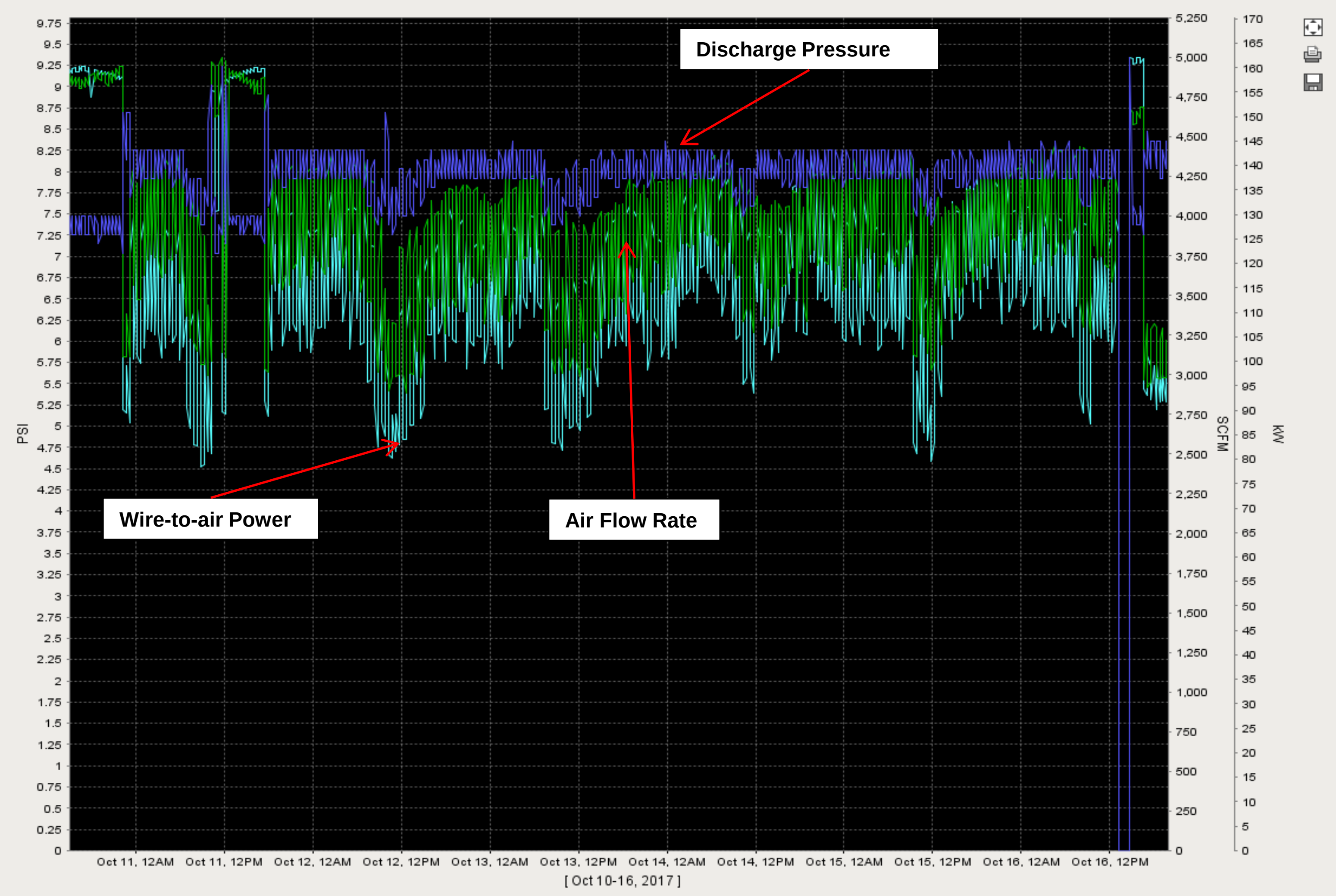
- Algorithms for better operation and safety
  - Dynamic Adjustment to Ambient Conditions
  - Dynamic Speed adjustment to prevent Surge
  - Remote communication via cellular com/VPN

Remote Monitoring For Aeration Control Systems



Captured from Linden Roselle – CDM Project – Commissioned 2011

Aeration Control with MOV

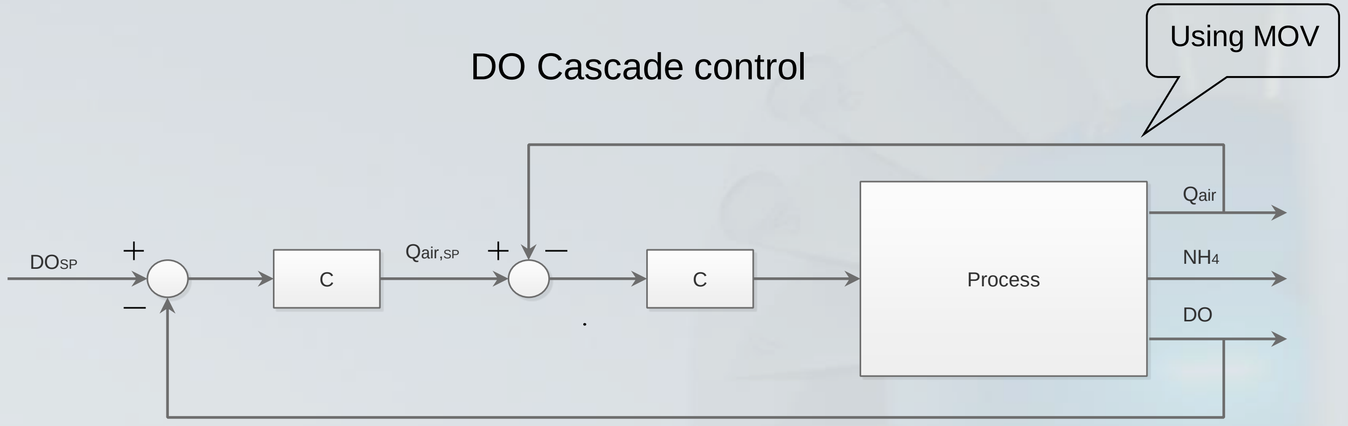


Captured from San Louis Obispo WRF RMS Trend - 2017

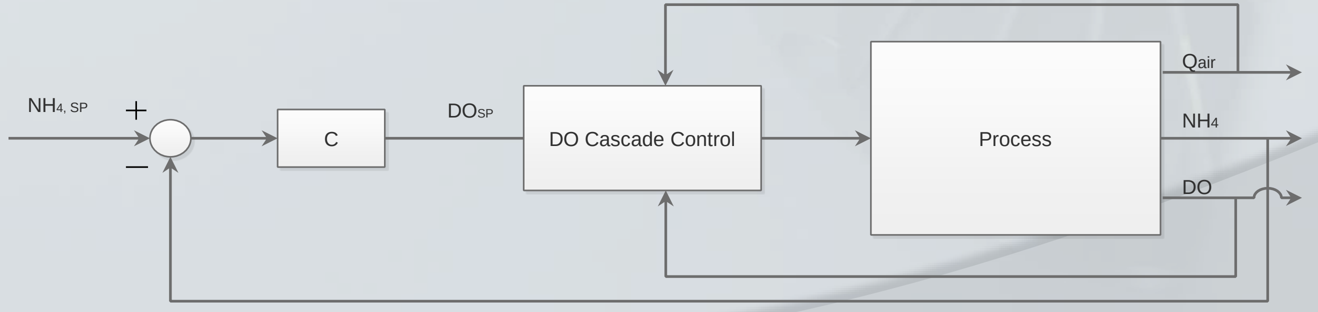
Aeration Control Structures

Aeration Control Structures

DO Cascade control

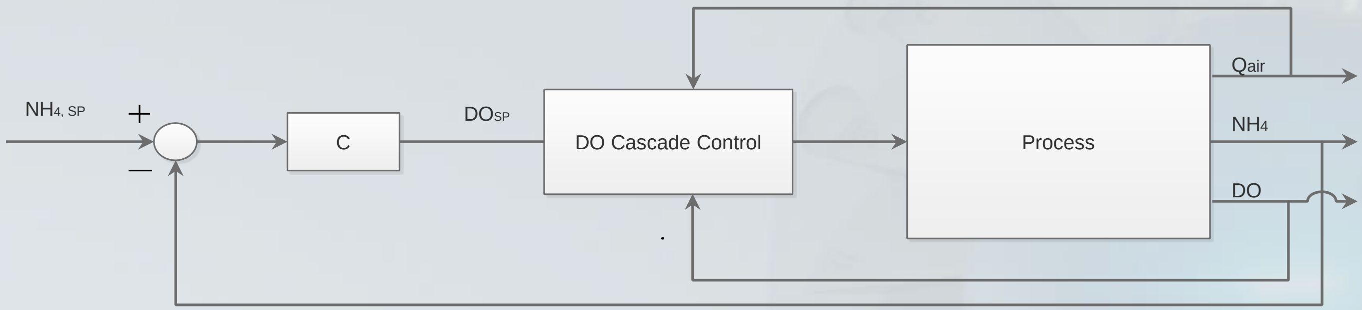


Ammonium-Based Supervisory Control (Feedback Control)

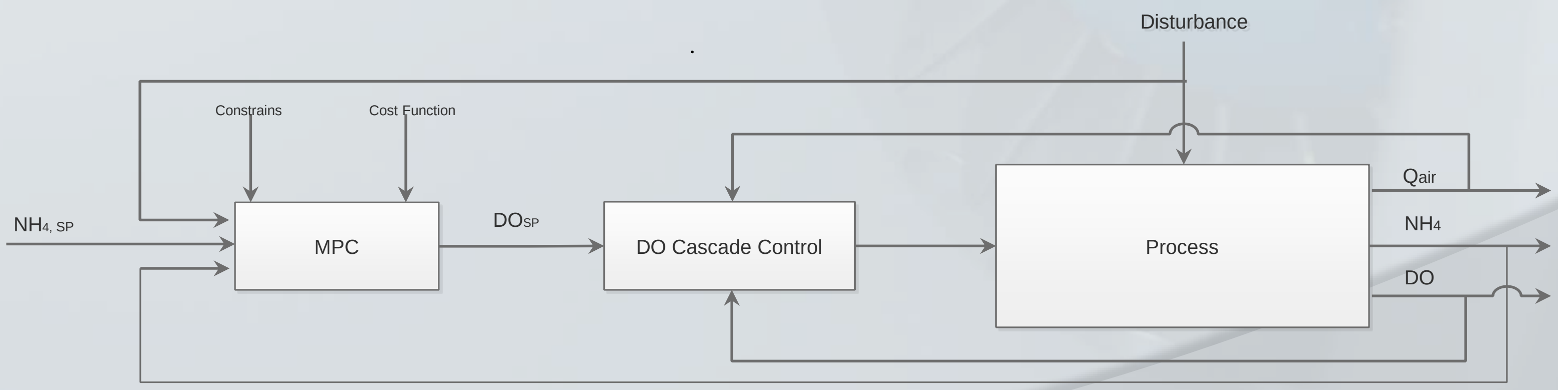


Aeration Control Structures

Ammonium-Based Supervisory Control (Feedback Control)



Model Predictive Controller (MPC)



Summary

- Turbo blowers almost maintain its high efficiency over the whole turndown.
- Integrated PLC in the turbo blowers gives many advantages to optimize efficiency systems with high reliability
- Aeration control structure can be selected to optimize efficiency and reliability

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Q&A

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Hank van Ormer
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