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Evaluating the Centralization of Vacuum Systems

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BUSCH Vacuum Pumps and Systems

Tim Dugan P.E., Compression Engineering Corporation

Featured Speaker

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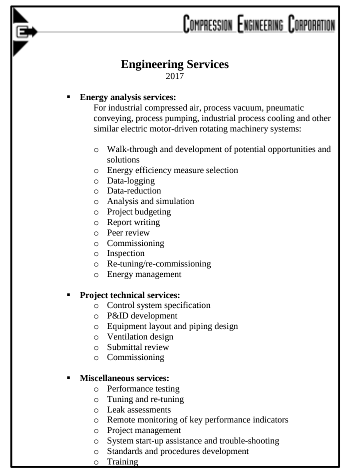
Handouts



Compression Engineering Corporation

Engineering Services
2017

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

Evaluating the Centralization of Vacuum Systems

Introduction by Rod Smith, Publisher

Blower & Vacuum Best Practices Magazine

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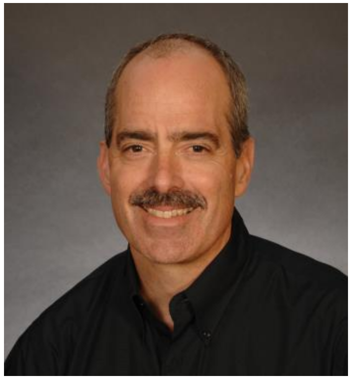
About the Speaker



Tim Dugan P.E.,
Compression Engineering Corporation

- President and Principal Engineer of Compression Engineering Corporation

- Over 25 years of experience in the industry

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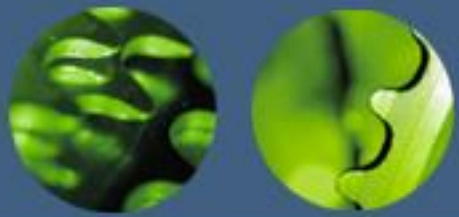
Centalized Vacuum Systems

Tim Dugan
Compression Engineering Corp.

Blower & Vacuum Best Practices Magazine
6-29-17



Outline

- Fundamentals of Vacuum
- Problem Description – Multiple Dead-headed Processes
- Solution 1: Consolidation
- Solution 2: Centralization

Fundamentals of Vacuum

- Mass Flow vs Volume Flow
- System Curve & Choked Flow
- Typical PD Vacuum Pump
- Typical PD Vacuum Pump Curve

Fundamentals: Mass Flow vs. Volume Flow

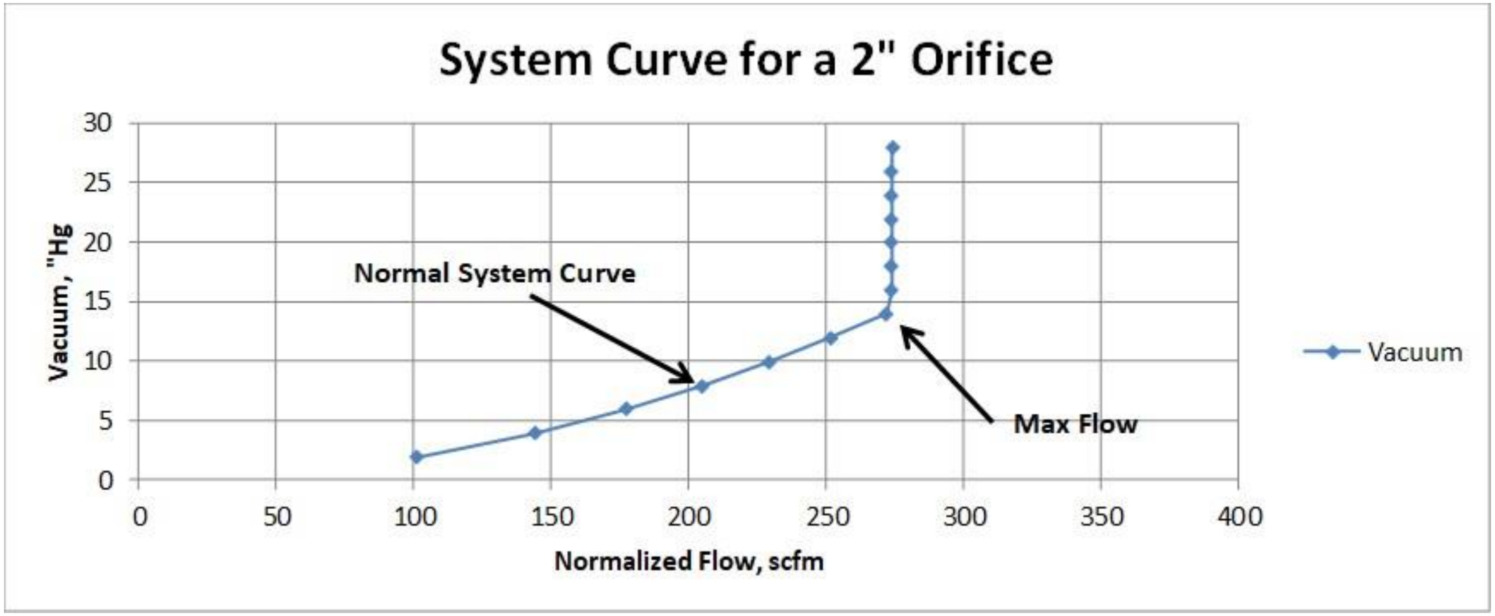
- Volume flow, in “icfm” or “m3/hr”, is always at the vacuum pump inlet, and is not density-weighted. Pure volume / time.
- Mass / volume flow = (Patm – Pin) / Patm
- Example: at 25”Hg vac and sea level, icfm/scfm = (29.92 - 25)/29.92 = 0.164

Fundamentals: Mass Flow vs. Volume Flow

- That means that you only get 16.4% of the flow at the outlet of the vacuum pump as you do the inlet, or that the process “sees” just 16.4% of the ambient air come in, and it gets “stretched” 6X by the time it comes into the vacuum pump.
- Since vacuum pump size and cost is determined by the inlet volume, this is a critical economic issue.
- *For instance, designing for 27.5”Hg drops icfm/scfm to 8.3%, doubling the size requirement vs. 25”Hg!*

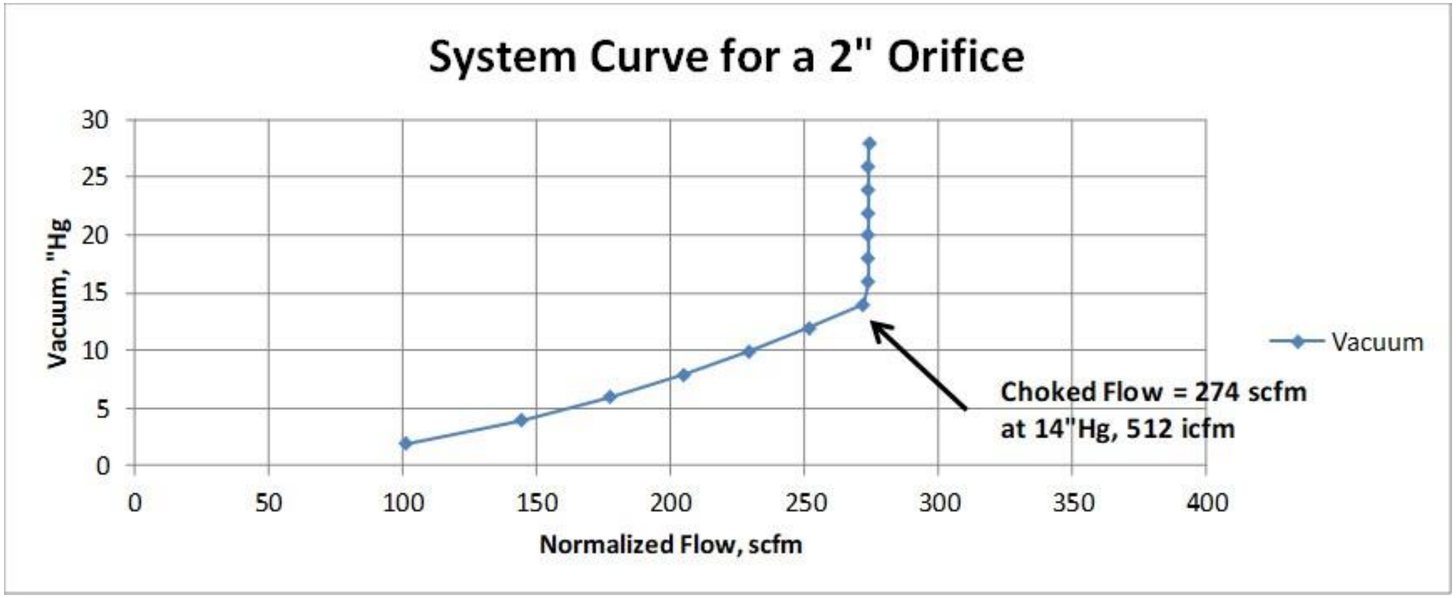
System Curve

- Flow across a resistance is proportional to the square root of the vacuum level. The relationship between flow is the “system curve”.
- There is a maximum flow, however.



Choked Flow

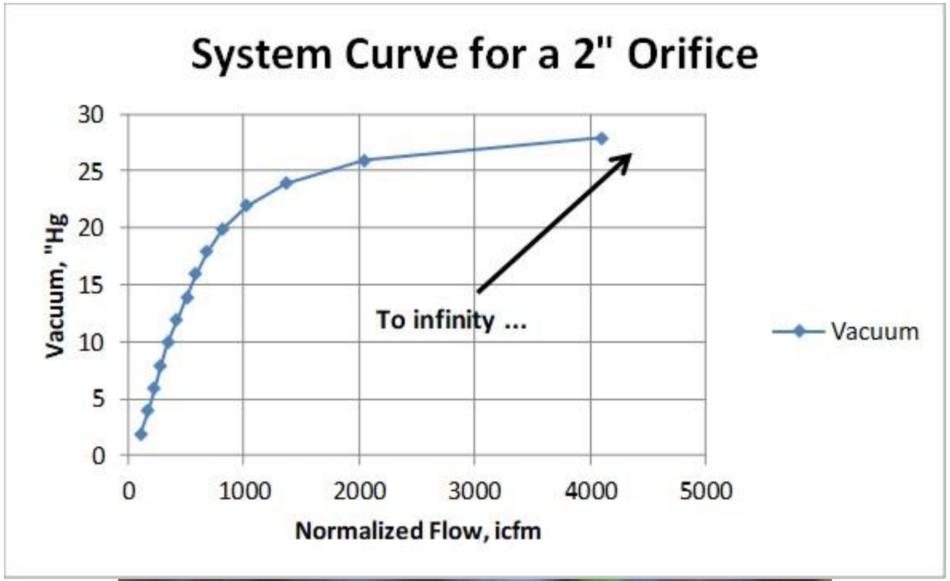
- At about 14”Hg, your system (essentially a hole) reaches sonic velocity, and mass flow is “choked”.



Choked Flow

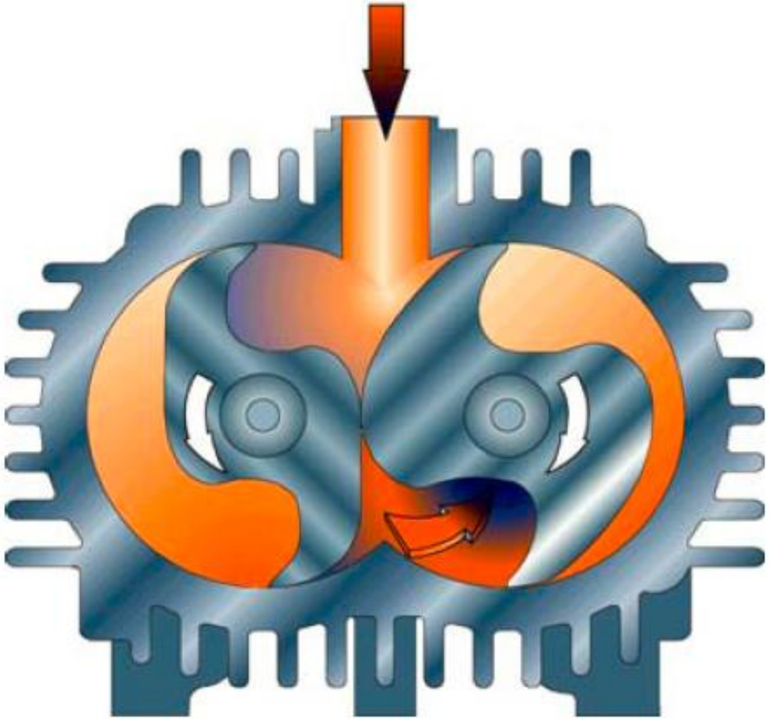
- Based on the icfm/scfm ratio, you can pull infinite inlet “flow”, but not get any more mass flow.

- You might think your system can win the World Series, but it will CHOKE!



Typical PD Vacuum Pump

- One Type of PD Vacuum Pump (Claw)



- Others Include Screw, Piston, Lobe, etc.

Typical Vacuum Pump System

- Dry PD vacuum pumps are simple: vacuum pump, motor, and controls.
- Lubricated vacuum pumps include oil-separator and lube system.
- Deep vacuum systems can have two vacuum pumps in series.

Typical Vacuum Pump System

- Vacuum pump skids can be consolidated in systems with piping and master controls.


Problem Description

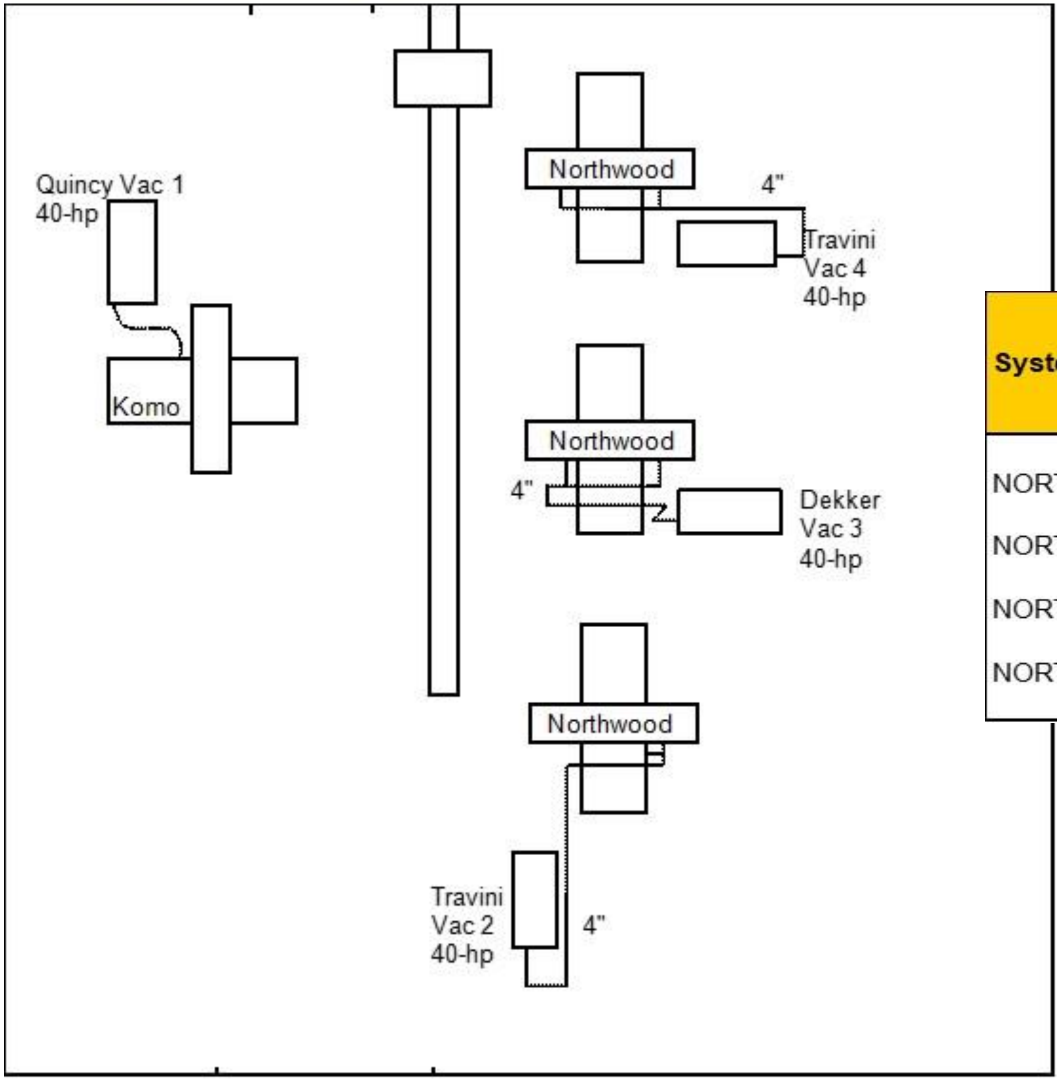
- Four cabinet door routing tables with 4’x8’ capacity.
- Table is a “variable orifice”, and vacuum pump pulls from atmosphere, through table, to pump inlet.
- More production = more coverage. Less production = less coverage.
- Dedicated 40hp vacuum pumps, several makes, all lubricated.
- ***Max*** power is at ***min*** production.
- Very little “turn-down” as production (coverage) goes up.

Problem Description

- Full routing table:

- Empty routing table:

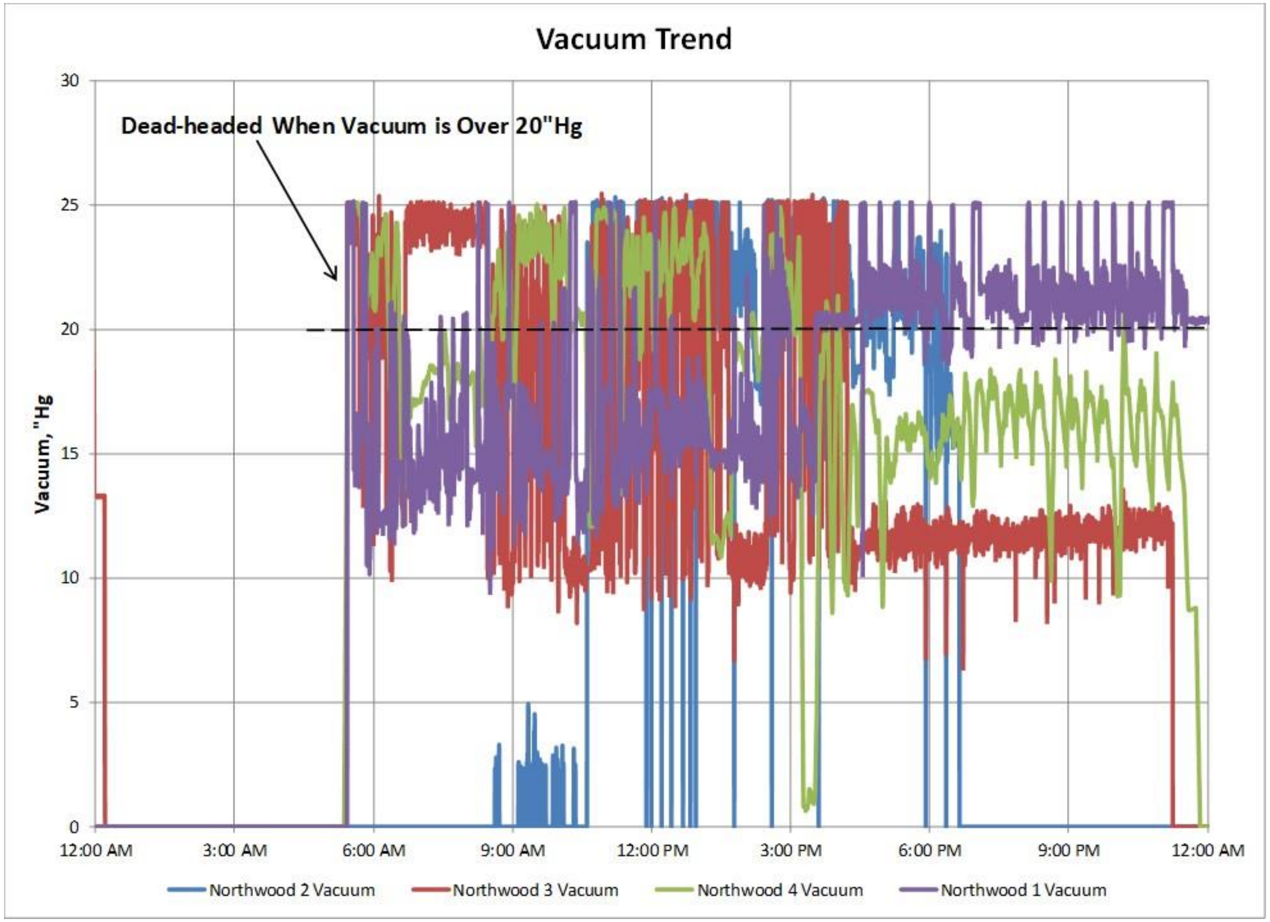
Problem Description



System	Vacuum Pump
NORTHWOOD #1 VAC PUMP	Quincy 40hp
NORTHWOOD #2 VAC PUMP	Travaini 40hp
NORTHWOOD #3 VAC PUMP	Dekker 40hp
NORTHWOOD #4 VAC PUMP	Travaini 40hp

Problem Description

- Assess System: Vac & kW was data-logged. Often dead-headed.
- Often enough to justify a project (about 60 kW average savings).

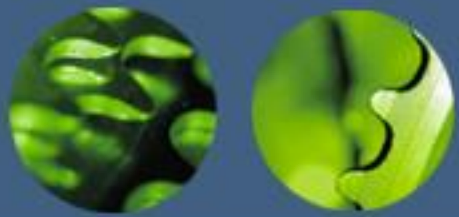


Problem Description

- That’s like having to build a house for the whole baseball team to drop in at any time, or just you and your spouse. It might be a bit oversized!

Problem Description

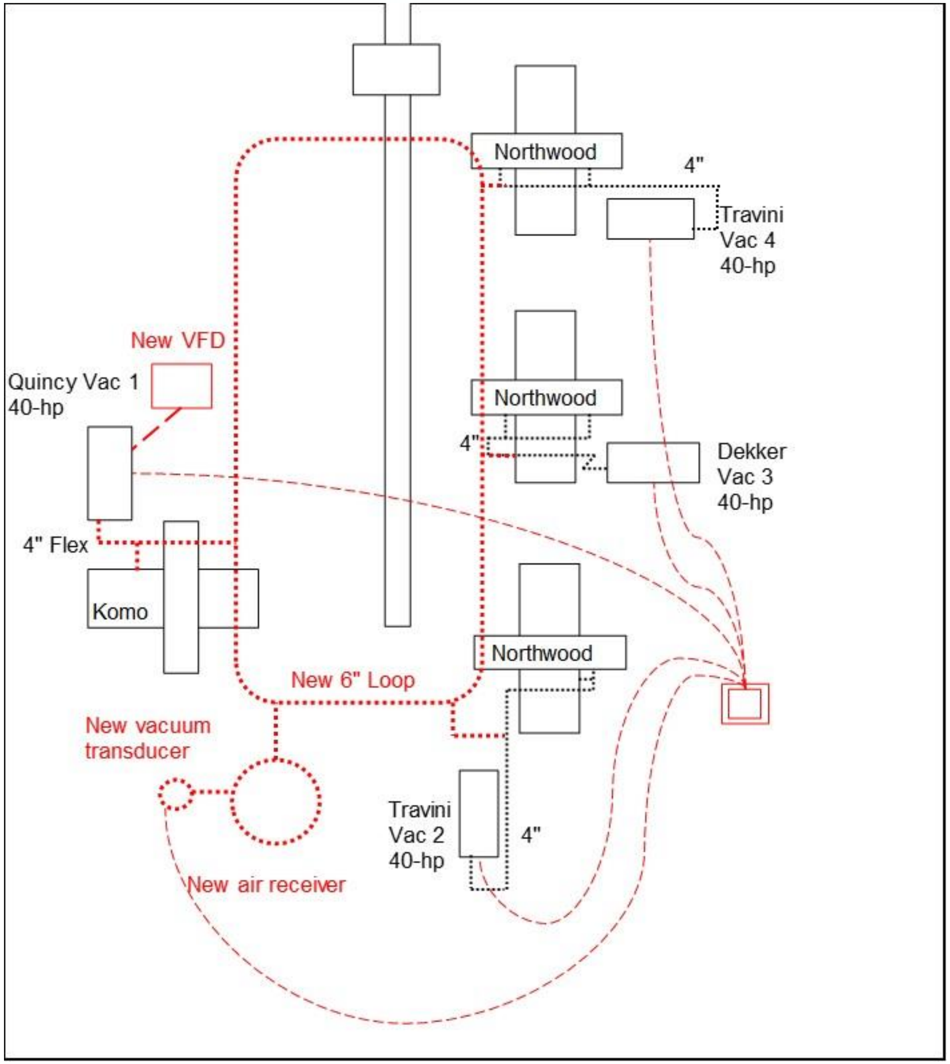
- Worse than that!
- You have many machine centers. You have a “Street of Dreams”, with most of the houses empty!



Solution 1: Consolidation

- Design Consolidation (engineering needed):
  - Piping: Looped, large enough for max flow of all 4 tables
  - VSD on at least one vacuum pump recommended
  - Storage: Sufficient for controls (depends on pump size, VSD, etc)
  - Master controls. If a VSD, keep in “trim” all the time, “target” algorithm.
  - Consider adding back-up vacuum pump or new VSD vacuum pump.

Solution 1: Consolidation



Solution 1: Consolidation

- Pros:
  - Uses existing vacuum pumps
  - Less installation cost
- Cons:
  - Tank size and location
  - More complex project. Requires some engineering and integration

Solution 2: Centralization

- Design centralization (engineering needed):
  - Site engineering:
    - Looped piping, large enough for max flow of all 4 tables
    - Electrical/mechanical installation of multiplex skid.
  - Size mulitplex vacuum pump skid for max flow of all tables, with single redundancy.
  - Have vendor propose several alternatives, VSD and not. Might need more smaller vacuum pumps for no VSD, and larger receiver.
  - Master controls, factory-wired, programmed, and tested.

Solution 2: Consolidation

- Pros:
  - Less site engineering and installation time.
  - Lower electrical & integration cost.
  - Potentially higher efficiency vacuum pumps.
- Cons:
  - More space – for skid.
  - Possibly higher initial cost (trade-off of equipment vs. installation).

Summary

- **Vacuum Fundamentals**
  - Your system is inherently “choked”, so don’t oversize.
  - Deeper vacuum than needed creates large vac pumps.
- **Problem Description**
  - Multiple systems with max to dead-head flow
  - Vacuum pumps run at max power at no production
- **Consolidation Option:**
  - Use existing vac pumps; add piping, storage, & controls
- **Centralization Option:**
  - Add piping; install new multiplex vacuum skid with storage & controls from factory

Thank you

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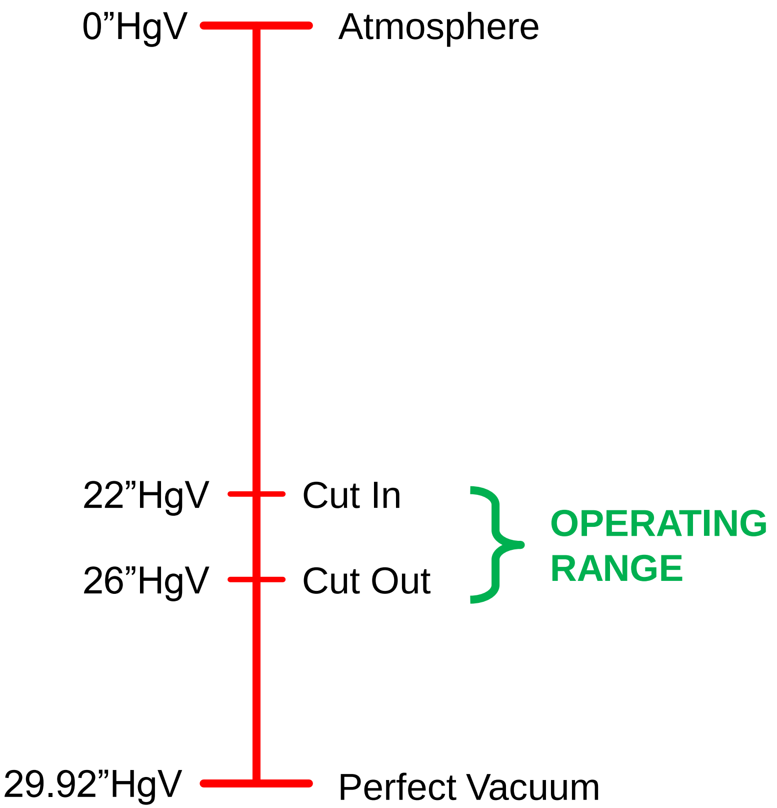
CENTRALIZED VSD VACUUM SYSTEMS

Greg Marciniak

Product Marketing Manager – Atlas Copco

TRADITIONAL FIXED SPEED CONTROLS

TRADITIONAL FIXED SPEED CONTROLS



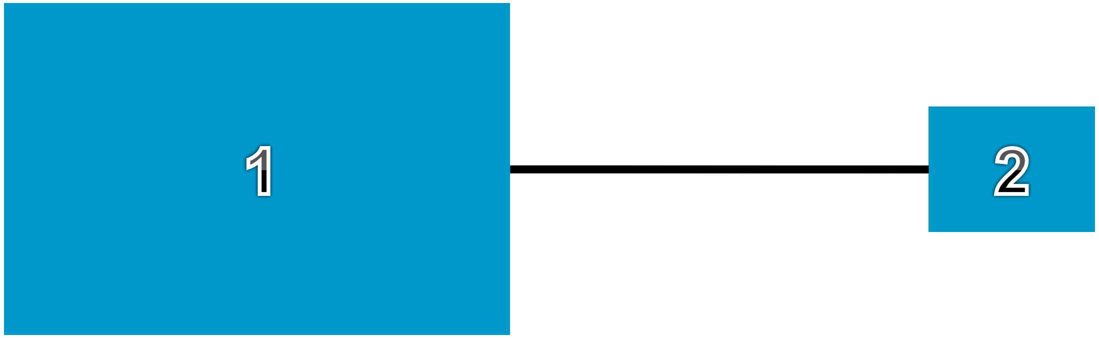
Vacuum Switch

Vacuum Transducer

OPTIMIZING PRESSURE - BOYLE'S LAW

…designing for 27.5"Hg requires twice the size vacuum pump as 25"Hg

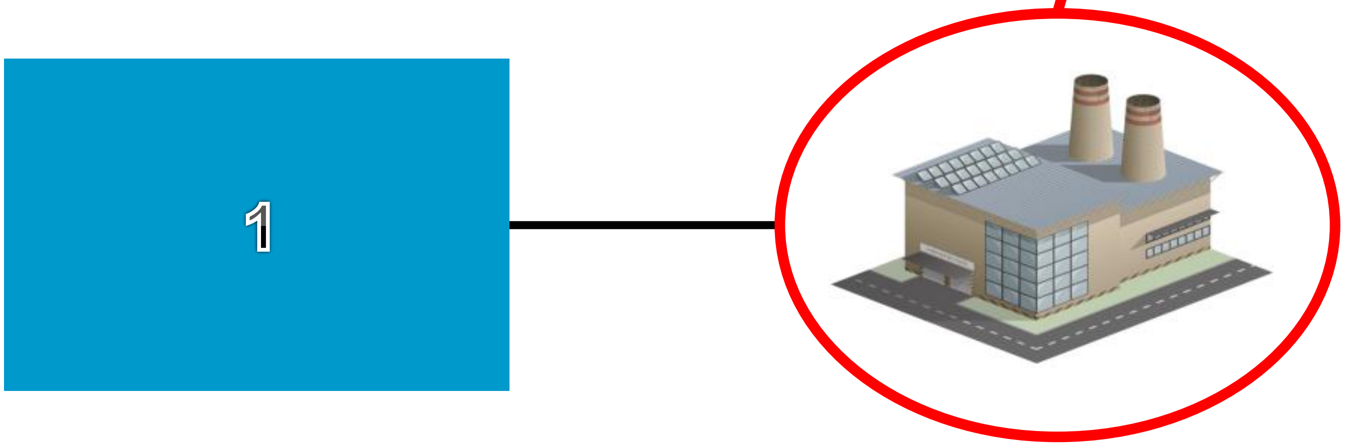
$$P_1V_1 = P_2V_2$$



OPTIMIZING PRESSURE - BOYLE'S LAW

K = Constant

$$P_1V_1 = P_2V_2$$



OPTIMIZING PRESSURE - BOYLE’S LAW

$$P_1V_1 = K$$

K = Constant

1

OPTIMIZING PRESSURE - BOYLE'S LAW

What does it all mean for the end customer?

Imagine a process demand of:

- 27.5"HgV (29.92 - 27.5 = 2.42"HgA)
- 300 acfm

P = 2.42"HgA (always use absolute terms)
V = 300 acfm

PV = (2.42)(300) = **K** = 726 (constant)

OPTIMIZING PRESSURE - BOYLE'S LAW

What does it all mean for the end customer?

So, if we can adjust the vacuum level to 25"HgV (29.92 – 25 = 4.92"HgA)

P = 4.92"HgV (always use absolute terms)
K = 24,600 (from previous calculation)
V = ? acfm

PV = (4.92)**V** = 726

V = 147 acfm

OPTIMIZING PRESSURE - BOYLE'S LAW

What does it all mean for the end customer?

So, if we can adjust the vacuum level to 25"HgV (29.92 – 25 = 4.92"HgA)

P = 4.92"HgV (always use absolute terms)
K = 24,600 (from previous calculation)
V = ? acfm

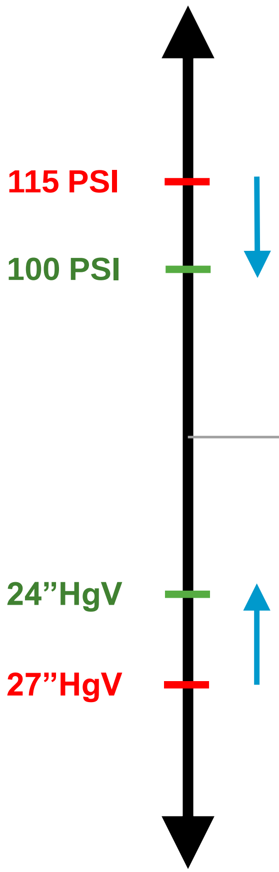
PV = (4.92)**V** = 726

V = 147 acfm

…designing for 27.5"Hg requires twice the size vacuum pump as 25"Hg

Flow requirement went from **300** to **147** acfm

OPTIMIZING PRESSURE



Compressed Air

Lower Pressure = Energy Savings

Atmosphere 1bar(a) = 1000mbar(a)

Vacuum Pump

Same message, set the pump at the maximum allowable vacuum level = Energy Savings

SET POINT CONTROL

- In the traditional fixed speed controls, a target was approximate by setting cut in/cut out to average a given pressure
- With VSD vacuum, you can set the exact pressure desired
- The variable speed drive will adjust motor speed to meet this target accurately
- This allows the end user to lock in and maintain a constant system pressure

SET POINT CONTROL

Product Quality

- Lower scrap rate

Lower Energy Costs

- VSD ramps up or down to meet required demand
- Wide turn down ratio
- No excessive flow when not needed

Standby mode

- When demand drops, unit will shut off to a standby mode
- When demand increase, it will ramp back up
- No dead-heading the pump

Potential Energy Rebates

EXAMPLE – CUSTOMER XYZ

Previous Vacuum Scenario:

- Consisted of (6) 2 HP liquid ring vacuum pumps
- Operating level of 20”HgV
- Vacuum pumps supplied point of use vacuum to (6) capsule filling stations and (1) packaging station – point of use application

VSD Solution:

- (1) 7.5 HP VSD oil-flooded rotary screw machine utilized in a centralized system
- Machine had enough capacity to allow for future expansion of 2-3 more filling stations if required
- Customer ended up recommending this change to another similar manufacturer, who has also purchased a variable speed screw machine

Thank you!

Greg Marciniak

Product Marketing Manager

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About the Speaker

VJ Gupta
Busch Vacuum Pumps and Systems

- Systems Engineering Manager for Busch Vacuum Pumps and Systems

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Design and Optimization of Central Vacuum Systems

Webinar: Evaluating the Centralization of Vacuum Systems

VJ Gupta, Systems Engineering Manager
June 29, 2017

Central Vacuum Systems
A Proven Concept

- We have designed, supplied and installed central vacuum systems for 40 years!
- Over 1,000 central vacuum systems installed globally.
- Industries Served:
  - ✓ Plastics
  - ✓ Printing
  - ✓ Vacuum Packaging
  - ✓ Semiconductor
  - ✓ Solar
  - ✓ Chemical & Pharmaceutical
  - ✓ Many more……
- Busch central systems have successfully provided great benefits and savings with the following features:
  - ✓ Controls with Variable Frequency Drives (VFD) and/or cascading logic
  - ✓ With or without vacuum buffer tanks
  - ✓ Systems capable of operating at up to 3 different vacuum levels

Central Vacuum Systems
Why Centralize?

Return on investment (ROI)

- With proper design, can prove a return on investment on a cost of ownership basis demonstrated by energy saving and increased productivity.
- Design can allow for a reduction in maintenance costs (both material and labor)

Efficiency

- Electrical Savings– pump sizing and controls design is key!
- Heat Reduction in production areas.
- Heat recovery from central system exhausts.

Uptime

- Maintenance can be planned & performed while system continues to run.
- Spare capacity can ensure continuous operation in the event of pump failure.

Environmental

- Sound removed to desired remote location & controllable.
- Heat removed to a desired remote location & containable.
- Removes messy pumps & discharge from floor area.
- Great appearance.

Plant efficiency & expandability

- Provides instantaneous vacuum.
- Provides only the required vacuum level.
- Additional applications can easily be added and central units can be expanded.

Central Vacuum Systems
Should I Centralize?

Conduct a Study

- Conduct a dedicated study. Every customer's requirements are unique.
- Centralization must be done right to realize optimum savings. Not all applications are a good fit.
- Does my plant have multiple machines with different vacuum needs?
- Does my plant require different vacuum levels (up to one, two or even three different vacuum levels)?
- Is my vacuum process Dynamic, Static or Both?
- One preset vacuum pressure design (i.e. VFD) for plants with different vacuum level needs may not be optimal.
- Examples of varying vacuum levels in different industries:

Industry	Application (less vacuum required)	Application (more vacuum required)
Solar	Pick & Place	Laminating
Meat Industry	Pneumatic Conveying of Waste Product	Vacuum Packaging
Semiconductor	House Vacuum	Process Vacuum
Plastics	Pneumatic Conveying of Pellets	Calibration Table
Graphics Industry	Trimming Machine	Printing Machine

Vacuum System Design Options
Should I Centralize?

Example of Varying Vacuum Levels in a Plant:

Printing Machine (Feeder): 24 ACFM Dry Vane Pump	**Trimming Machine: 100 cfm Side Channel Blower**
› Motor Power: 2.0 HP › Pump Suction Pressure: 18"HgV (303 Torr) › Pump Suction Flow: 24 ACFM (standard flow = 9.5 SCFM)	› Motor Power: 1.0 HP › Pump Suction Pressure: 3"HgV (684 Torr) › Pump Suction Flow: 65 ACFM (standard flow = 58.5 SCFM)

To Centralize these two applications, add standard flows:

Total standard flow needed = 9.5 SCFM + 58.5 SCFM = **68 SCFM**

But, Central System be designed to operate at the maximum vacuum level needed, i.e. 18"HgV (303 Torr)

Resulting Pump Suction Flow @ 18"HgV = 170 ACFM

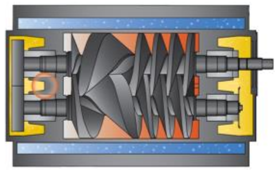
Equivalent to a 170 CFM Pump with a 10.0 HP motor!!

Vacuum System Design Options

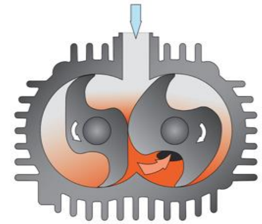
Possibilities – Various Pump Technologies Available

Each Operating Principle has its Optimum Vacuum Operating Range wherein it provides Maximum Efficiency!

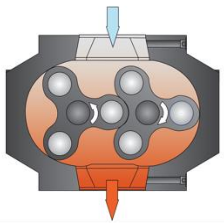
Dry Screw
Vacuum Pumps



Dry Claw
Vacuum Pumps



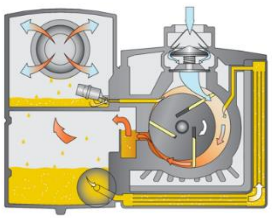
Rotary Lobe
Blowers



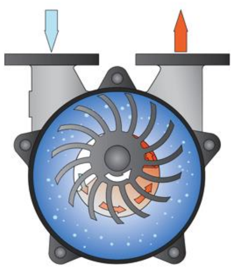
MANY
OPERATING
PRINCIPLES

Consider All Options!
Pick the Best Fit

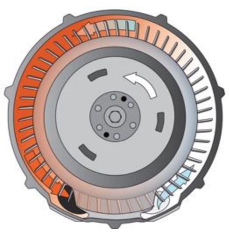
Oil-Lubricated
Rotary Vane
Vacuum Pumps



Liquid Ring
Vacuum Pumps



Side-Channel
Blowers



And Many
More!!

Vacuum System Design Options
Starters & Controls Hardware

Starter Panel
w/ On/Off Switches

Less PPE (Personal Protective Equipment) means less downtime!

Control Panel
w/o VFD

Control Panel
w/ VFD

Vacuum System Design Options
Vacuum Control

- Pick the right Controls Scheme. Simply installing VFD alone does not guarantee maximum savings.
- Consider cascading control logic with ON/OFF switch points for single or multiple pump configurations. This has been a very successful practice in the industry for a long time.
- Consider using a VFD to “trim” excess capacity for more energy savings.
- Central systems connected to large flow machines can cause significant vacuum “spikes”. VFD may be unable to keep up! Vacuum buffers can be considered.
- Chose optimum Pipe Size and Pipe Volume considering costs, pressure drop and system dynamics.
- Additional vacuum buffers can be added (i.e. tanks, larger piping etc.)

Central Vacuum Systems
In Summary

- Every Customer’s plant requirements are unique.
- There is no “One Size Fits All” solution! An Optimal Centralized System is custom tailored to meet customer needs.
- Conduct a complete study of your existing needs. Busch can help with this!
- Pick the pump technology that is designed for your vacuum level and application. Central systems can look very different from one another!
- The Optimum Control Scheme is key to a successful design. VFD can be used where it makes sense!
- Take advantage of Vacuum Buffer and Pipe Sizing to optimize performance.
- **Central systems have to be custom tailored to meet your requirements. Contact an expert!**

Thank you!

For more information about Busch Vacuum Pumps and Systems, please visit: **www.buschusa.com**

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Hank van Ormer, Air Power USA
Keynote Speaker

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