Control Systems: Design, Performance and Commissioning Issues

Outputs

Instructor:

David Sellers

Senior Engineer

Facility Dynamics Engineering

October 23, 2017

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Actuator Types

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Proportional Actuators

Electric

- Tristate
  - Two sets of contacts
    - Clockwise rotation
    - Counterclockwise
  - Can be used as two position
- Proportional signal
  - 4-20 milliamp
  - 2-10 vdc
  - 1-5 vdc

Image courtesy Bray Controls; used with permission

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Proportional Actuators

Electric

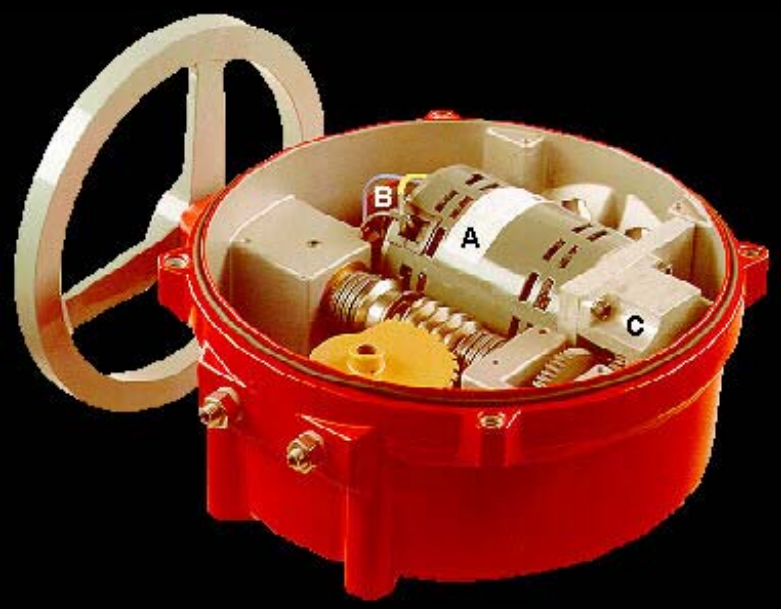
- Electronic controller boards required to integrate the drive system with the control and power system

Image courtesy Bray Controls; used with permission

Proportional Actuators

Electric

- Frequently powered with low voltage cabling system to minimize cost
  - Power limited circuits mean that the instantaneous power available to move something is limited
  - Small motors are geared to manage the available power
    - Torque may be limited unless high voltage power is provided



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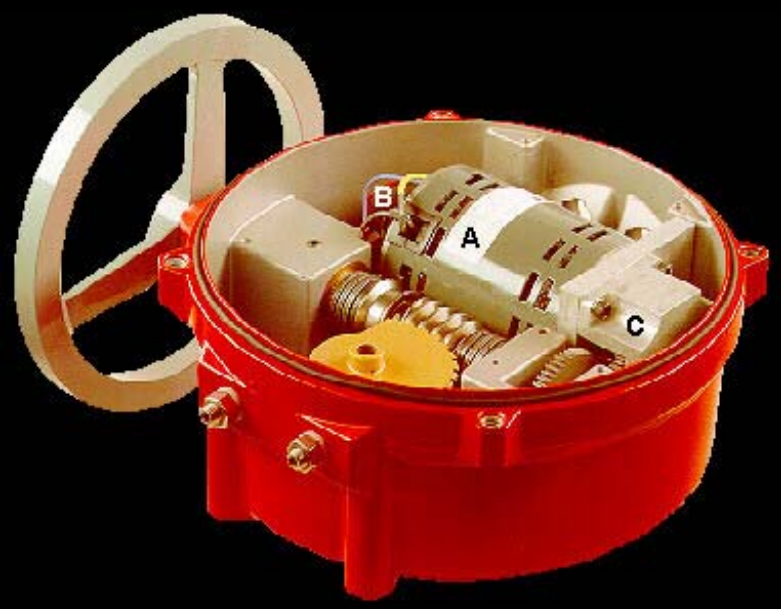

- Speed is compromised
  - 15 seconds is fast
  - 30-60 seconds is common
  - 90 – 120 seconds is not unheard of in large actautors

Proportional Actuators

Pneumatic

- Power is a function of diaphragm or piston area
- Even with low pressure (20 psi) air you can get a lot of force and torque
- 50-150 psi operation is possible
- Can be used for modulation or two position operation

Image courtesy Bray Controls; used with permission

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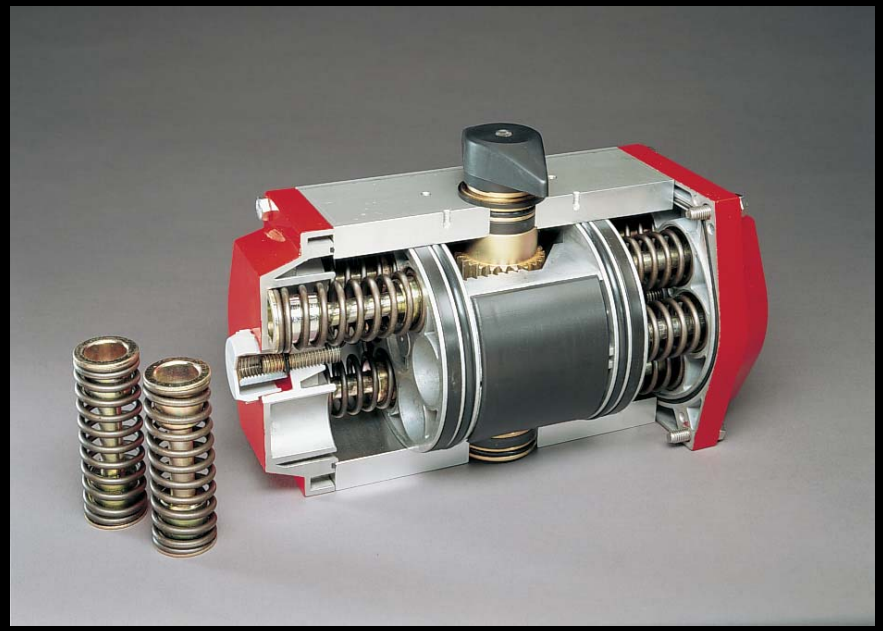
Proportional Actuators

Pneumatic

- Relatively simple construction
- Easy to understand and repair
- Actuating speed can be a matter of seconds to go full stroke
  - The air line needs to be sized to provide the volume required for the desired speed
  - Beware of water hammer and air hammer



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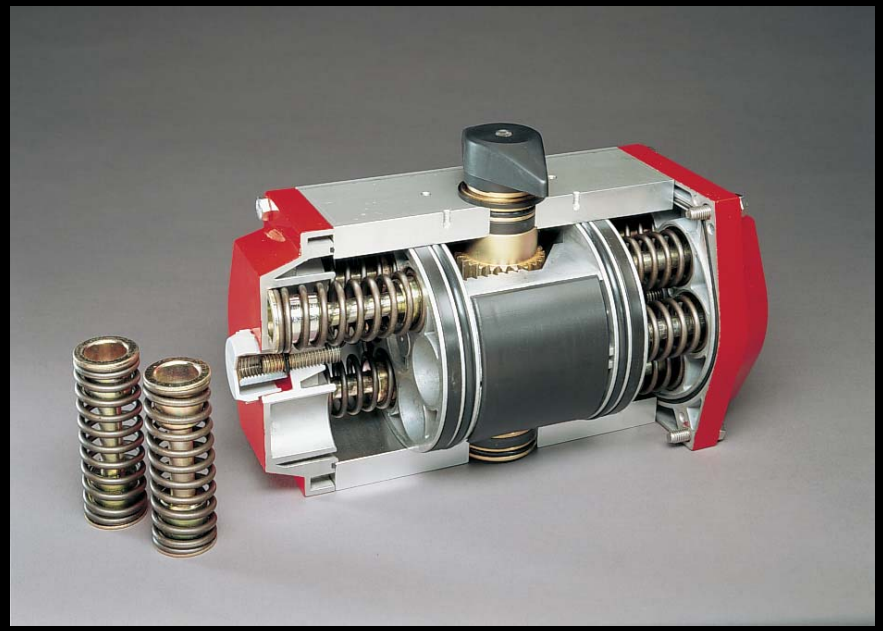

- Double acting cylinders can use air to provide equal power in either direction
  - Accumulators with check valves provide fail safe operation

Proportional Actuators

Pneumatic Sequencing

- 3-15 psi = standard signal
- Spring ranges allow sequencing
  - HW Coil – 3-5 psi = Full flow to no flow
  - Economizer – 7 – 10 psi = MOA to Maximum OA
  - CHW Coil – 12-15 psi – No flow to full flow
  - Can be used as a two position actuator

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Spring Ranges and Linkage Systems

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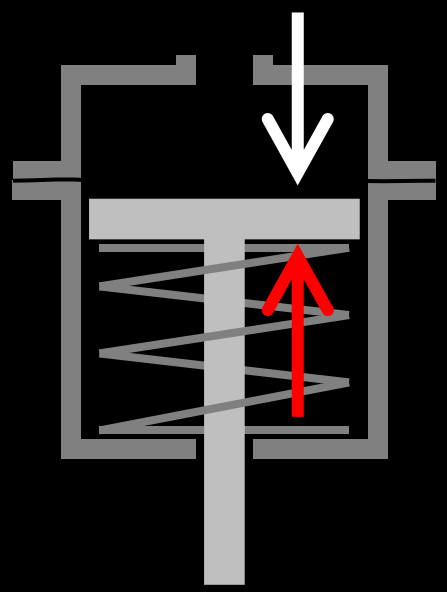
The Forces Acting on a Valve Actuator as Described in the Literature



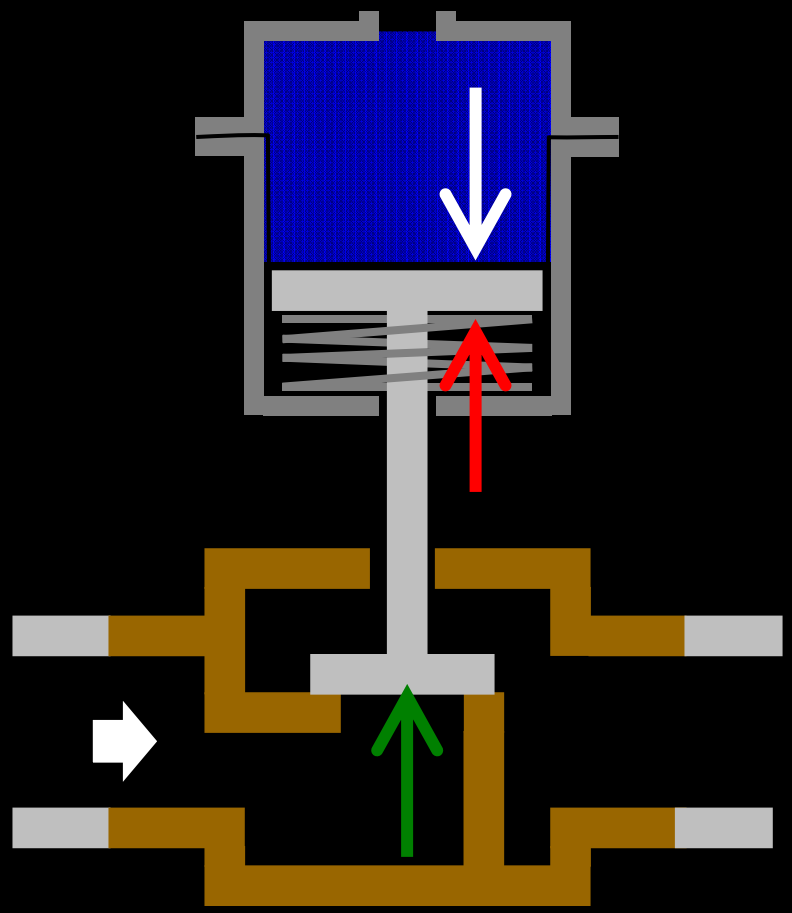
Control Signal

Force = Pressure x Area

Spring

Force = Spring Rate x Deflection

The Forces Acting on a Valve Actuator in the Field



Control Signal

Force = Pressure x Area

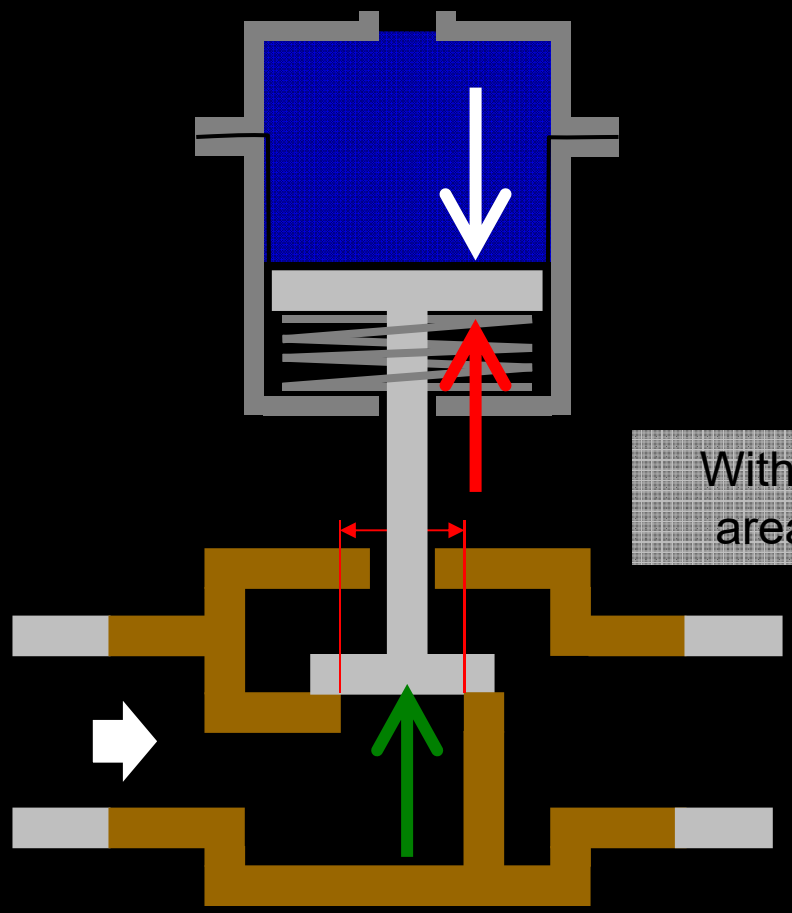
Spring

Force = Spring Rate x Deflection

Valve Plug Differential Pressure

Force = Effective Area x ΔP

The Forces Acting on a Valve Actuator in the Field

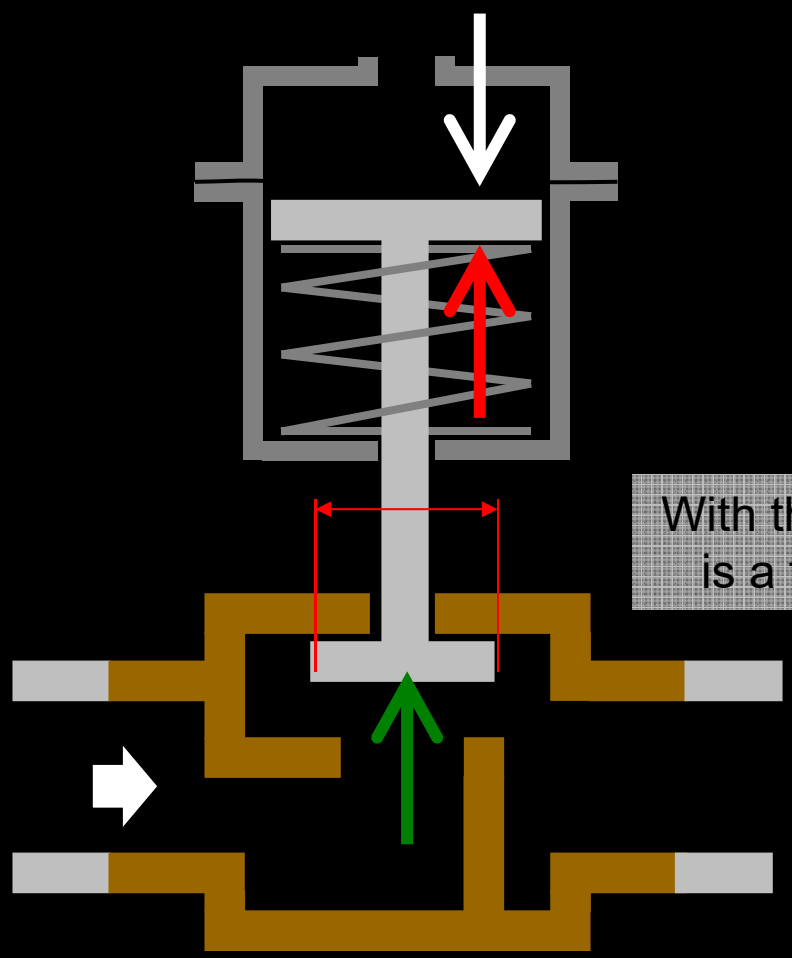


Plug force will vary as the result of a number of operating variables

- Effective area can change

With the valve closed, the effective area is a function of this diameter

The Forces Acting on a Valve Actuator in the Field



Plug force will vary as the result of a number of operating variables

- Effective area can change

With the valve open, the effective area is a function of a different diameter

Positioners

Pneumatic and Electric

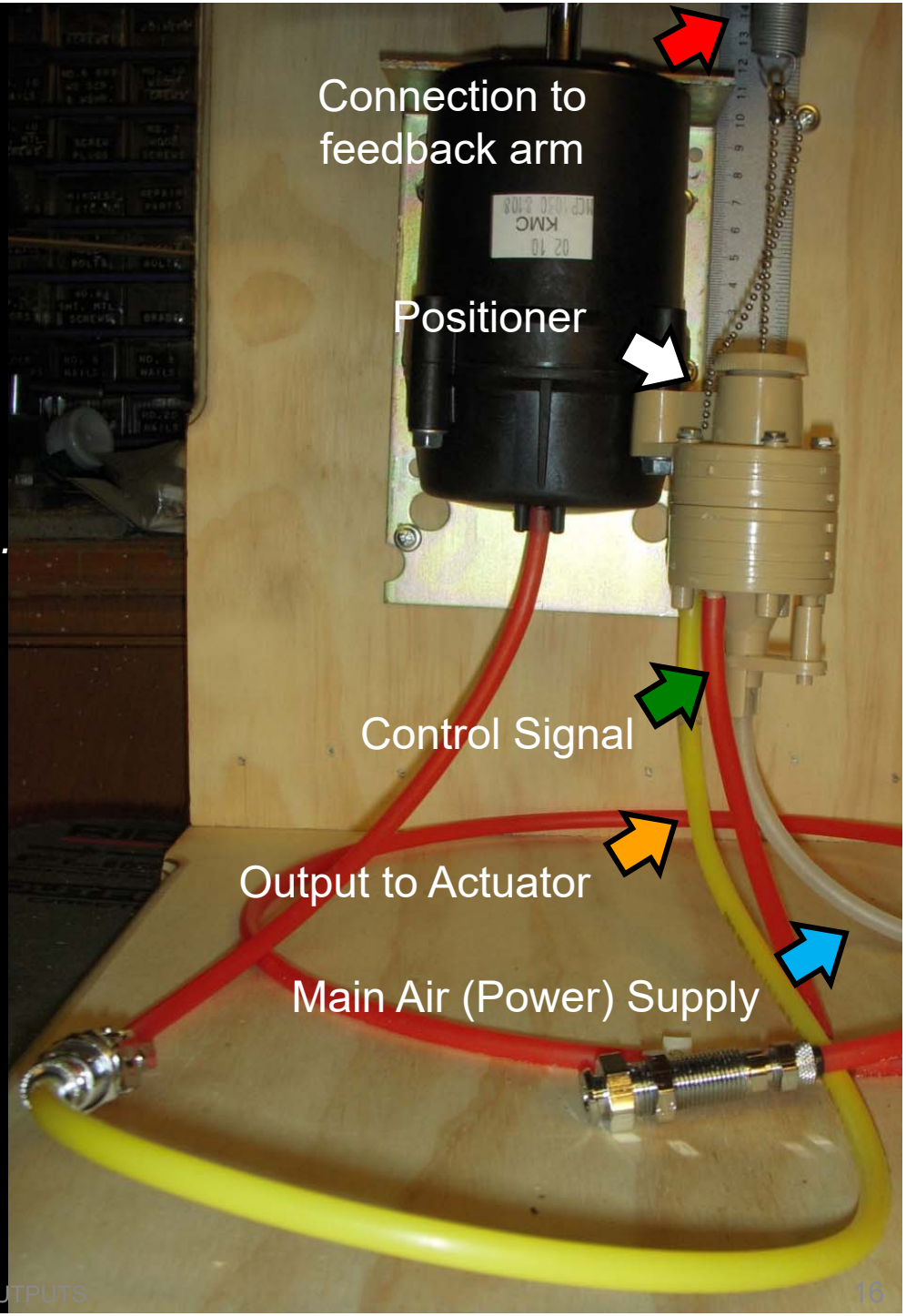
- Positive positioning relays *… a.k.a "Positive positioners" a.k.a. "Positioning relay" a.k.a. "Positioners" …*

  monitor actuator motion …

  … and compare it to the desired actuator position ….

  … and "do what ever it takes" to get the actuator to move an amount that corresponds to the input change

- An independent energy source provides the power to do this



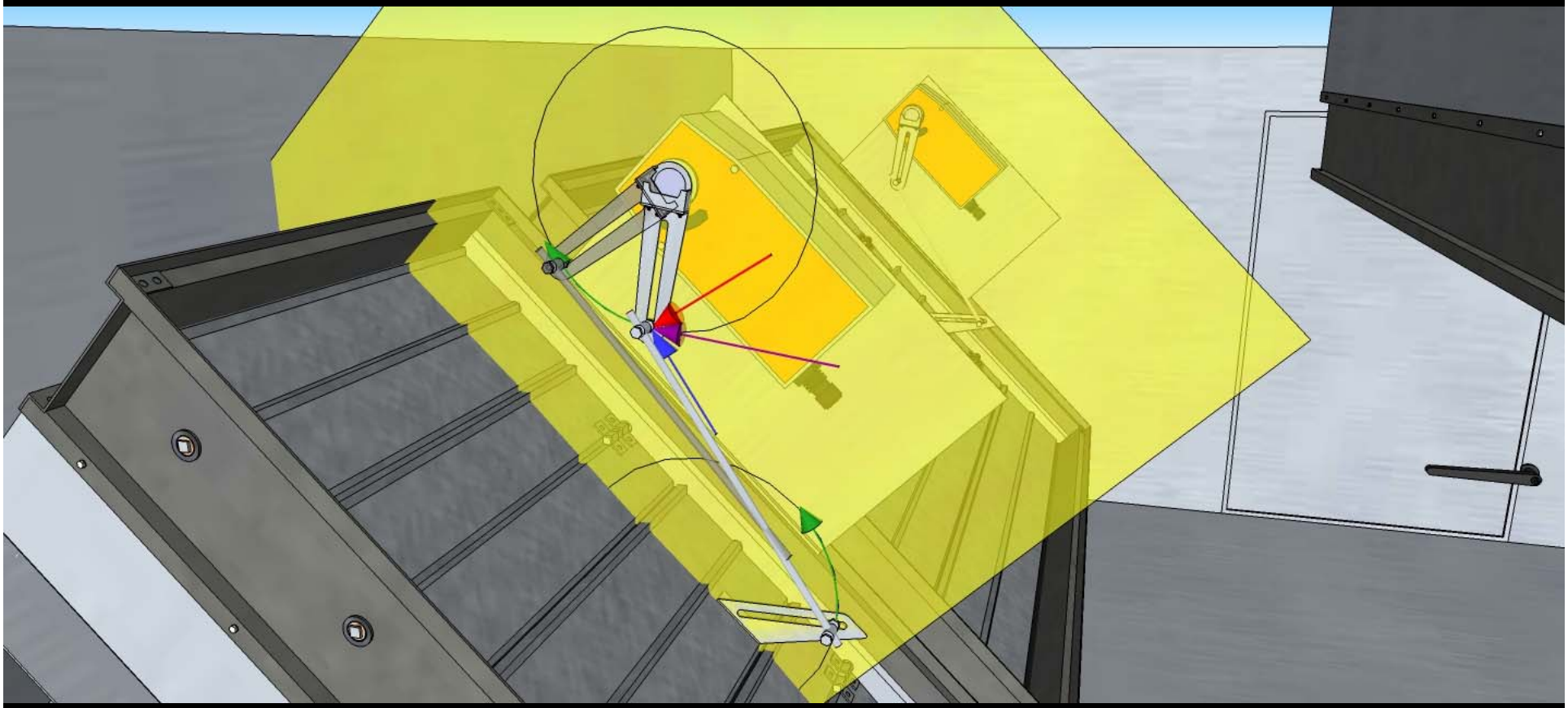
Dampers Can See Similar Variation in Power Required vs. Stroke

- Aerodynamic loads can vary with stroke
- Jamb seal loads can increase as the blades become aligned with the frame
- Blade seals require a very specific torque applied to the damper shaft to compress them and achieve rated leakage

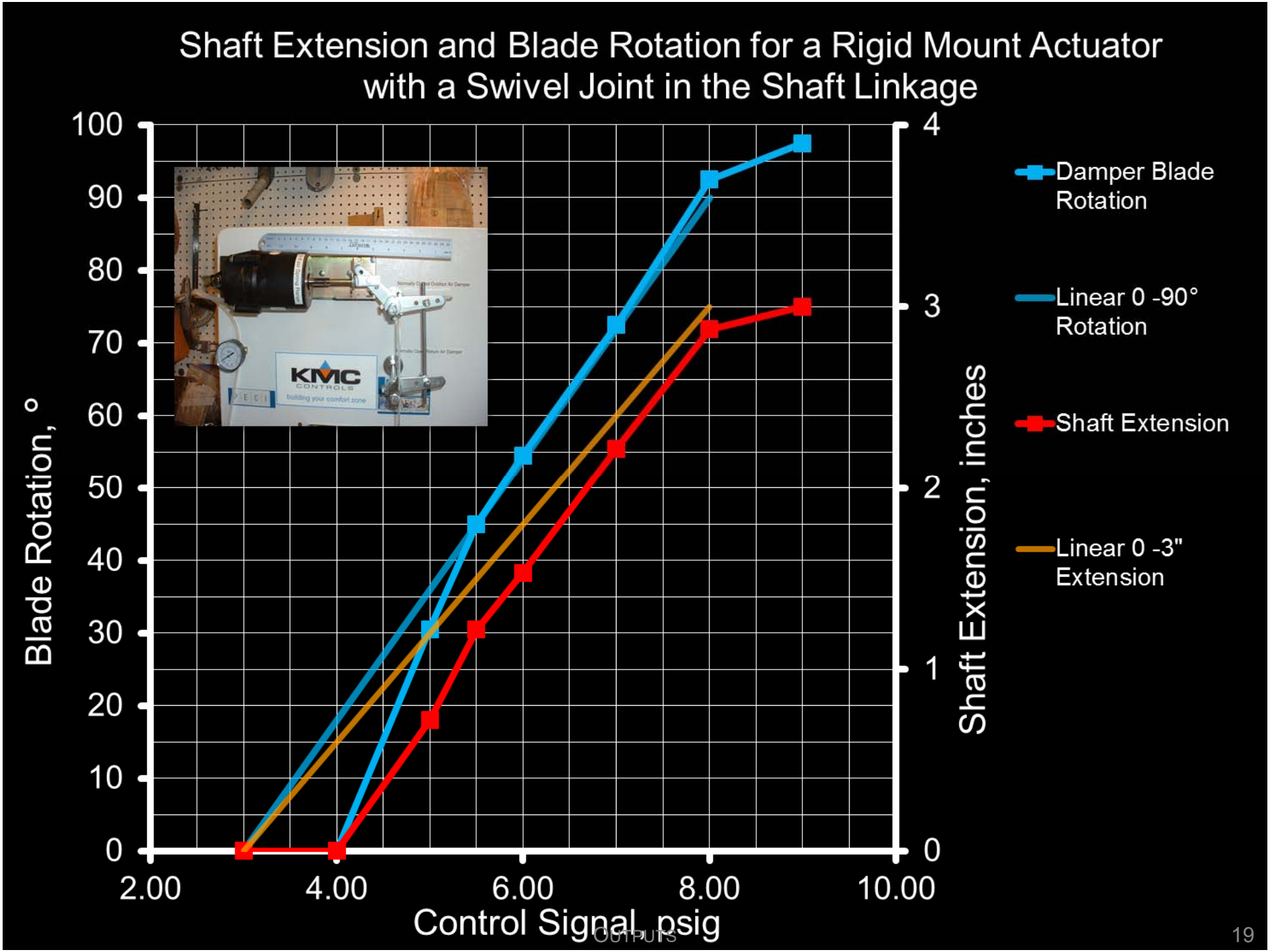
Kinematics

The Physics of Motion

Kinematics can play a huge role in terms of actuator to damper linearity and actuator torque available vs. useful force at the damper blade



See *Economizers–The Physics of Linkage Systems* on my blog for more information


Shaft Extension and Blade Rotation for a Rigid Mount Actuator with a Swivel Joint in the Shaft Linkage
Blade Rotation, °
100
90
80
70
60
50
40
30
20
10
0
Shaft Extension, inches
4
3
2
1
0
2.00
4.00
6.00
8.00
10.00
Control Signal, psig
Damper Blade Rotation
Linear 0 -90° Rotation
Shaft Extension
Linear 0 -3" Extension
KMC
CONTROLS
building your comfort zone

Fortunately, Centerline Drive Actuators Solve the Linkage Linearity Problems

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Solve the Linkage Linearity Problems;
BELIMO
NF24-SR US

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Pacific Energy Center Triple Deck Multizone Unit

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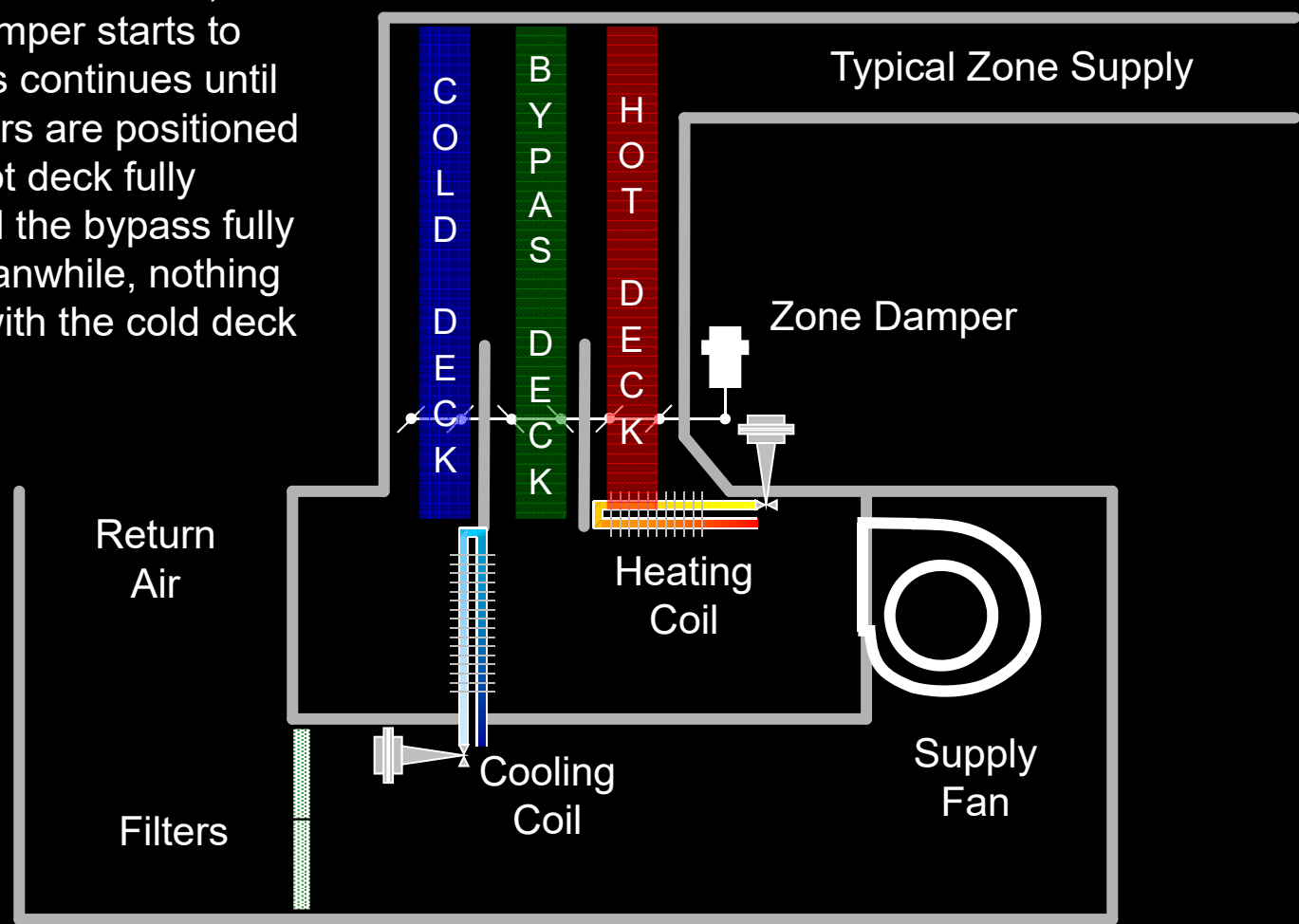
Walking Up to the Unit

Looking Left

Zone damper linkage system arranged so that as the actuator strokes, the damper blades modulate from:

- Full hot deck, no bypass, no cold deck* to;
- Full bypass deck no cold deck, not hot deck to;
- Full cold deck, no bypass, no hot deck

* This means as the hot deck damper starts to close, the bypass damper starts to open. This continues until the dampers are positioned with the hot deck fully closed and the bypass fully open. Meanwhile, nothing happens with the cold deck damper



Fortunately, Centerline Drive Actuators Solve the Linkage Linearity Problems;

~~Fortunately, Centerline Drive Actuators~~
~~Solve the Linkage Linearity Problems;~~

Actuators Actuate Final Control Elements

Examples

- Valves
- Dampers
- Variable Speed Drives
- Centrifugal Machines

Final control elements need to be properly applied

Valves and dampers must be properly sized

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Valve and Damper Sizing

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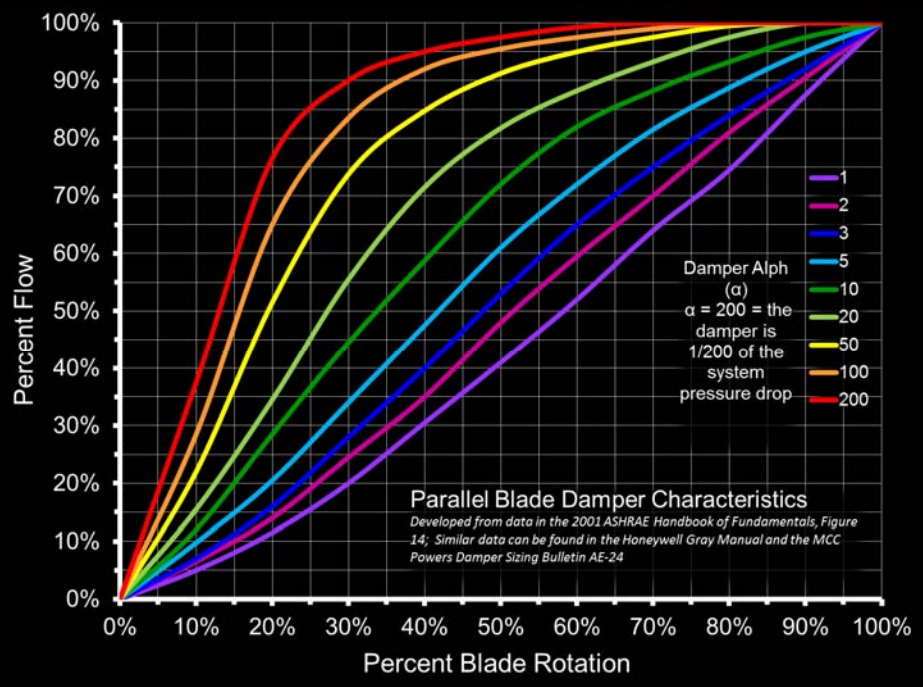
Dampers Need to be Sized for Modulating Control

Characteristics vary with damper design

Rules of thumb

- Pressure significant relative to the system
- Target face velocity of 1,500 to 2,500 fpm will usually work
- Air flow velocity conversions count in the over-all pressure loss



Valves Also Need to be Sized for Modulating Control

Characteristics vary with valve design

Rules of thumb

- Pressure drop equal to the load served
- At least one size smaller than the pipe

Governing equation

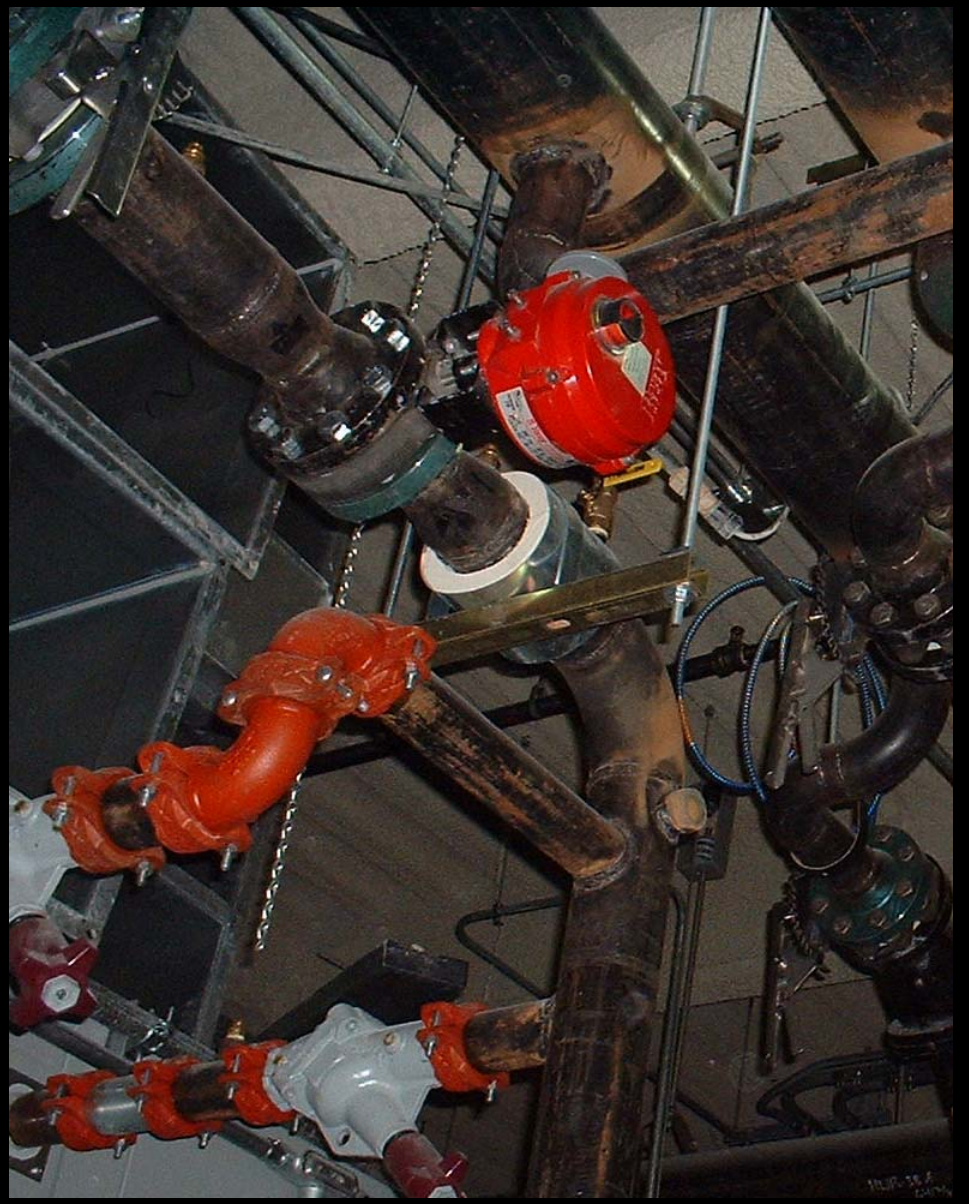
- $Q = C_V x \sqrt{\Delta p}$

  Where:

  Q = Flow in gpm

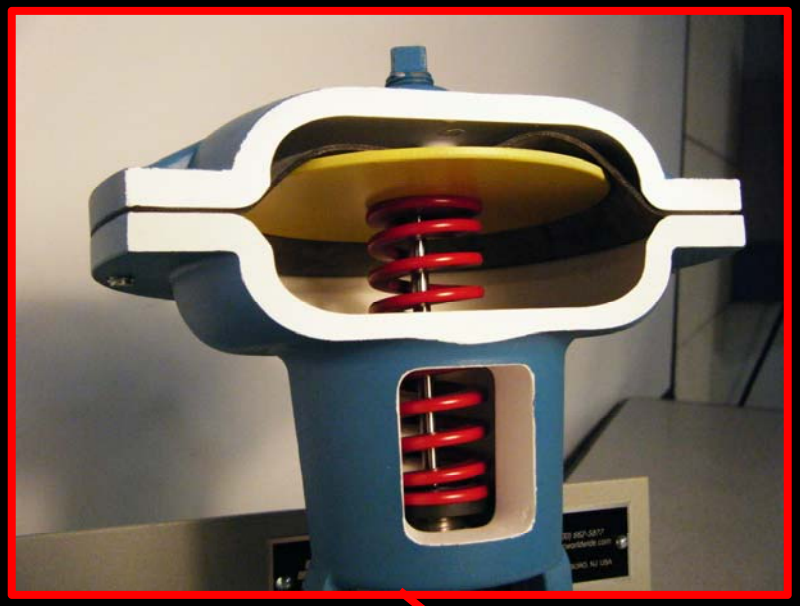
  C_V = Flow coefficient

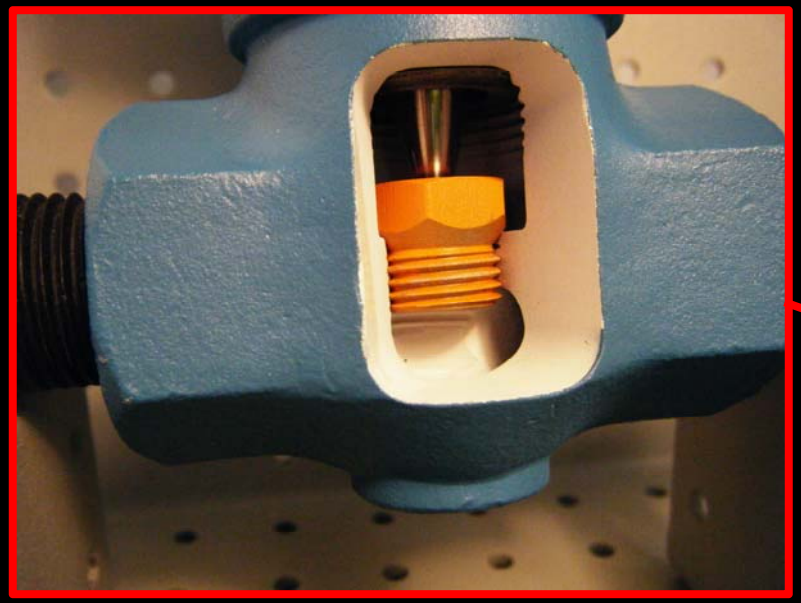
  Δp = Pressure drop in psi

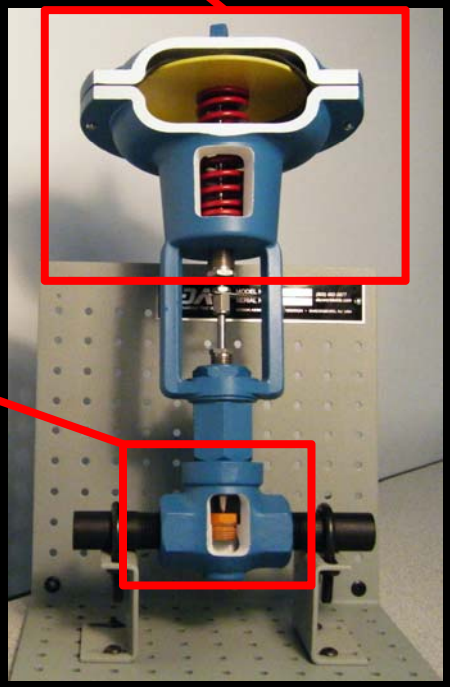


Valves Also Need to be Sized for Modulating Control

Steam valves use different equations depending on if the flow is subsonic or not







More on Valve and Damper Sizing

The following resources have good content on the topics of valve and damper sizing

- MCC Powers Damper Sizing Application Engineering Bulletin AE-24
- MCC Powers Valve Sizing Application Engineering Bulletin AE-1
- The Honeywell Gray Manual in the section at the end of the manual titled *Engineering Information*

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Final Control Elements

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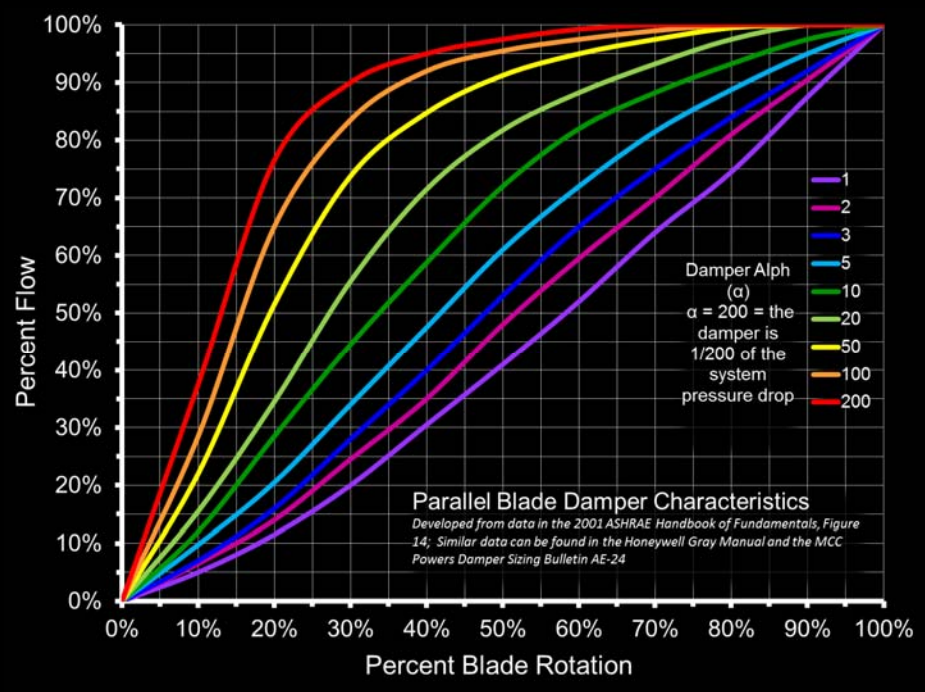
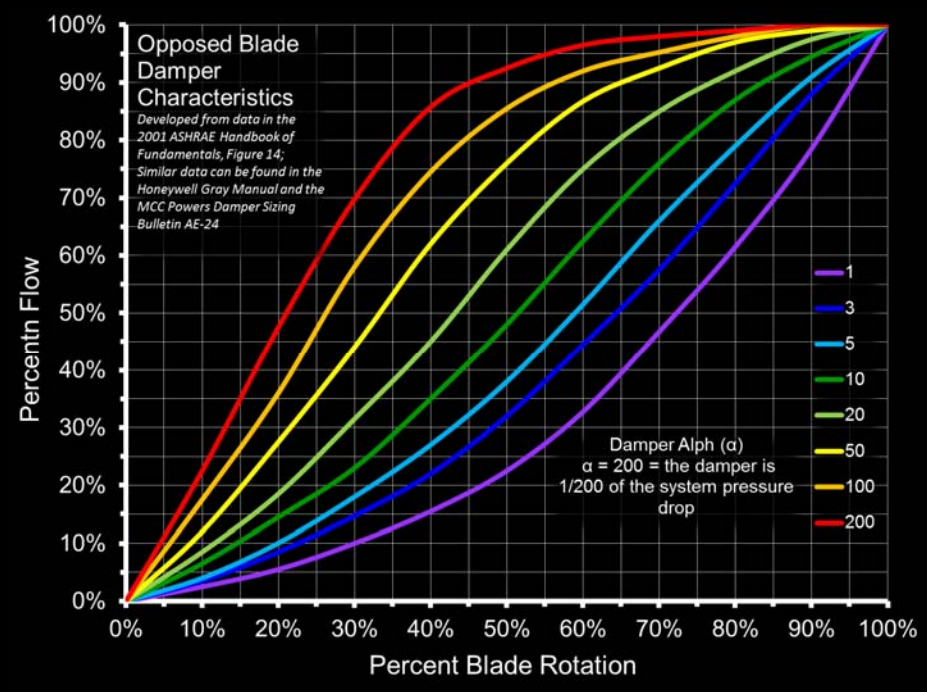
By Nature, Most HVAC Components Have Analog, Non-linear Characteristics





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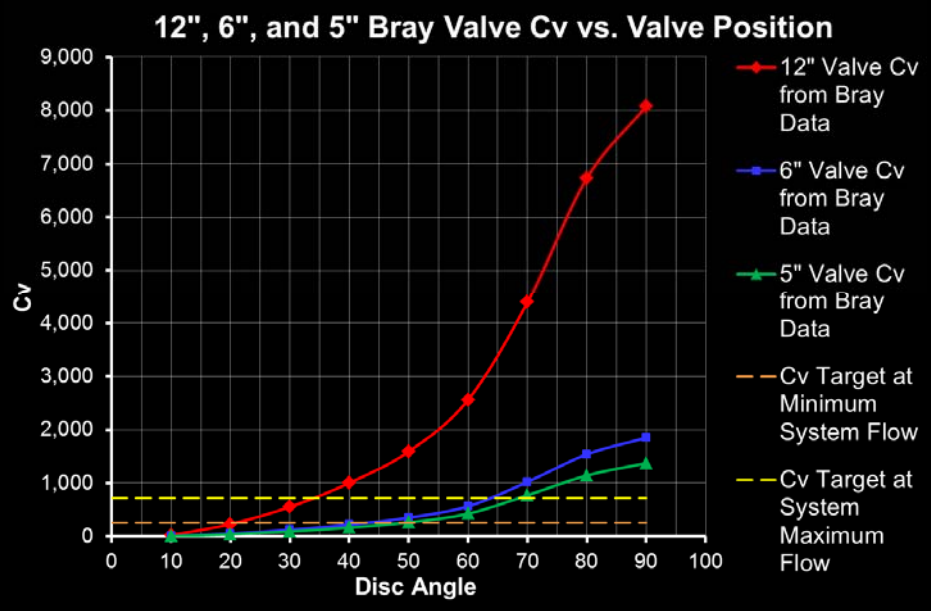

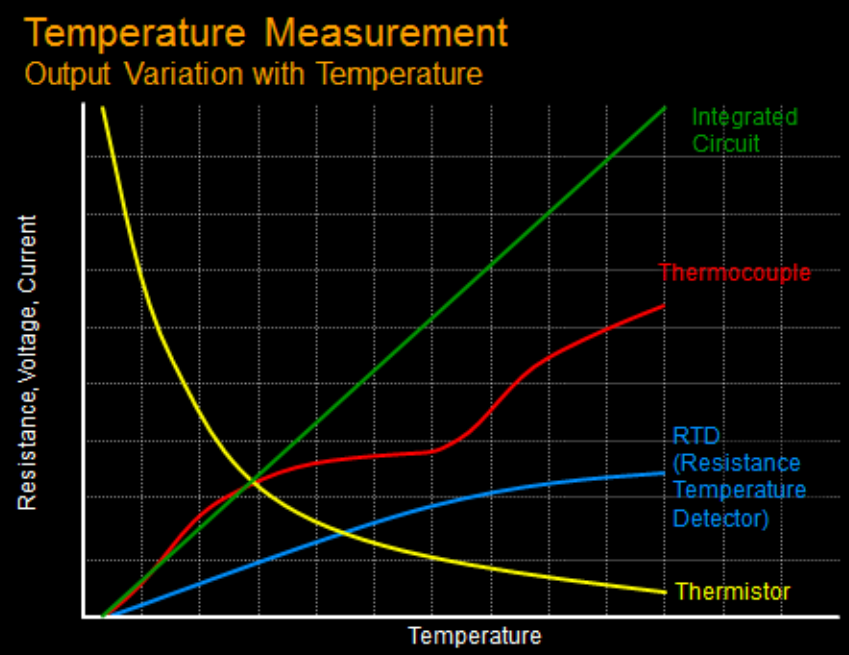

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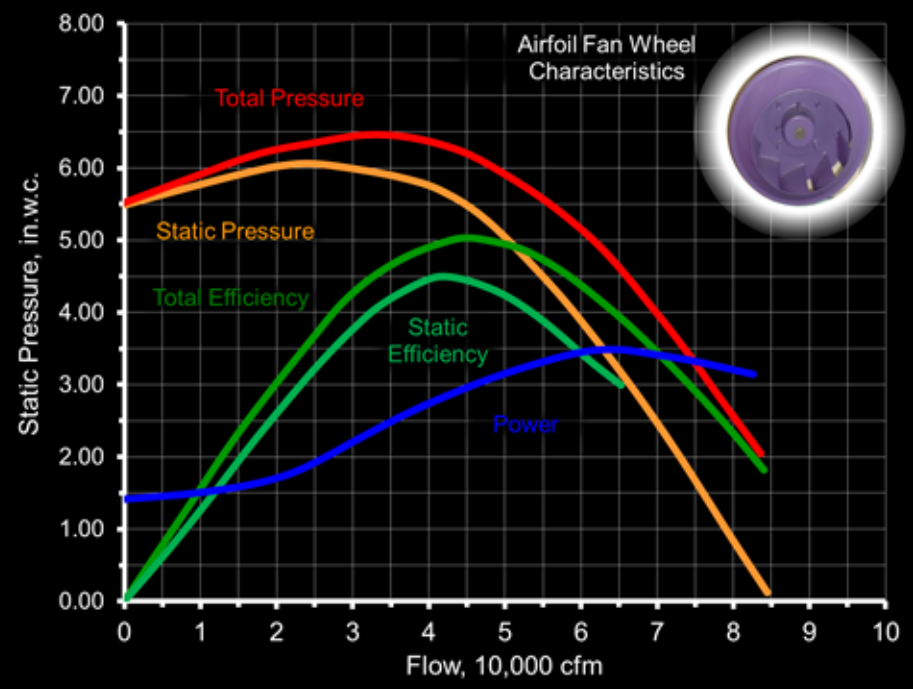

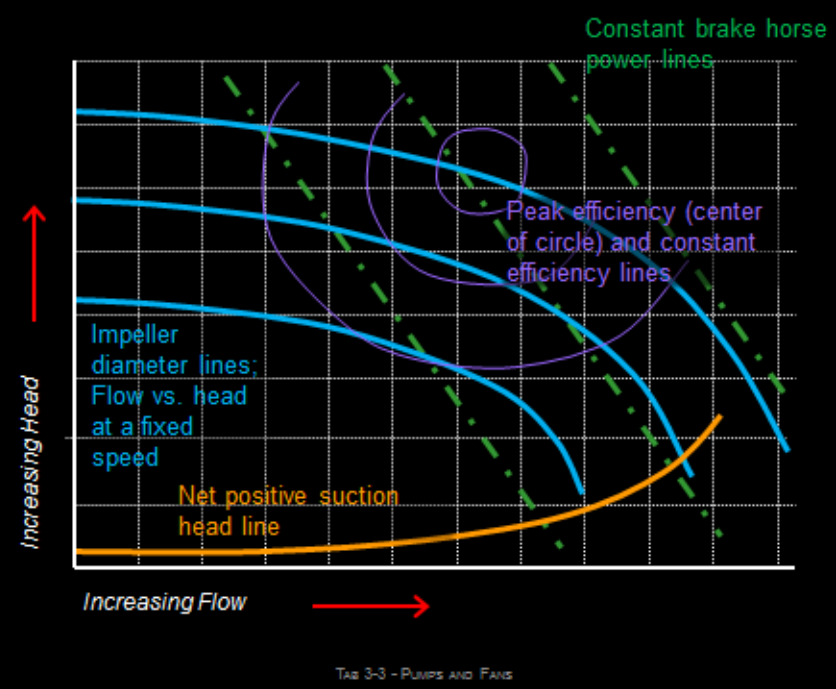

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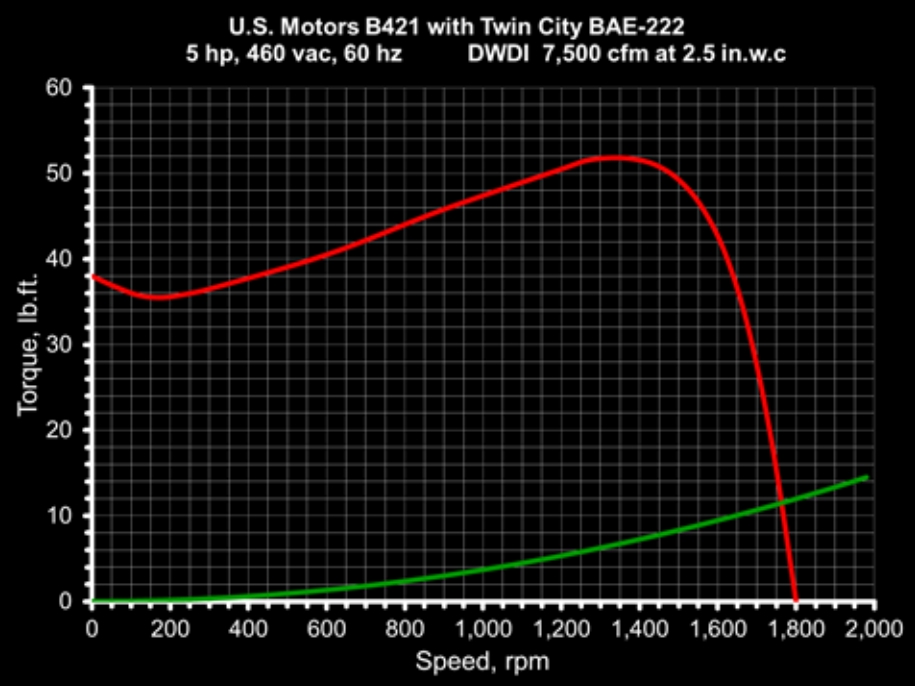

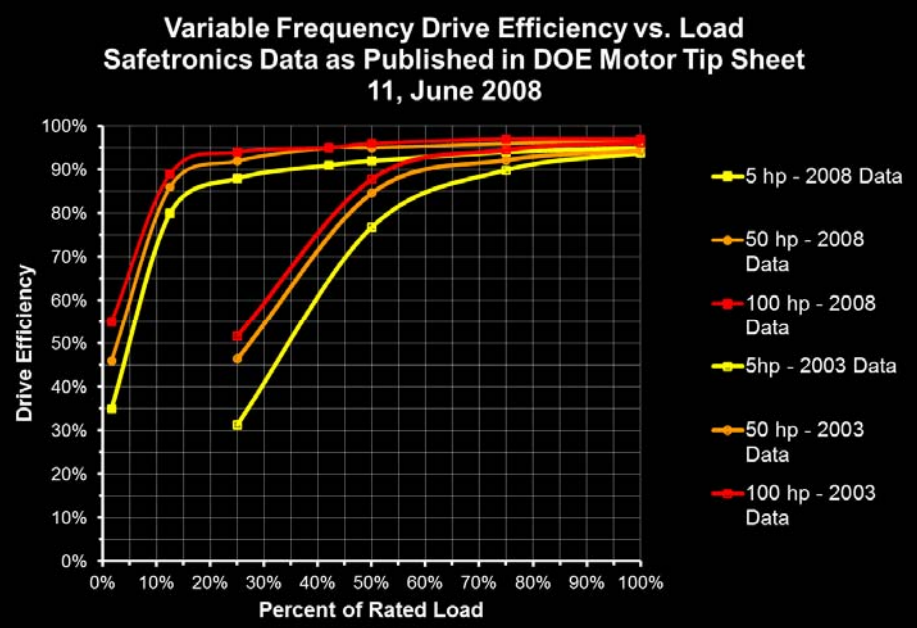

Bottom Line

Assuming a linear response from an analog output to an analog command is probably a bad assumption

- The actuation system interface to the final control element can be non-linear
- Valve and damper sizing affects linearity
- Most final control elements have non-linear characteristic curves