Electric Valve Application

Refrigeration and Air Conditioning Systems

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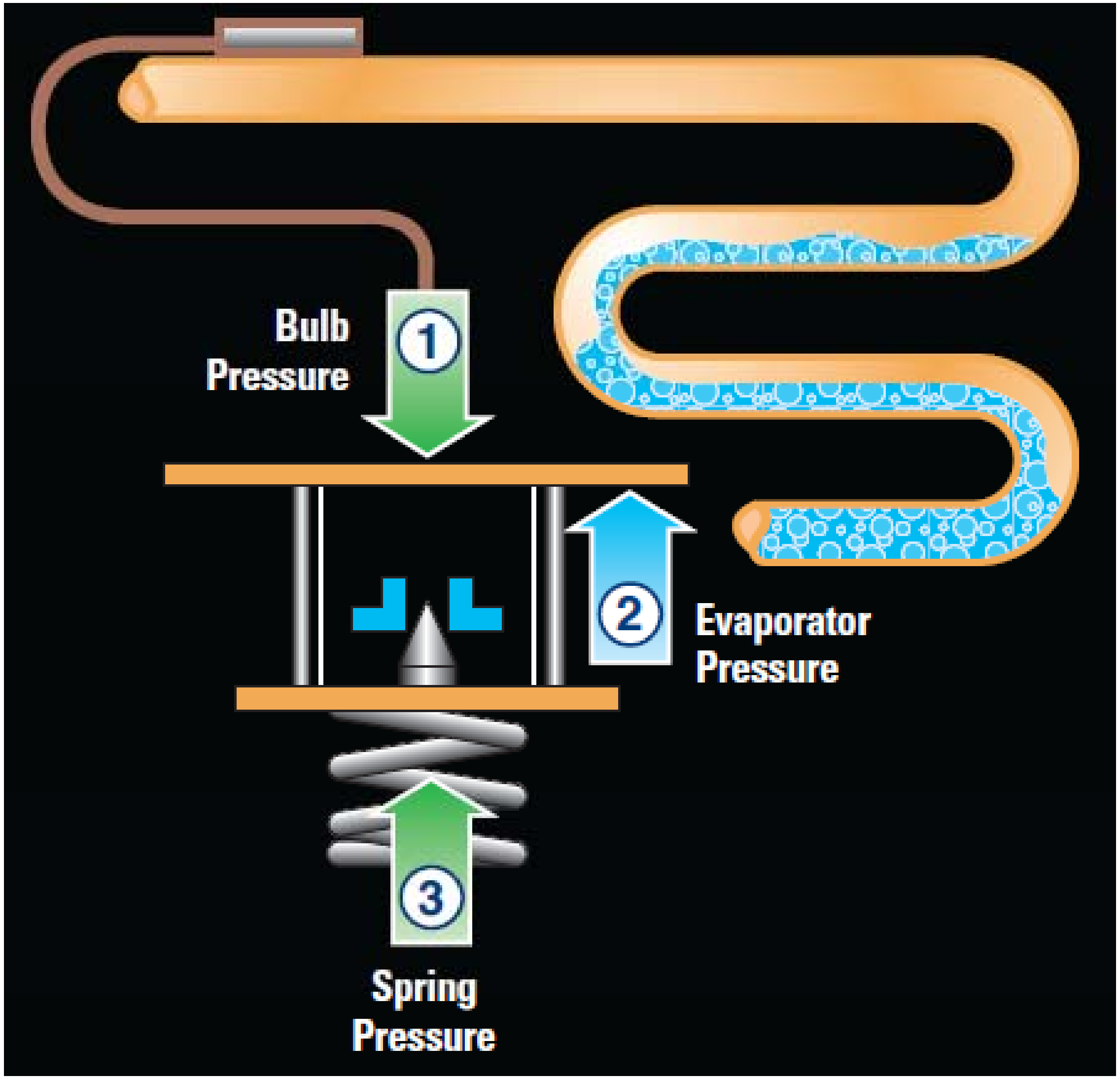
ENGINEERING YOUR SUCCESS.

February 14, 2012

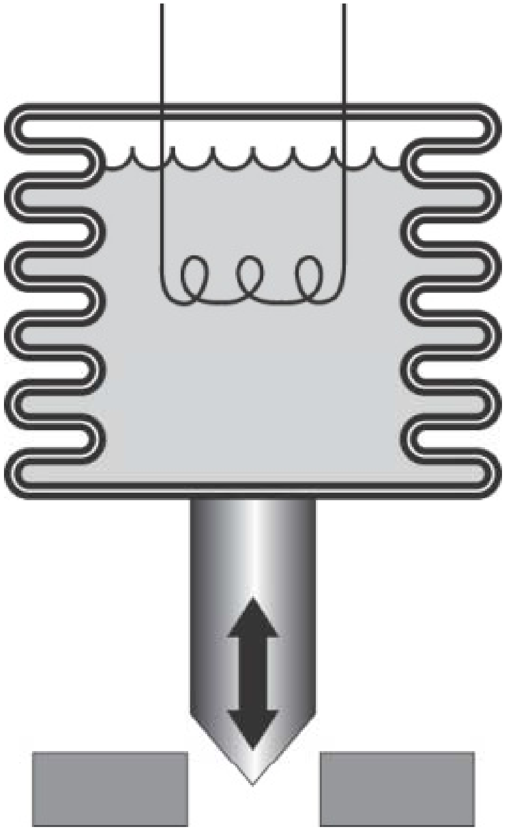
Mechanical Valve Fundamental Forces



Electric Valve Basics

- Electronically controlled
- Non refrigerant specific
- Wide load control capability
- Relatively few valves cover multiple applications and capacity
- "Tight" superheat control
- Direct temperature or pressure control capability
- Remote monitoring capability
- Not restricted by physics

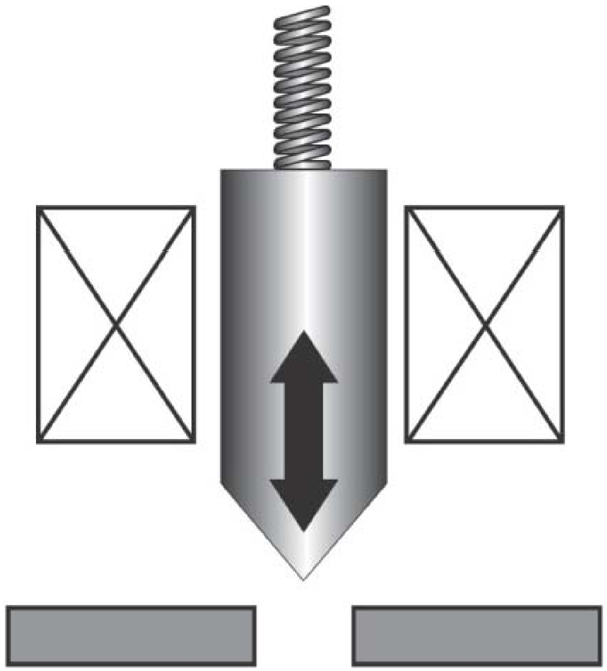
Heat Motor Valve



- Legacy electric valve design
- Sensor reacts to refrigerant temperature
- Control modulates energy to valve heater
- Heater expands liquid and modulates valve
- Hysteresis and response issues

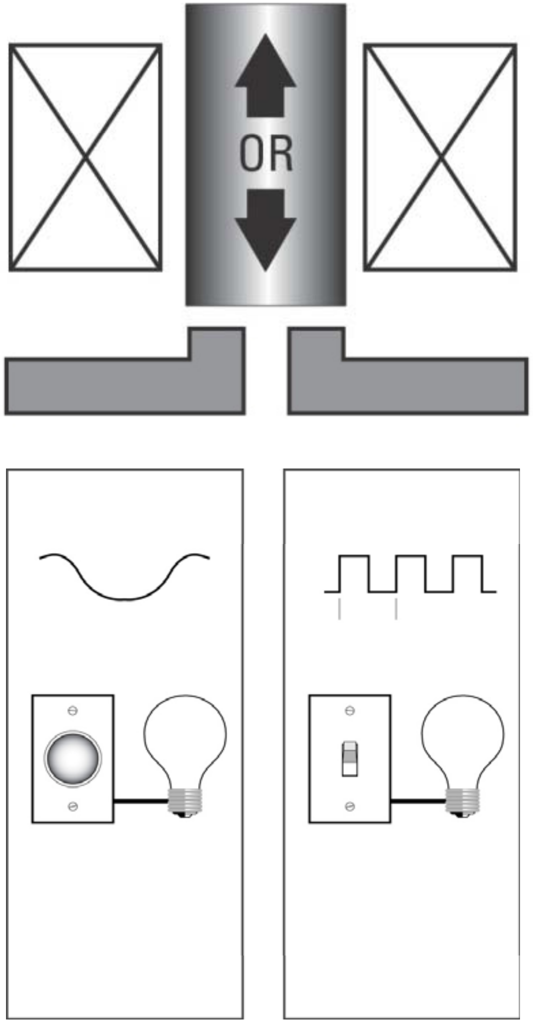
Modulating Solenoid Valve

- Magnetic field modulated to control valve position
  - Current or voltage modulation
- High hysteresis
- Repeatability concerns



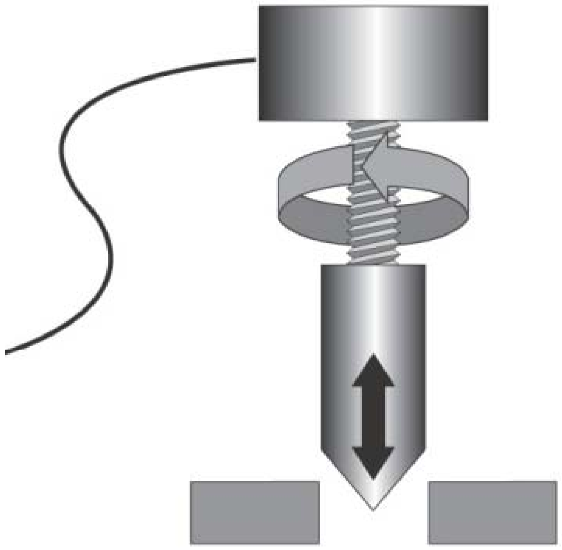
Pulse Width Solenoid Valve

- Valve is either open (energized) or closed – no modulation
- Percent of time energized determines flow capacity
- Can cause “refrigerant hammer”, stressing system components
  - Applicable for larger systems
- Can have longevity concerns



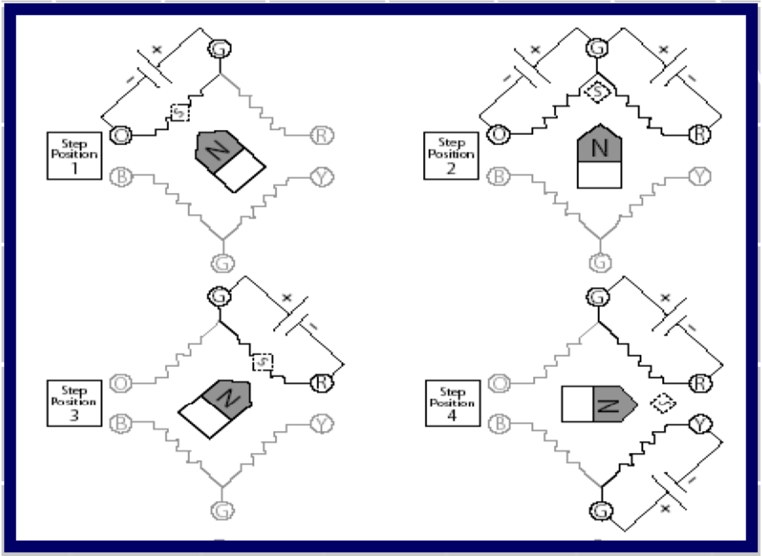
Stepper Motor Valves

- Controls in fine increments
- Each step is a small fraction of a revolution
- Excellent resolution and repeatability
  - Variation in step position is not cumulative
- Uni-polar and bi-polar motors
- Internal and external stators



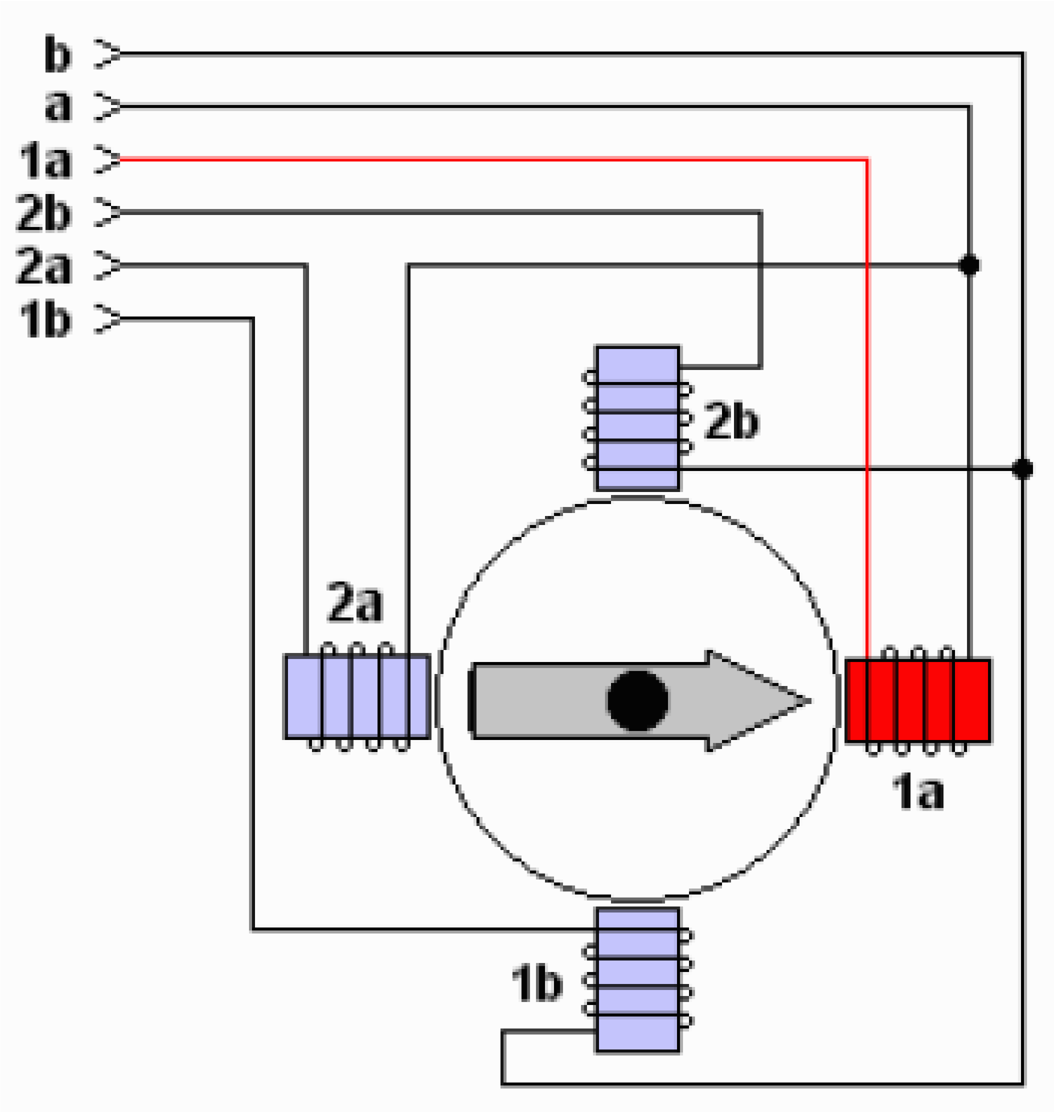
Uni-polar step motors

- Permanent magnet rotors
- “Pull” control strategy
  - Only part of stator windings used for each step
- Lower torque output
  - Typically applied in smaller applications



		Phase			
Pulse	Steps Rotated	O (Orange)	R (Red)	Y (Yellow)	B (Black)
1	1	Zero	HI	HI	HI
2	*2	Zero	Zero	HI	HI
3	3	HI	Zero	HI	HI
4	*4	HI	Zero	Zero	HI
5	5	HI	HI	Zero	HI
6	*6	HI	HI	Zero	Zero
7	7	HI	HI	HI	Zero
8	*8	Zero	HI	HI	Zero

Conceptual Model of Uni-polar step motor

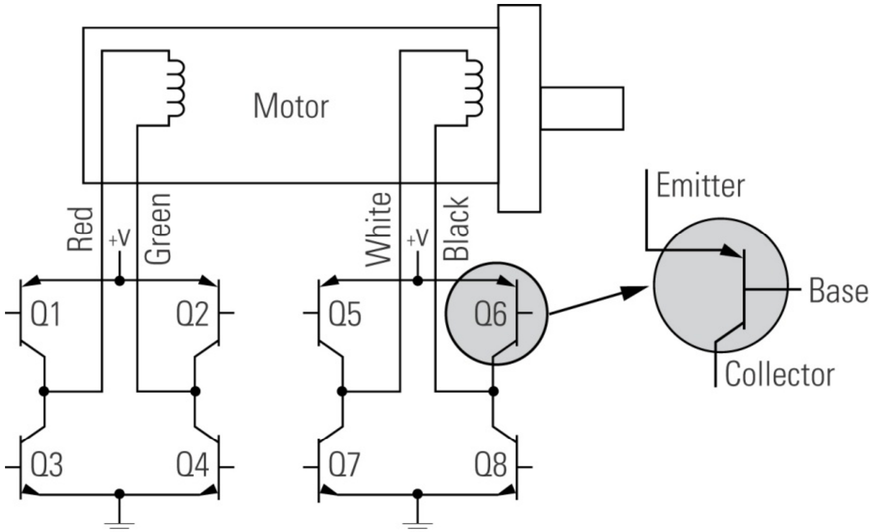


Bi-polar step motors

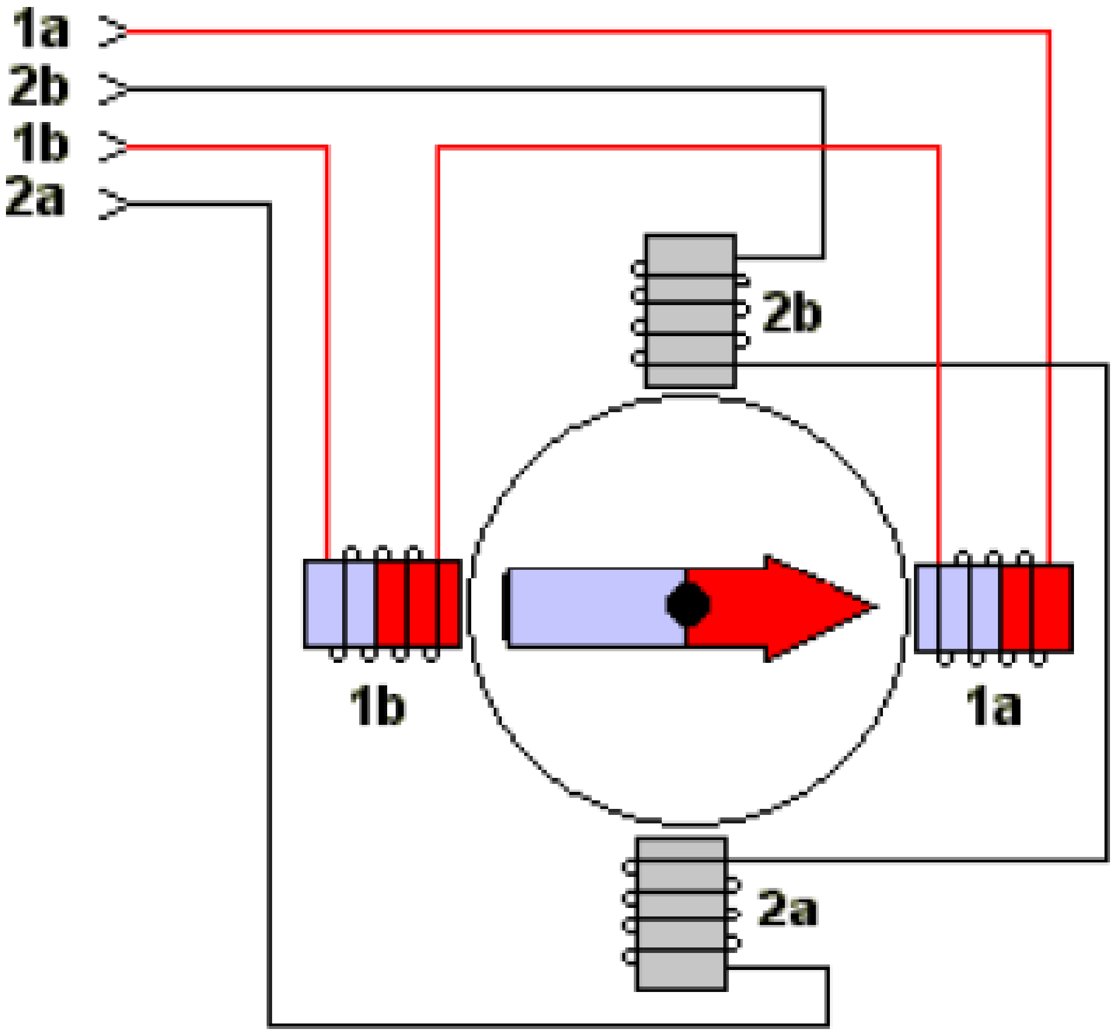
- Permanent magnet rotors
- “Push-Pull” control strategy
- Higher torque output
  - Suitable for any size application

CLOSE ↓ / OPEN ↑

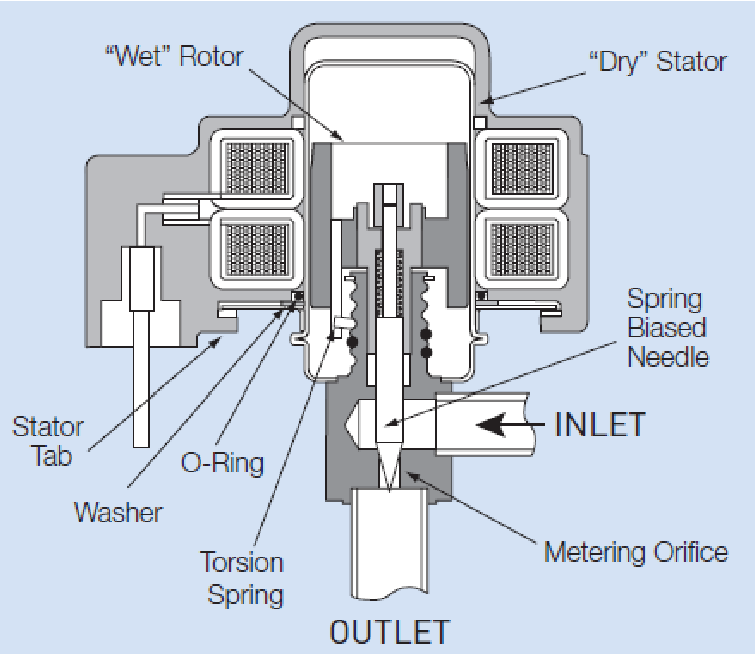
BIPOLAR DRIVE SEQUENCE				
STEP	Q1-Q4	Q2-Q3	Q5-Q8	Q6-Q7
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF



Conceptual Model of Bi-Polar Step Motor



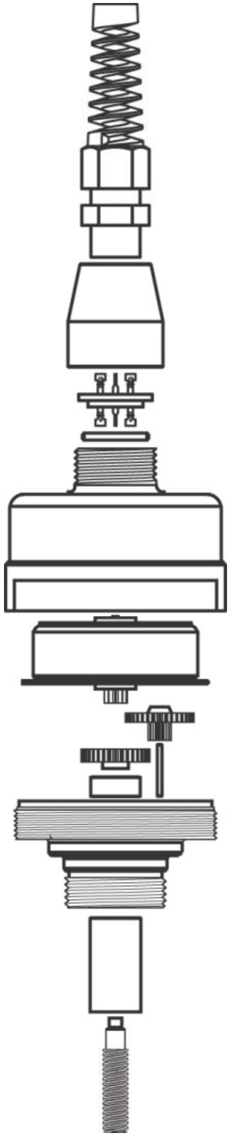
External Stator Step Motor Construction



- Stator is "dry" (external)
  - Electrical connections are accessible
  - Stator is replaceable
- Rotor is "wet" (internal)
- Magnetic field must pass through large air gap to affect rotor
  - Reduces available power for a given amount of material
- Mounting is orientation dependent

Internal Stator Step Motor Construction

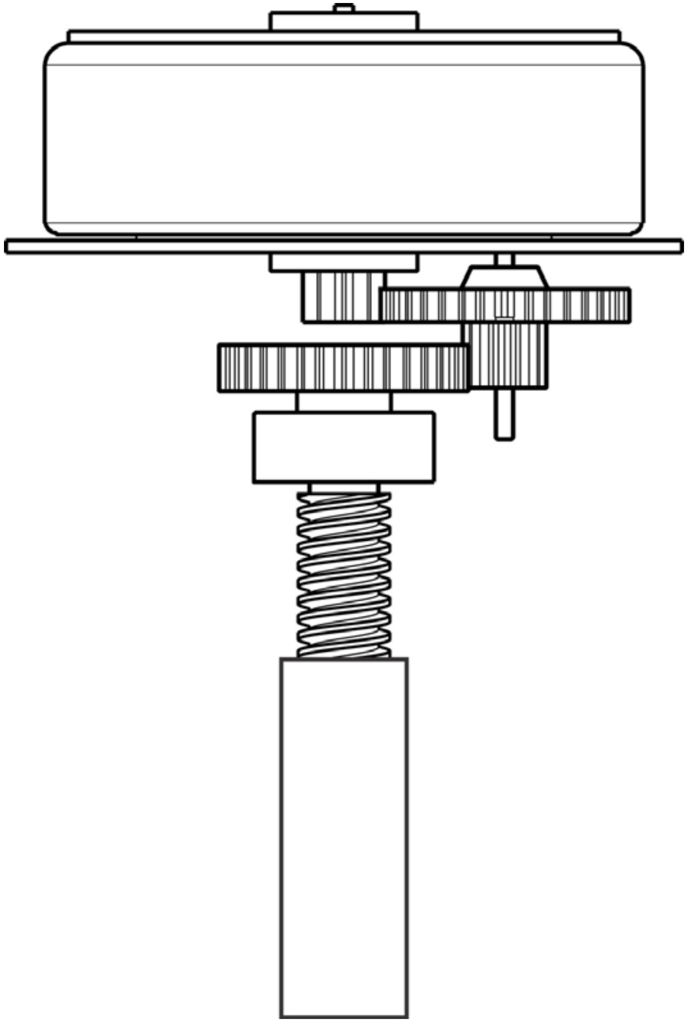
- Stator and rotor are both “wet” (internal)
  - Electrical connections must be made through a glass “feed-thru”
  - Actuator assembly and cable can be replaceable
- Air gap can be set to optimum dimension
  - Maximizes power for material
- Mounting can be independent of orientation



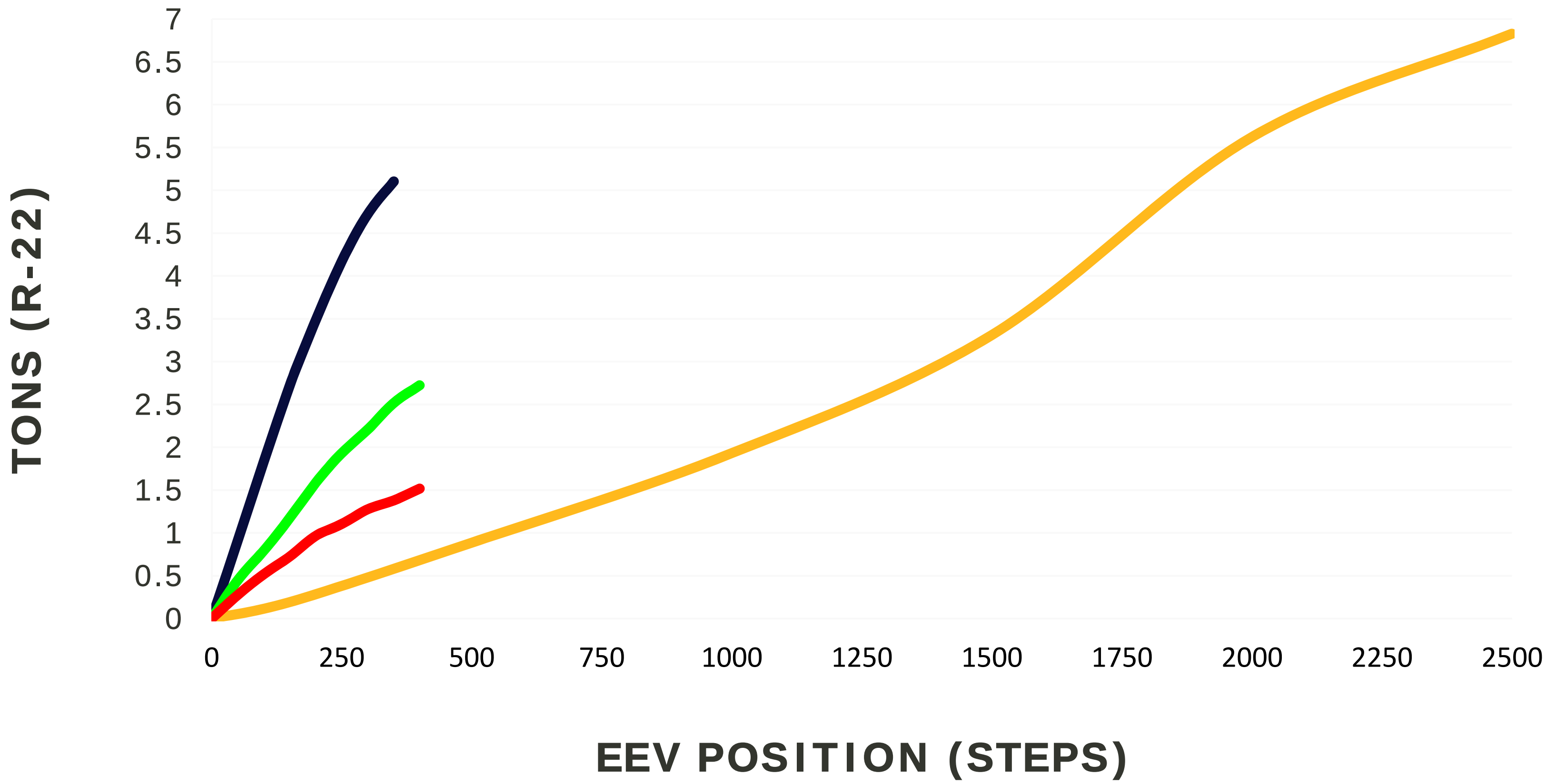
Typical Internal Stator Construction

Digital Linear Actuators

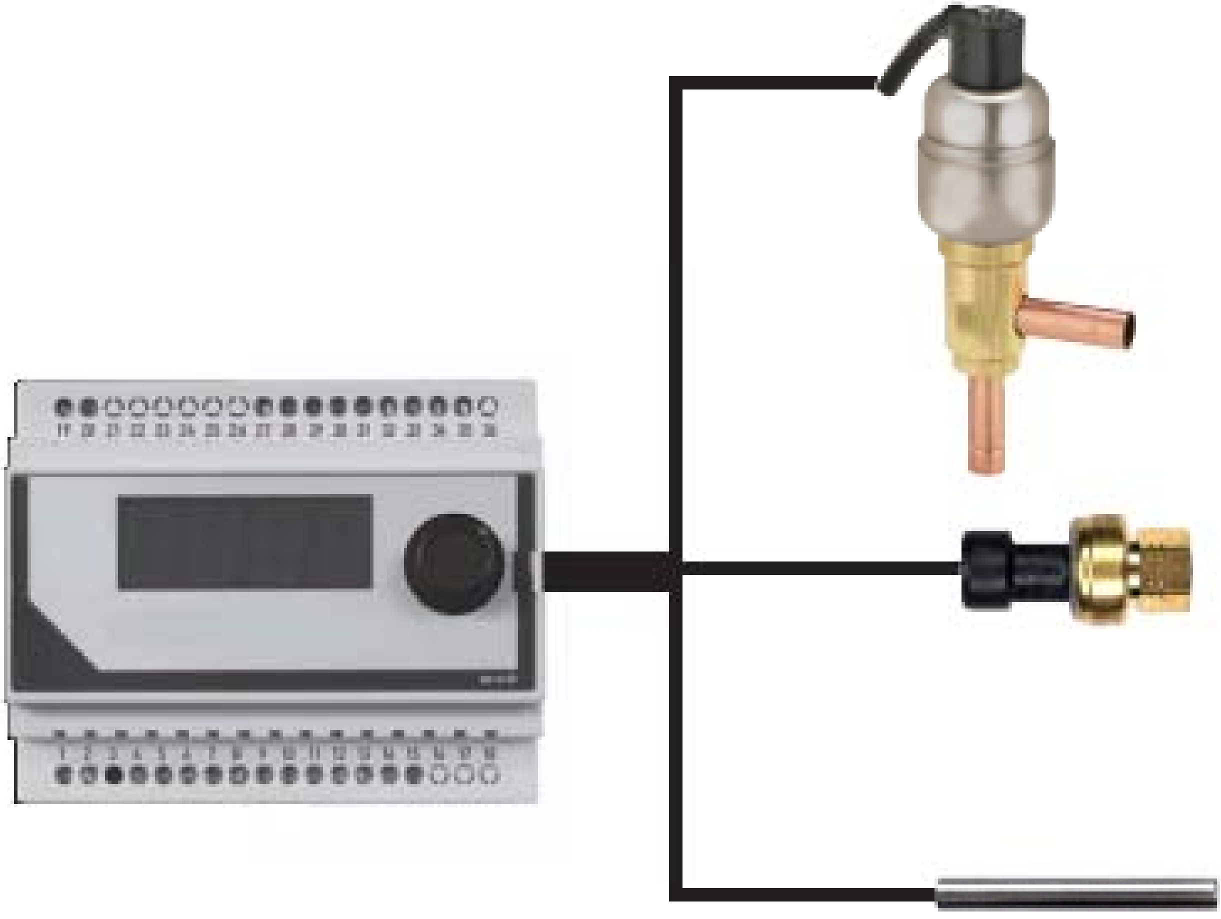
- Step motor rotation converted to linear motion via anti-rotation device
- Can utilize a gear train to magnify torque and linear force, and increase resolution



Significance of resolution

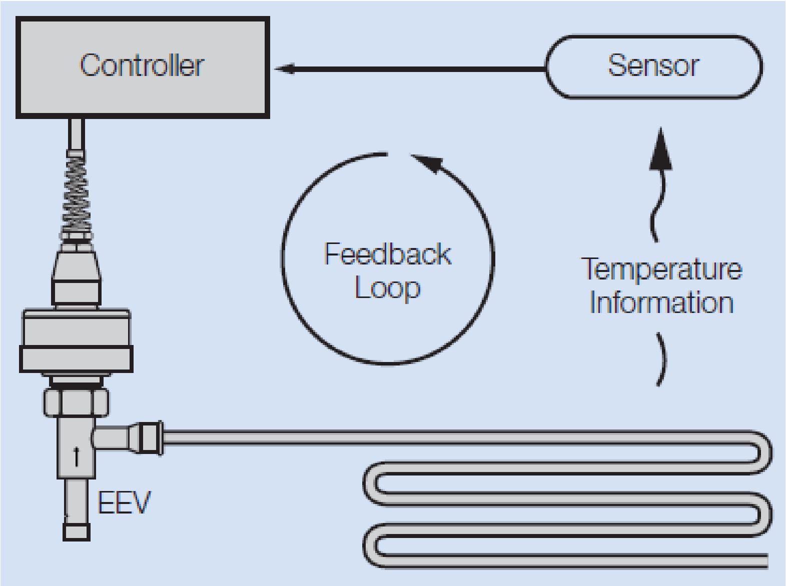


Electric Stepper Valve Control

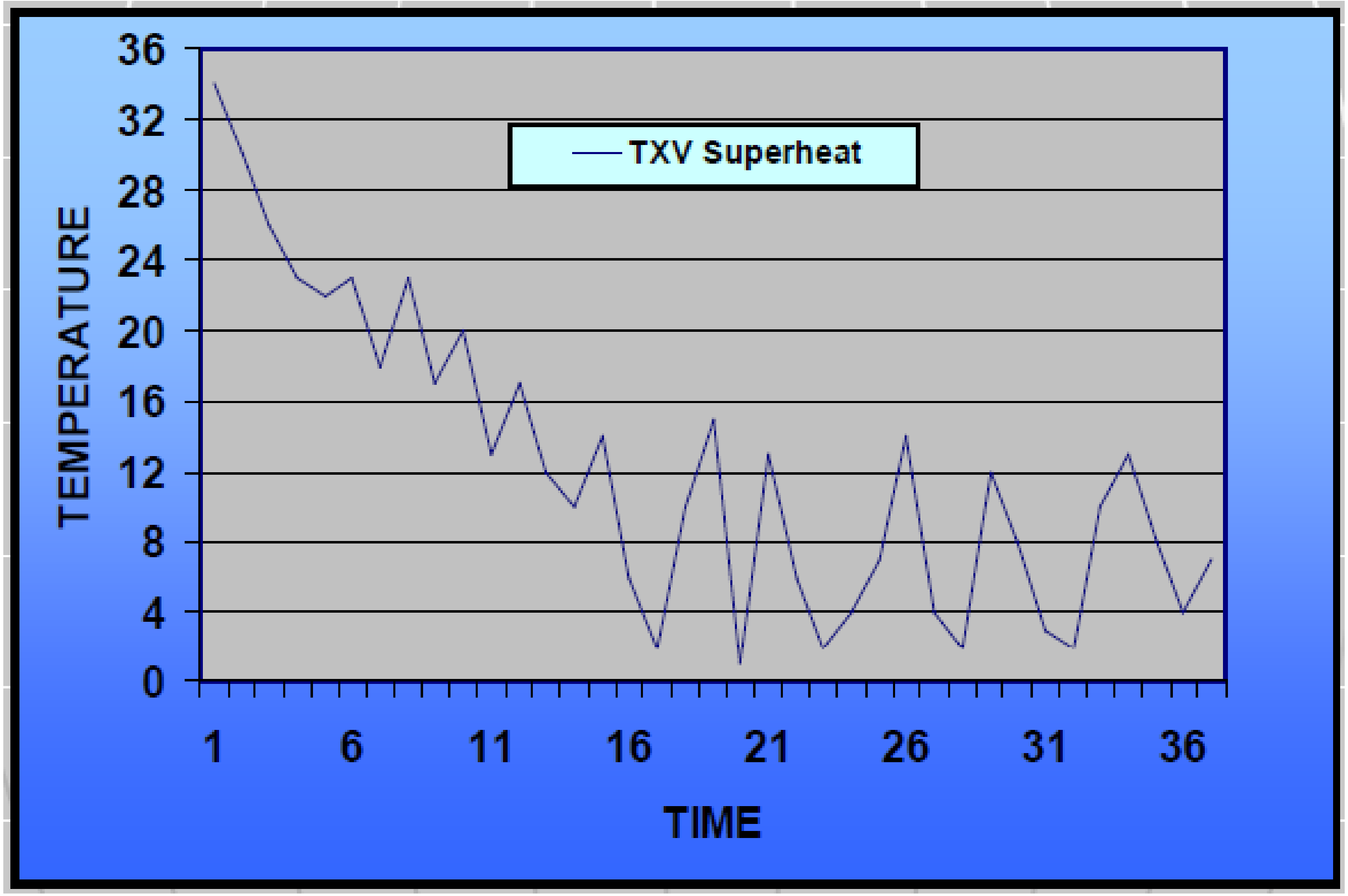


Electric Stepper Valve Control

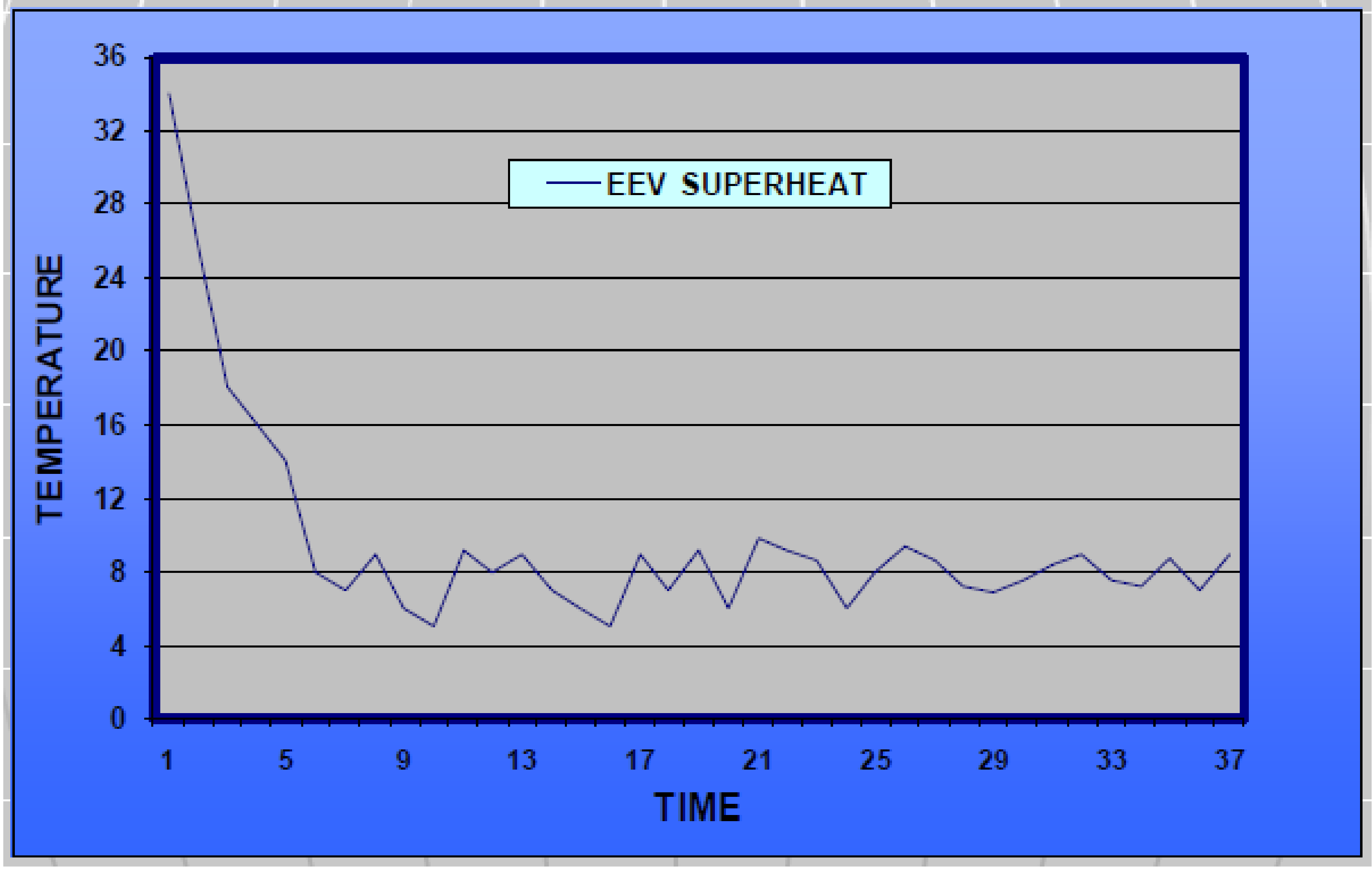
- Electronic control has embedded algorithm
  - Superheat, pressure, and/or temperature control
  - Standalone control or embedded in system hardware
- Sensors react to system temperature / pressure
- Control interprets data and modulates valve
- Process repeats continuously



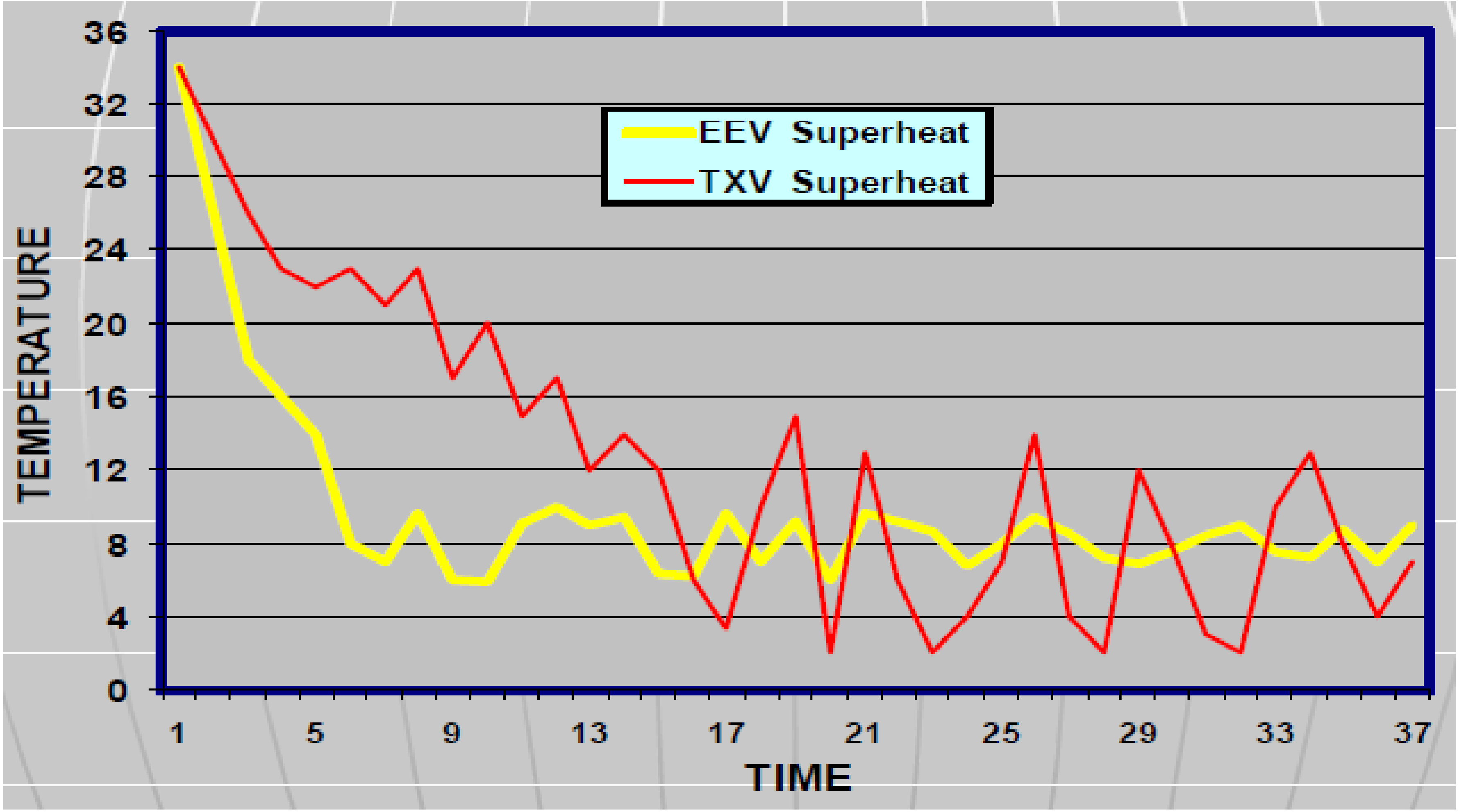
TXV Pulldown and Superheat Control



EEV Pulldown and Superheat Control



TXV versus EEV Superheat Control



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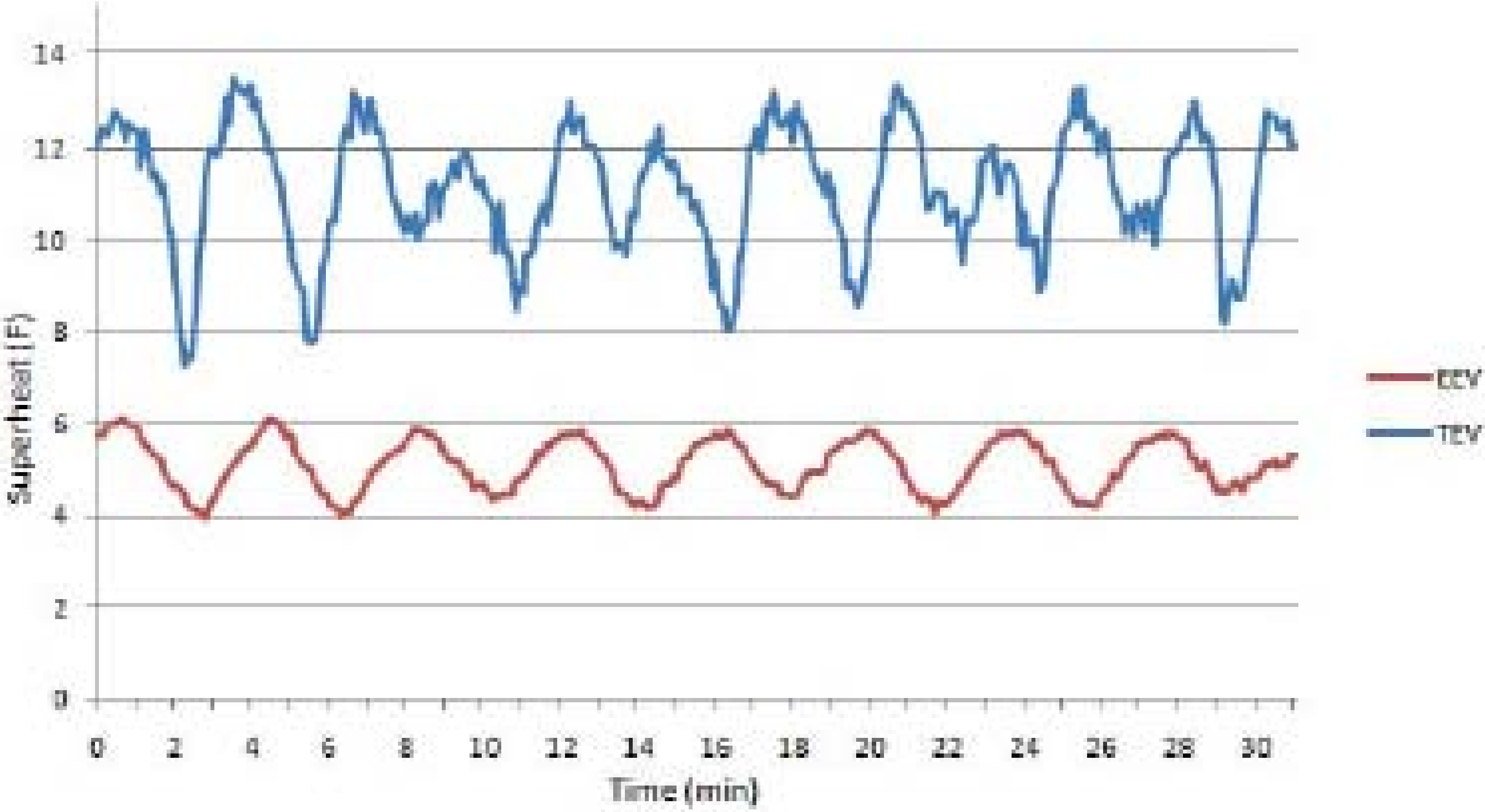

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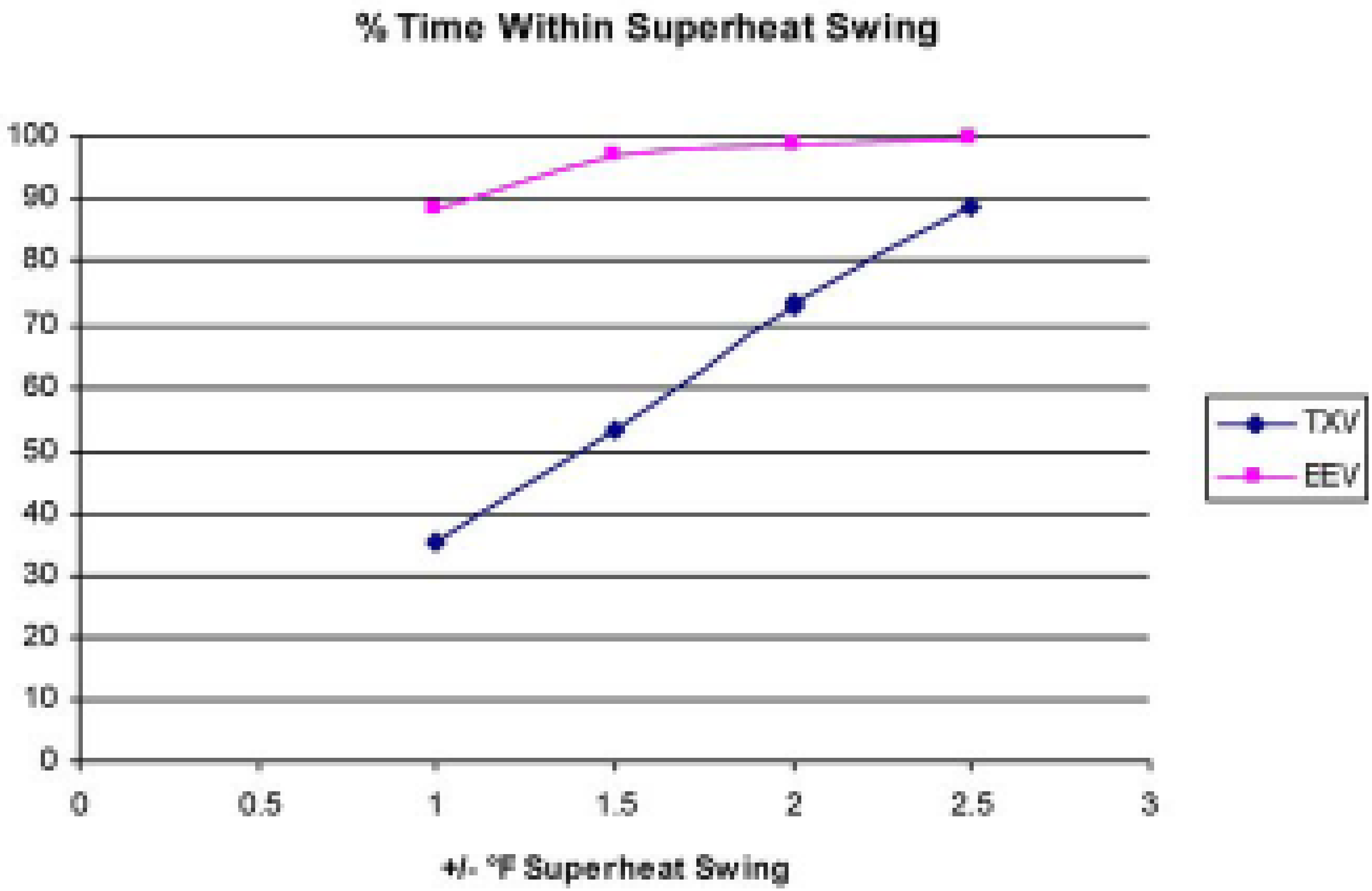
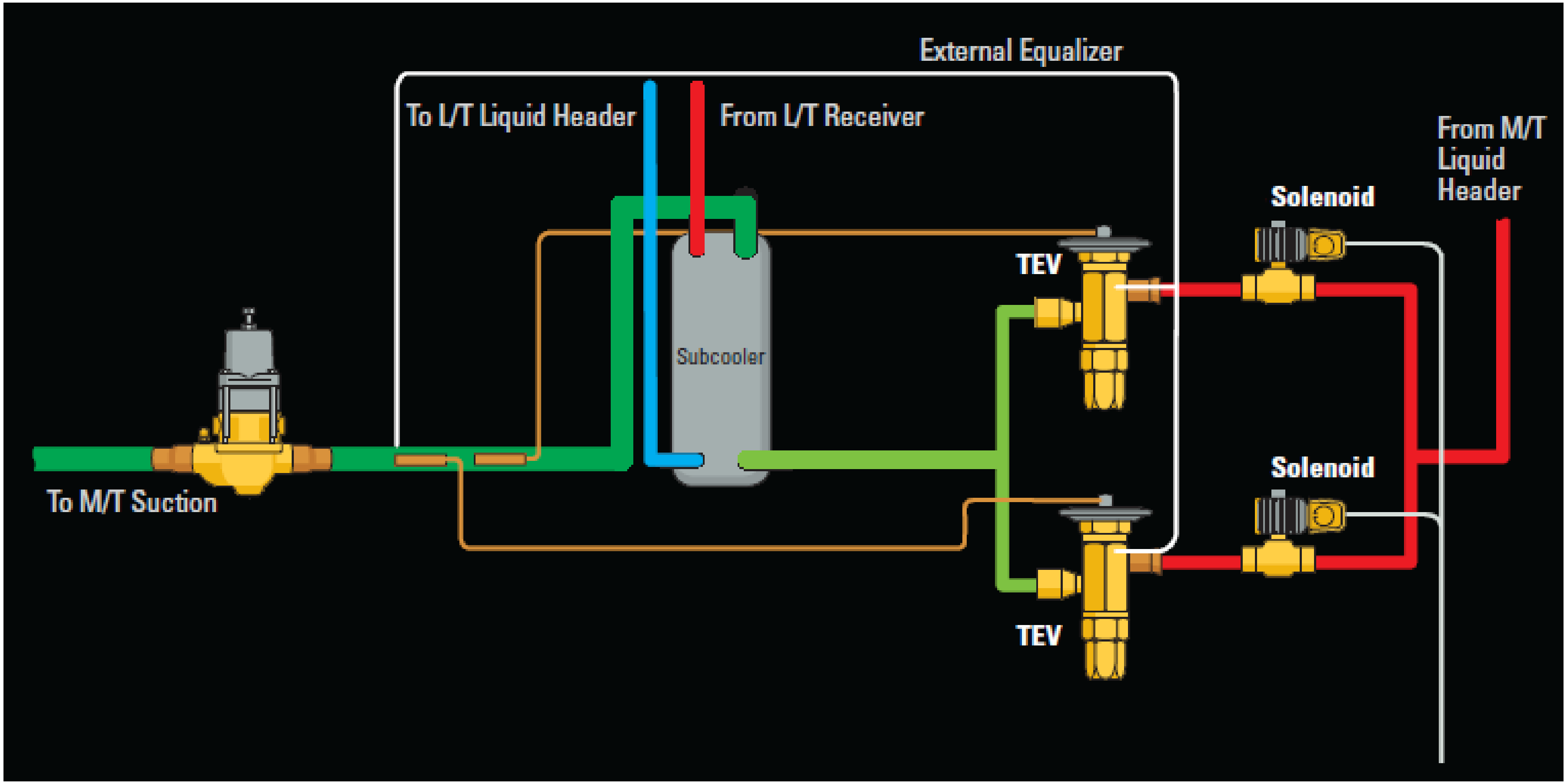


Mechanical / Solenoid Subcooler Control



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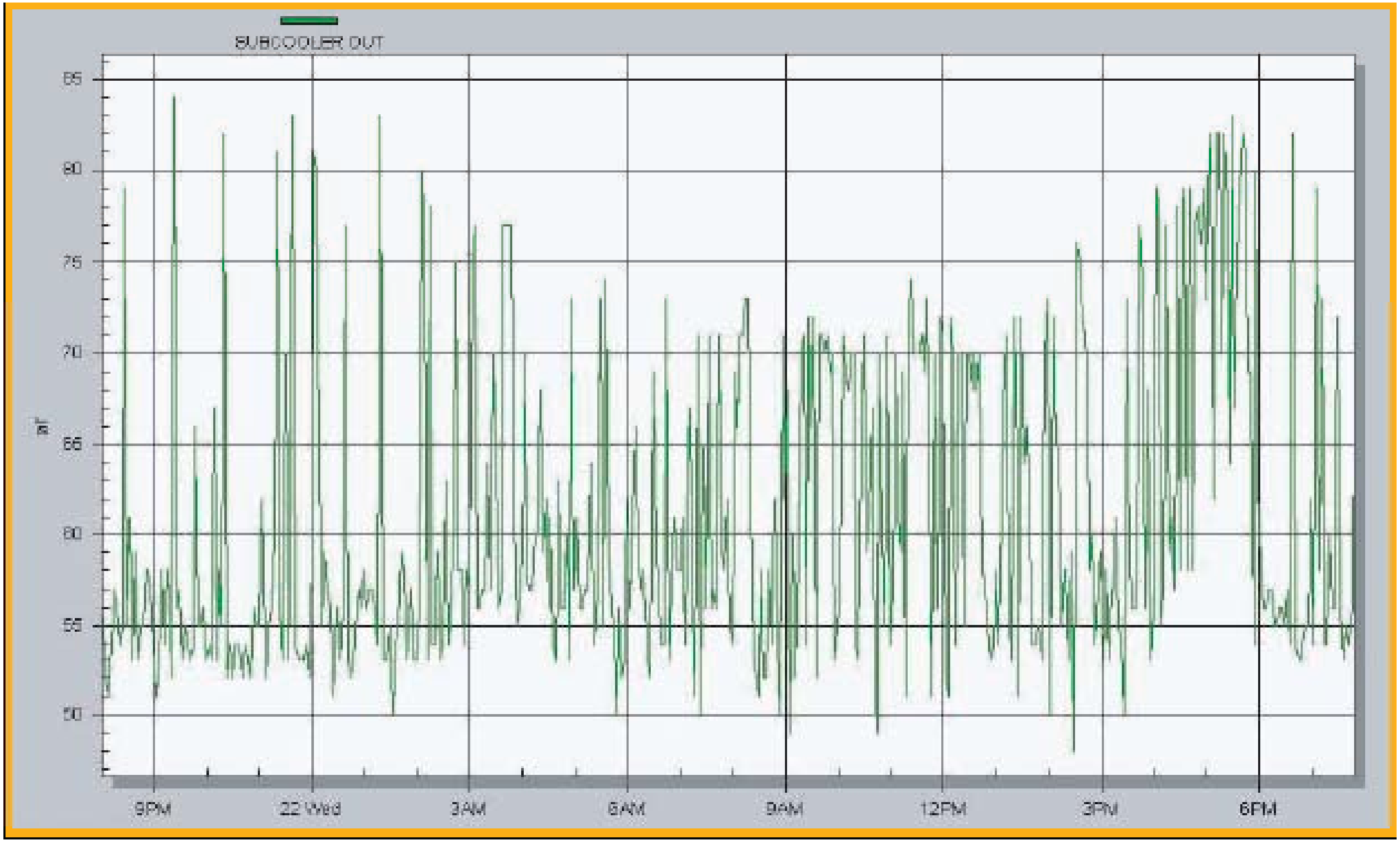
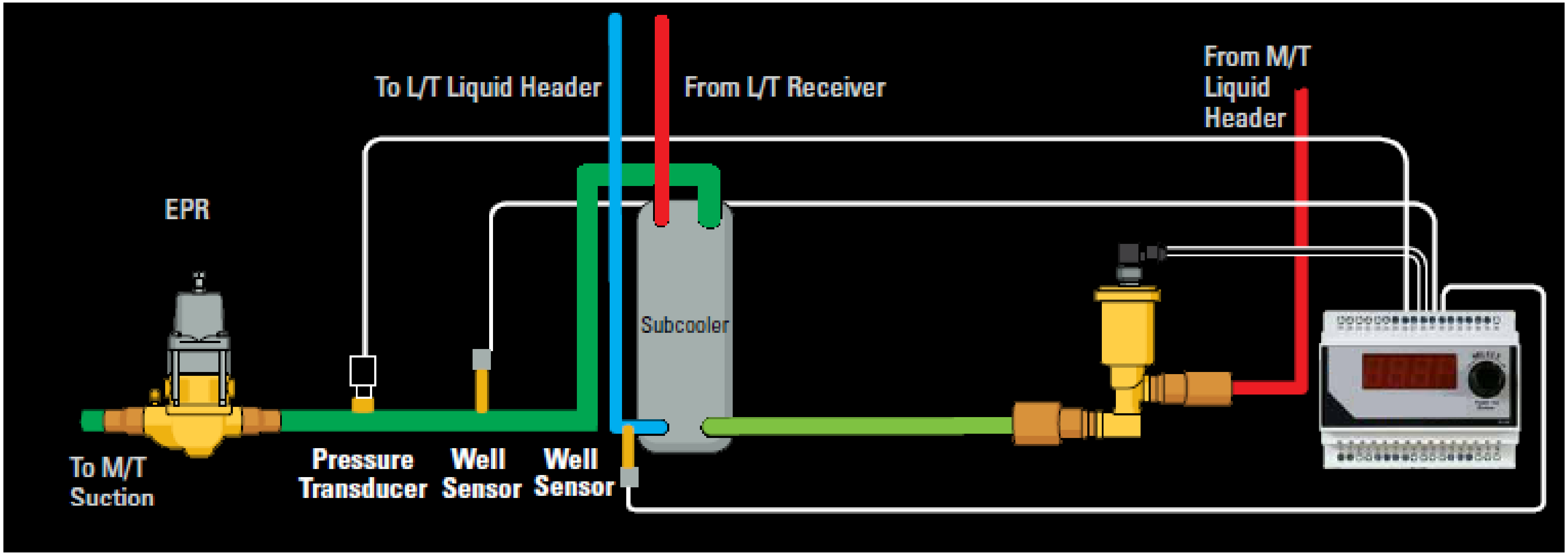
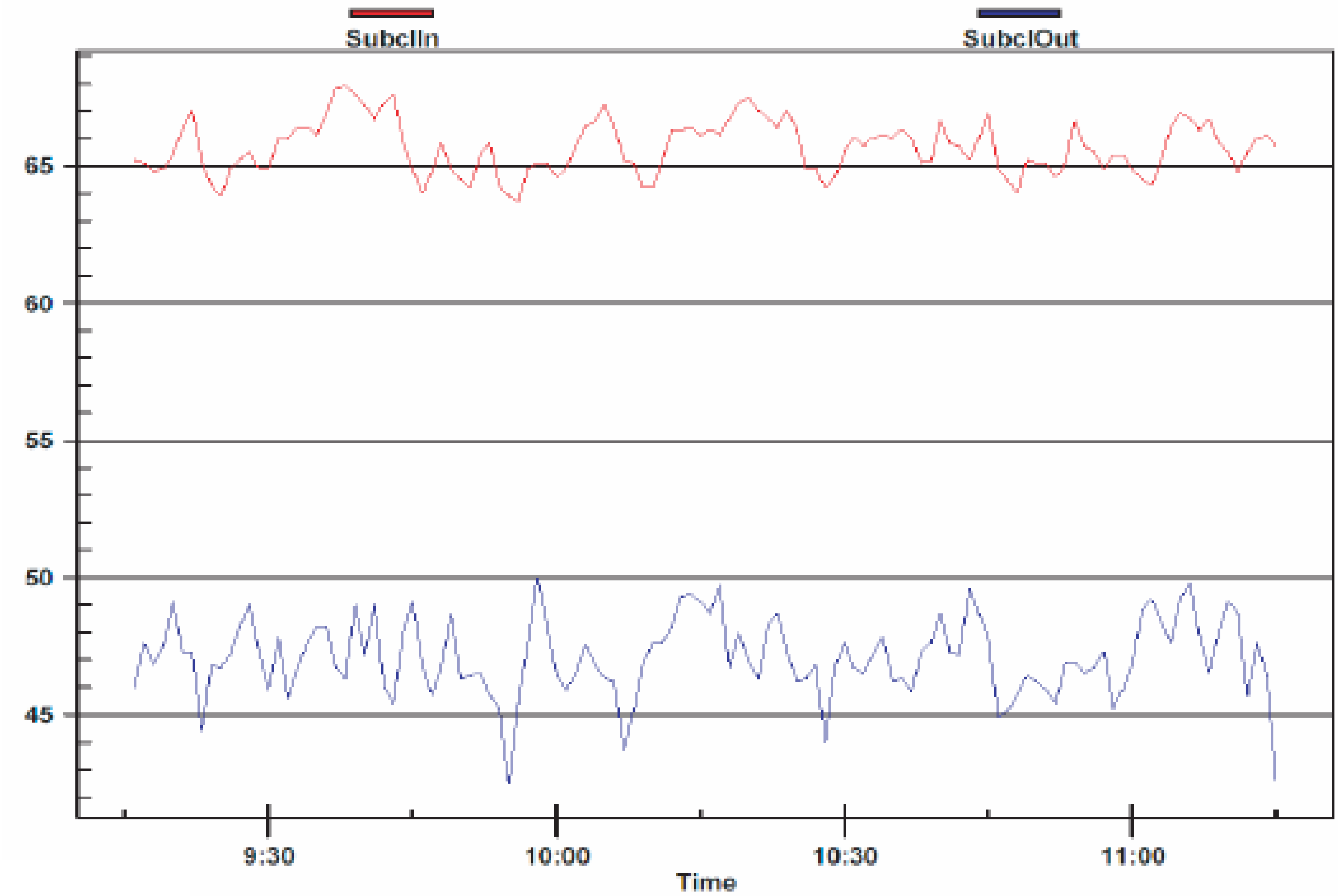


EEV / Mechanical EPR Subcooler Control

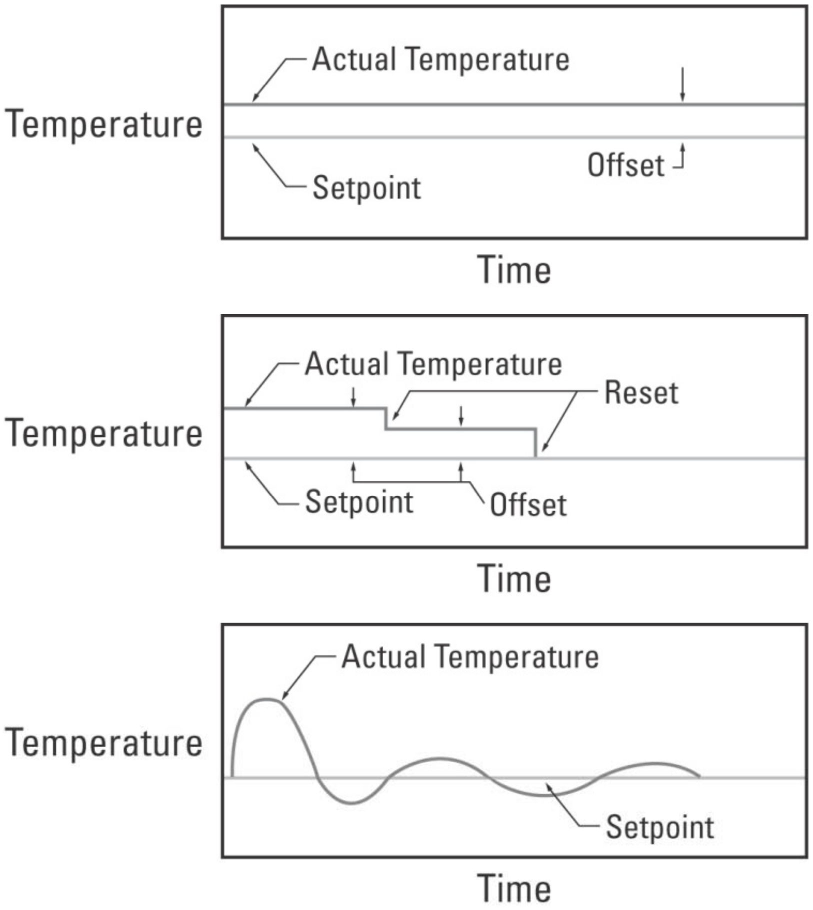


EEV / Mechanical EPR Subcooler Control

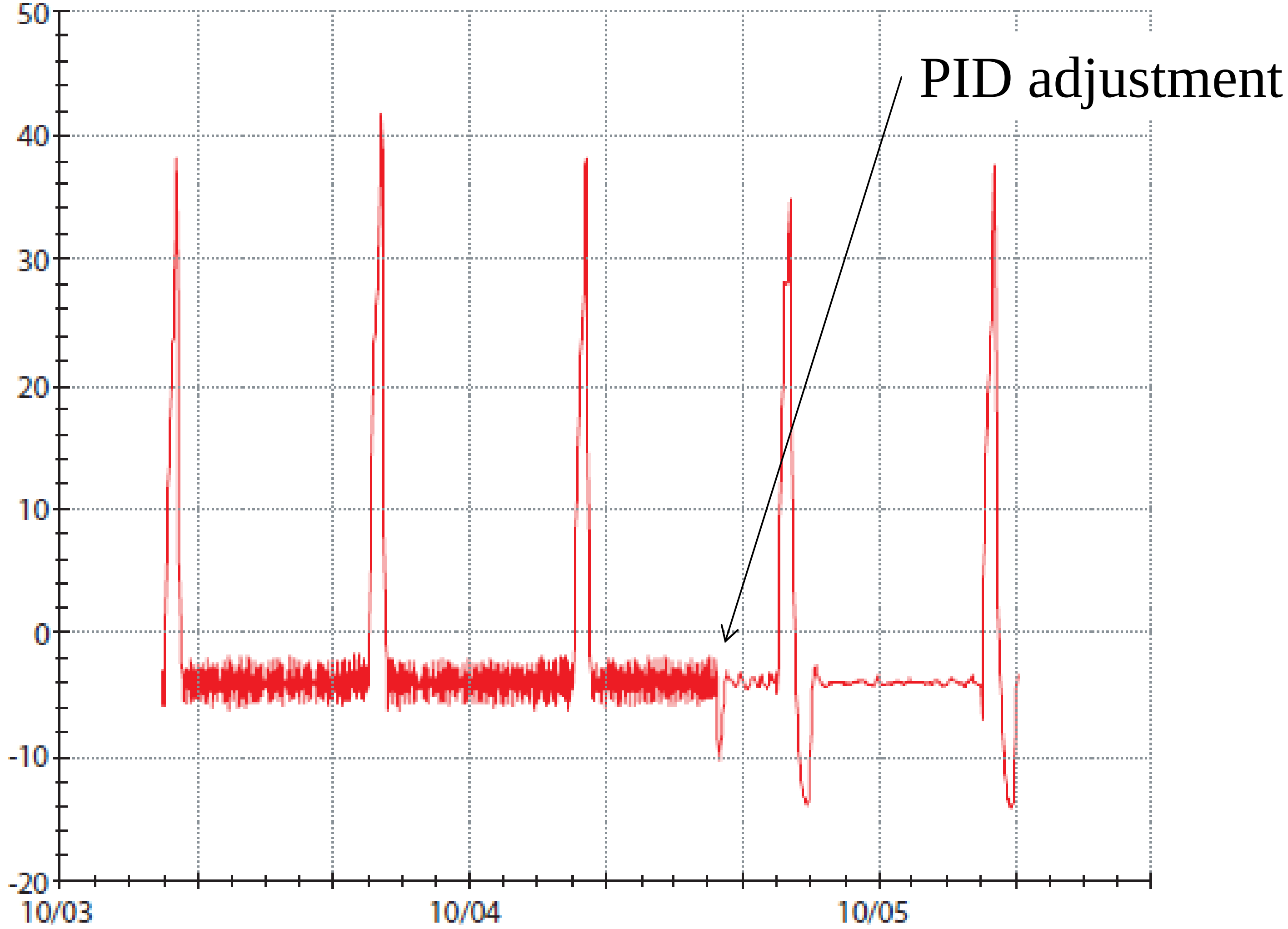


PID Control Algorithm

- 3 control methods in one algorithm
  - Proportional – responds to offset from setpoint
  - Integral – responds to change in offset
  - Derivative – responds to slope of adjustments



Impact of PID on System Control



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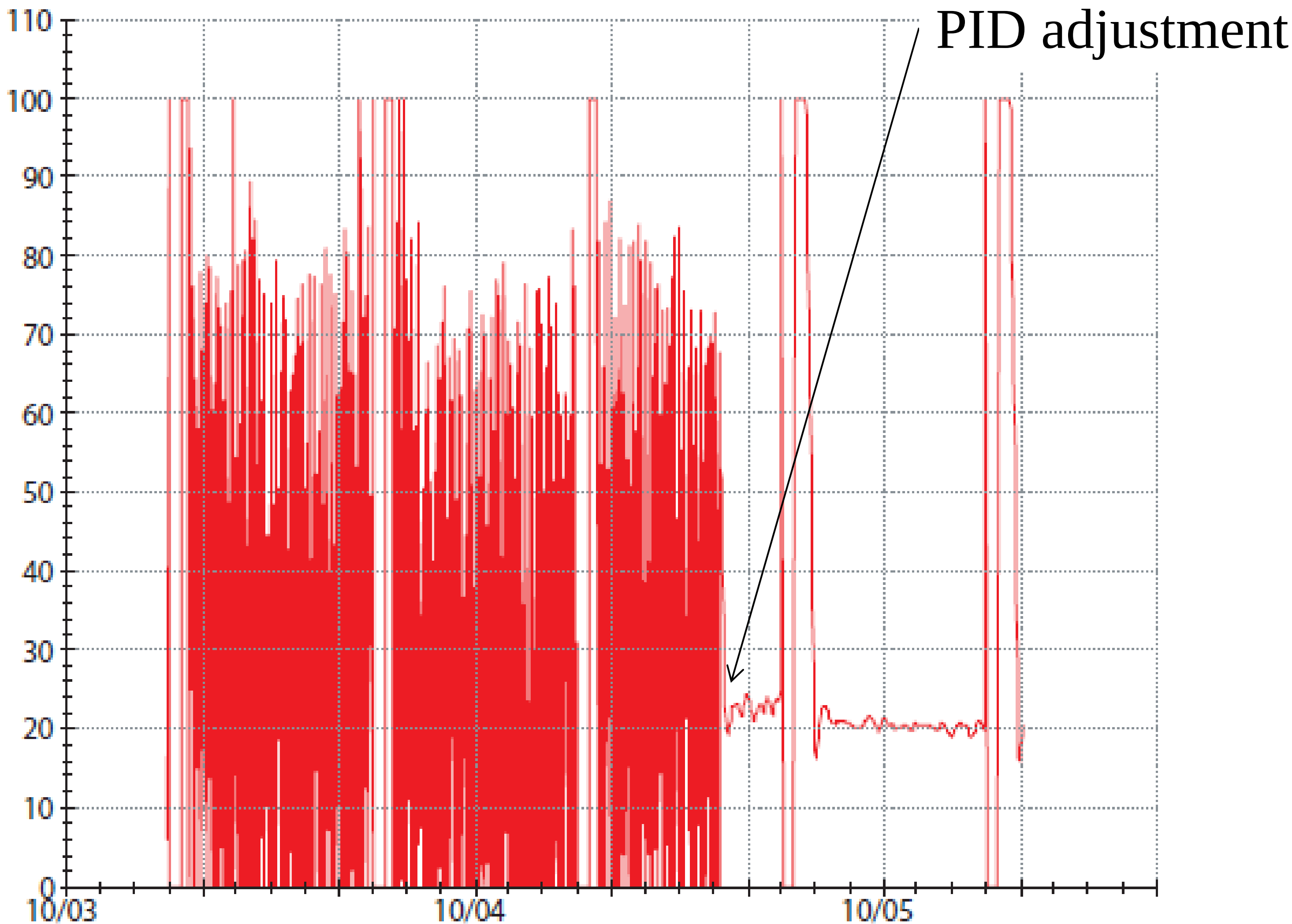
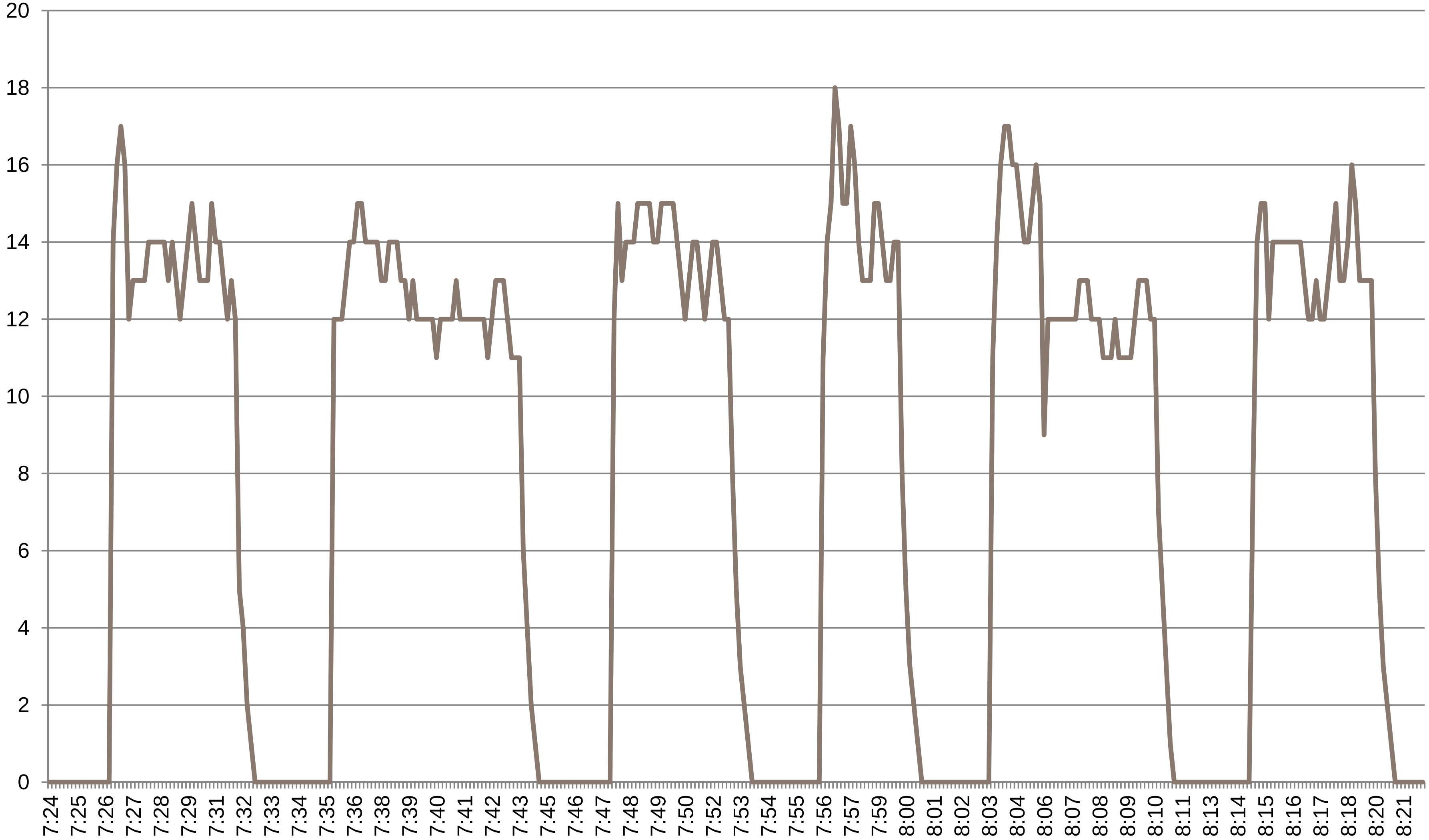


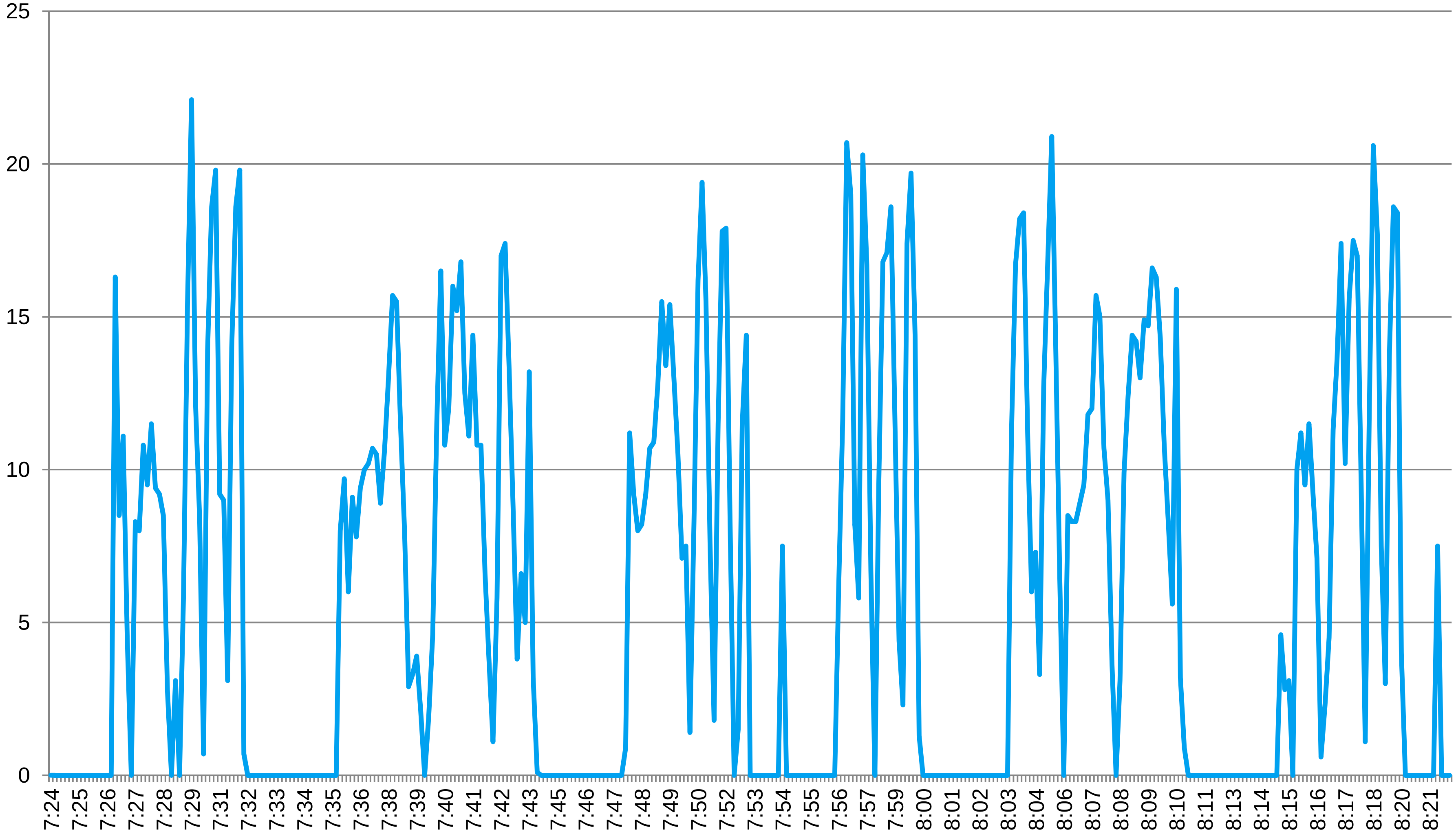
System Control Strategy

- Ideal system control involves integrating all component level controls
  - Allows for effective monitoring and eliminates “control confusion”
- Even without an integrated system control, considering potential control scheme conflicts is important

EEV Superheat Control – Suction Stop



EEV Valve Position – Suction Stop



Electric Valves – What's Next?

- Stepper motor valves have been utilized for over 20 years, but are still relatively immature compared to mechanical valves
  - Advances in electronic controls are accelerating implementation
- PID control is improving, and is trending toward more "self-tuning" style controls
- Creativity is becoming the limitation on system design

Thank you!