T TAKES WORLDWIDE CONTINGENCY PLAN

BUILIDING AUTOMATION WHATEVER IT TAK

WHATEVER IT TAKES FACILITY OPERATIONS

TECHNICAL SUPPORT WHATEVER IT TAKES

WHATEVER IT TAKES SECURITY SOLUTIONS

DISASTER RESPONSE

JOHNSON CONTROLS

ENERGY EFFICIENCY

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JCI Federal Business Goal

- "***Help the Army Accomplish its Mission Critical Goals***"
  - Energy security
    - Constant power
    - Secure facilities
    - Reduce energy usage
  - Base sustainability
    - Water resources
    - Infrastructure revitalization
  - BRAC 2005
    - Keep SWRO installations open
    - Master planning
    - Added value to the bases
  - Reduce capital budget burden

Army Systems and Services

- Energy Savings Performance Contracting
- Security Systems
- Fire Systems
- Construction Management
- Mechanical Equipment and BAS Service Contracts
- Facility Management
- Building Automation Systems

ESPC Overview

- ESPC Vehicles
  - Corps of Engineers
  - Department of Energy
  - GSA
  - MEDCOM
- ESPC Energy Conservation Measure Examples
  - Energy Security
  - Lighting
  - Water
  - Re-commissioning
  - Infrastructure improvements
  - Peak shaving
  - Building Automation Systems - Digital controls

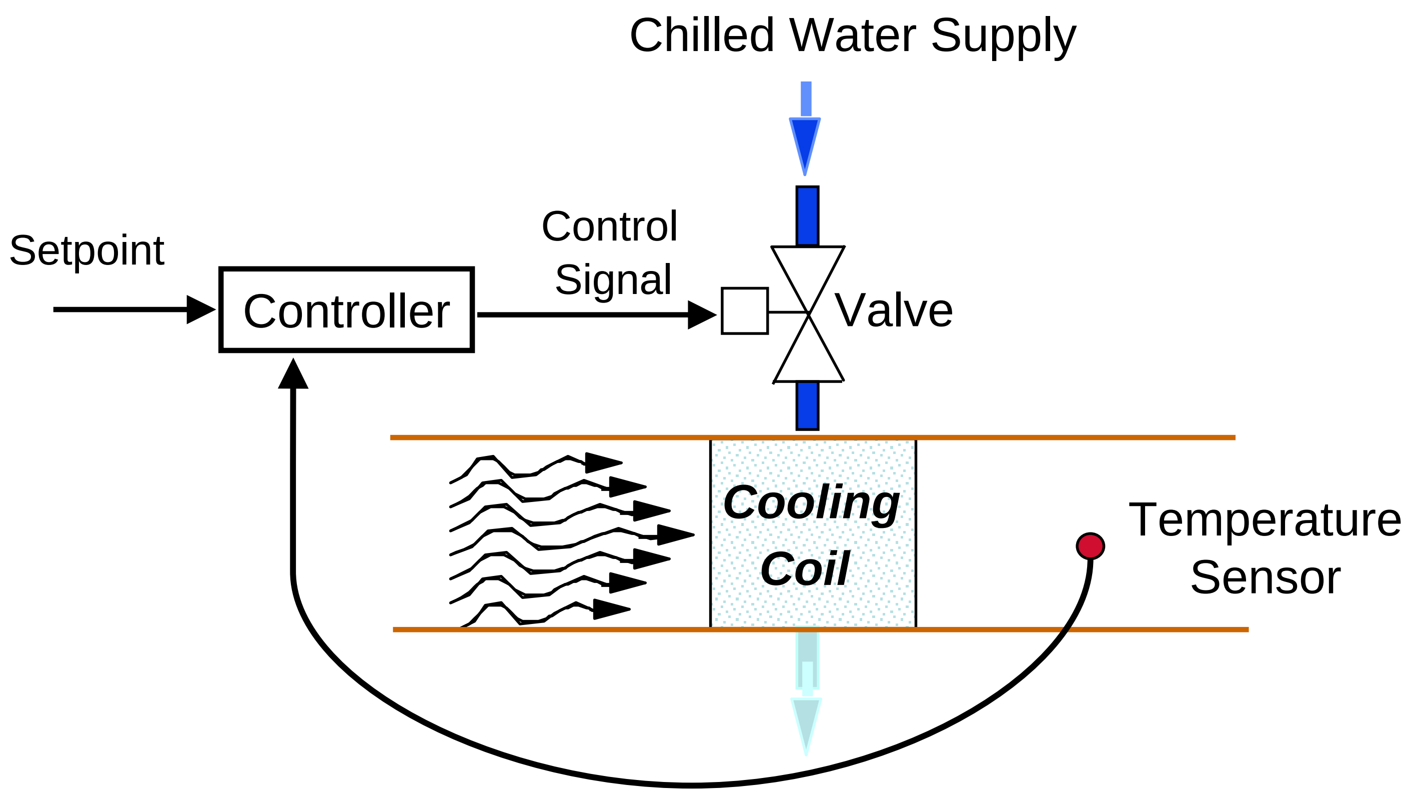
New Energy Saving Strategies for HVAC Control Systems

John E. Seem, Ph.D.

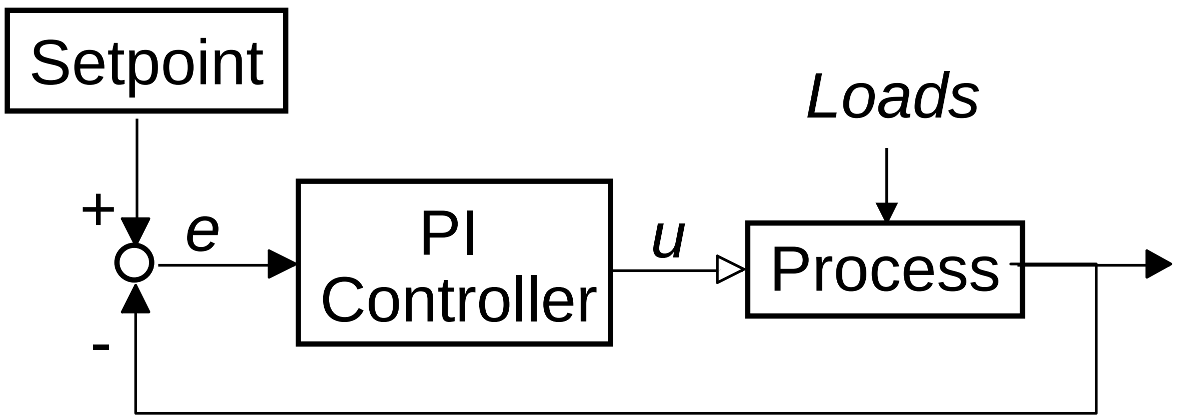
Agenda

- Adaptive Feedback Control
- Fault Detection & Diagnostics
- Sequencing Control
- Energy Optimization Control

Feedback Control System



PI Controller



Gain

$$u(t) = \bar{u} + K\left[e(t) + \frac{1}{\tau_I}\int_0^t e(t^*)\,dt^*\right]$$

Integral Time

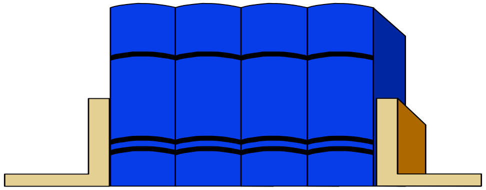
Problem

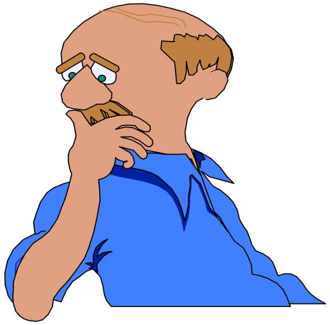
Although PID Controllers are common and well known, they are often *poorly tuned*.

Åström and Hagglund (1988)

Automatic Tuning of PID Controllers

Adaptive Feedback Control





\+ Thousands of Papers

\- Hard to Develop Industrial Controller

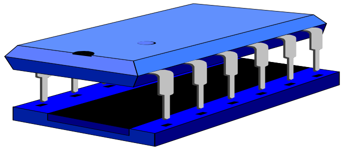
Approaches

- Self-Tuning Control
- Model Reference Adaptive Control
- Pattern Recognition Adaptive Control

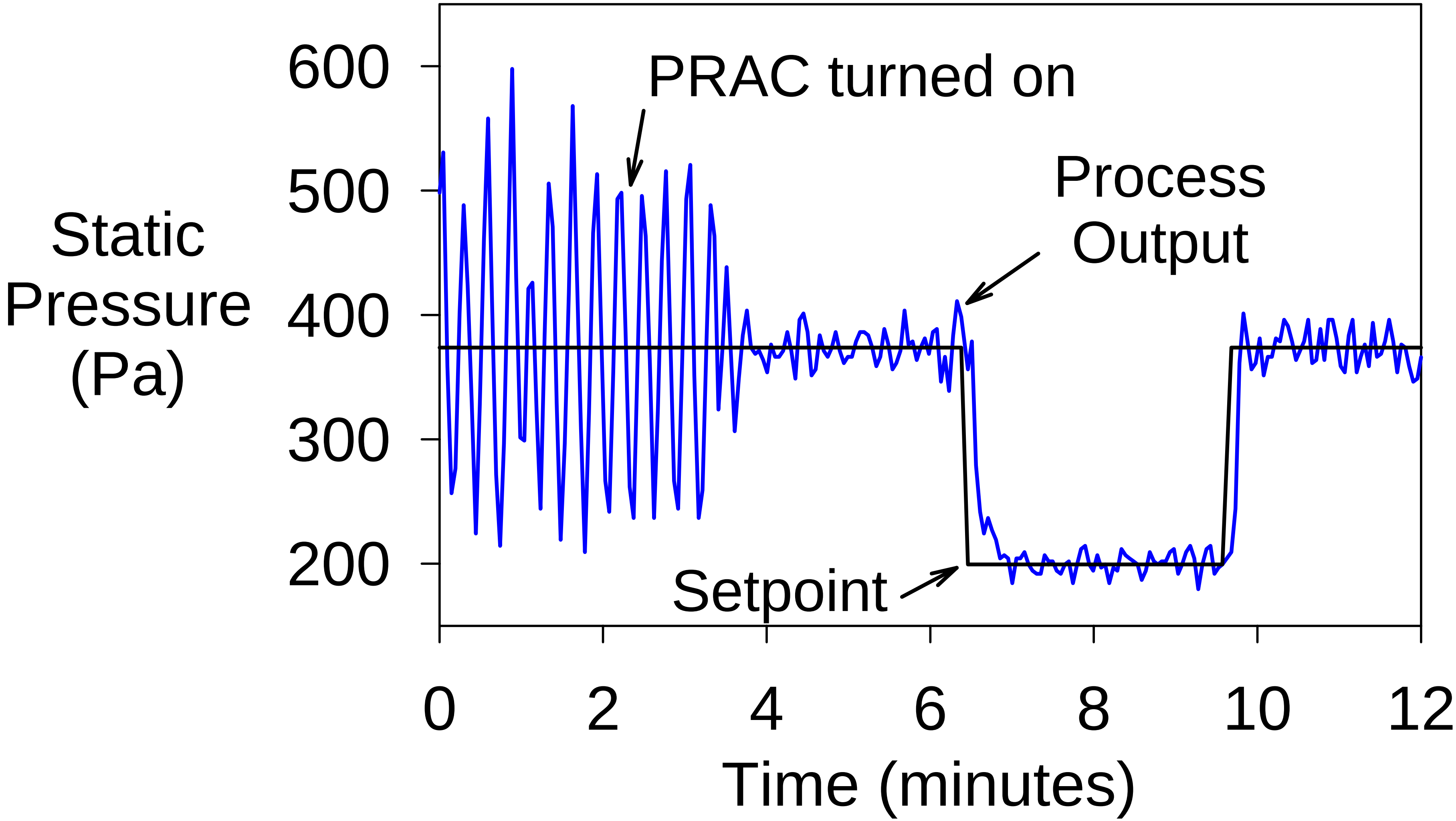
Research Objective: Adaptive Feedback Control

Develop Continuous Tuning Method for PI Controllers

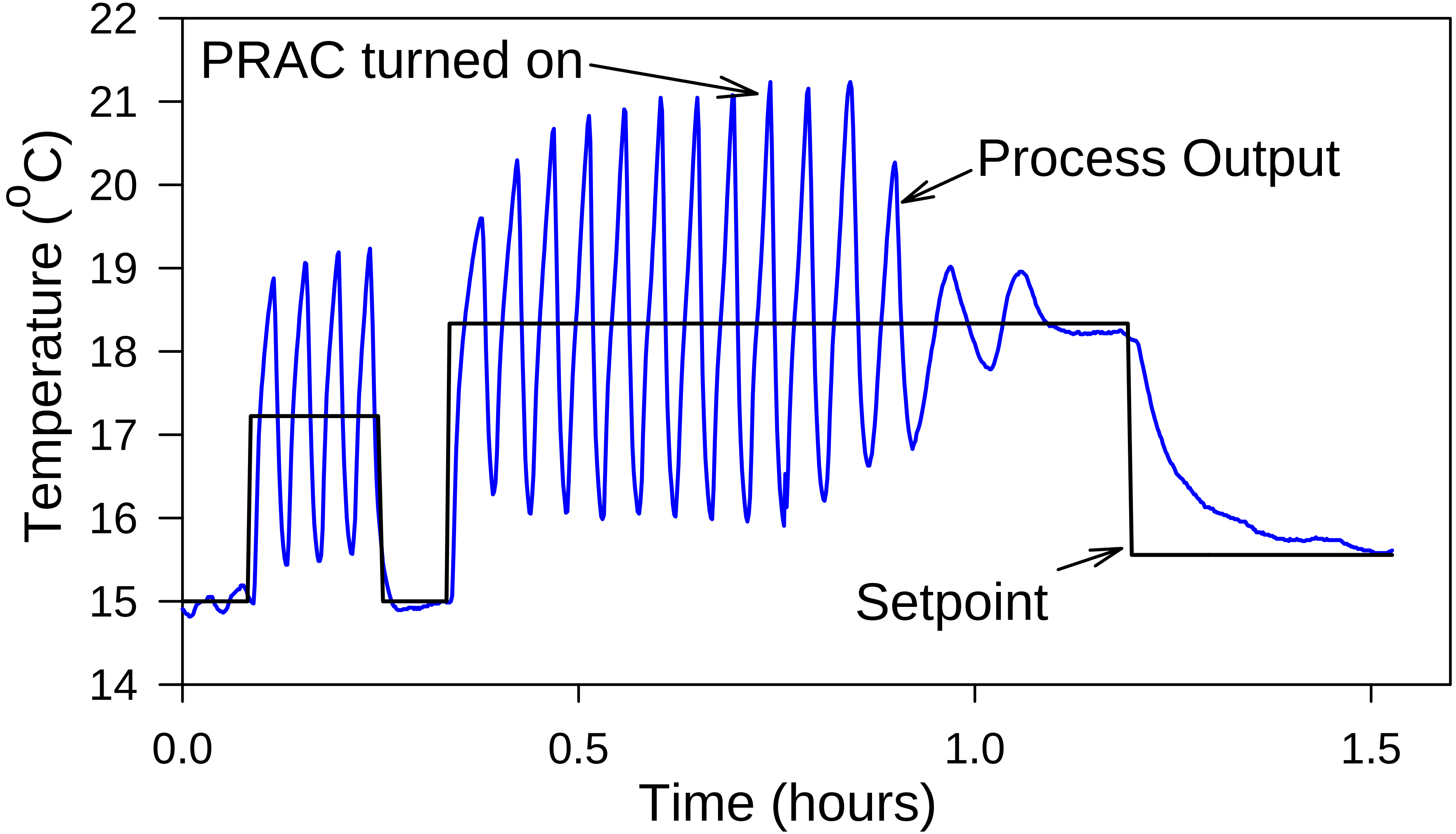
Features

- Easy to Use
- Near-Optimal Performance (IAE)
  - Load Disturbances
  - Setpoint Changes
- Robust
- Low  Requirements

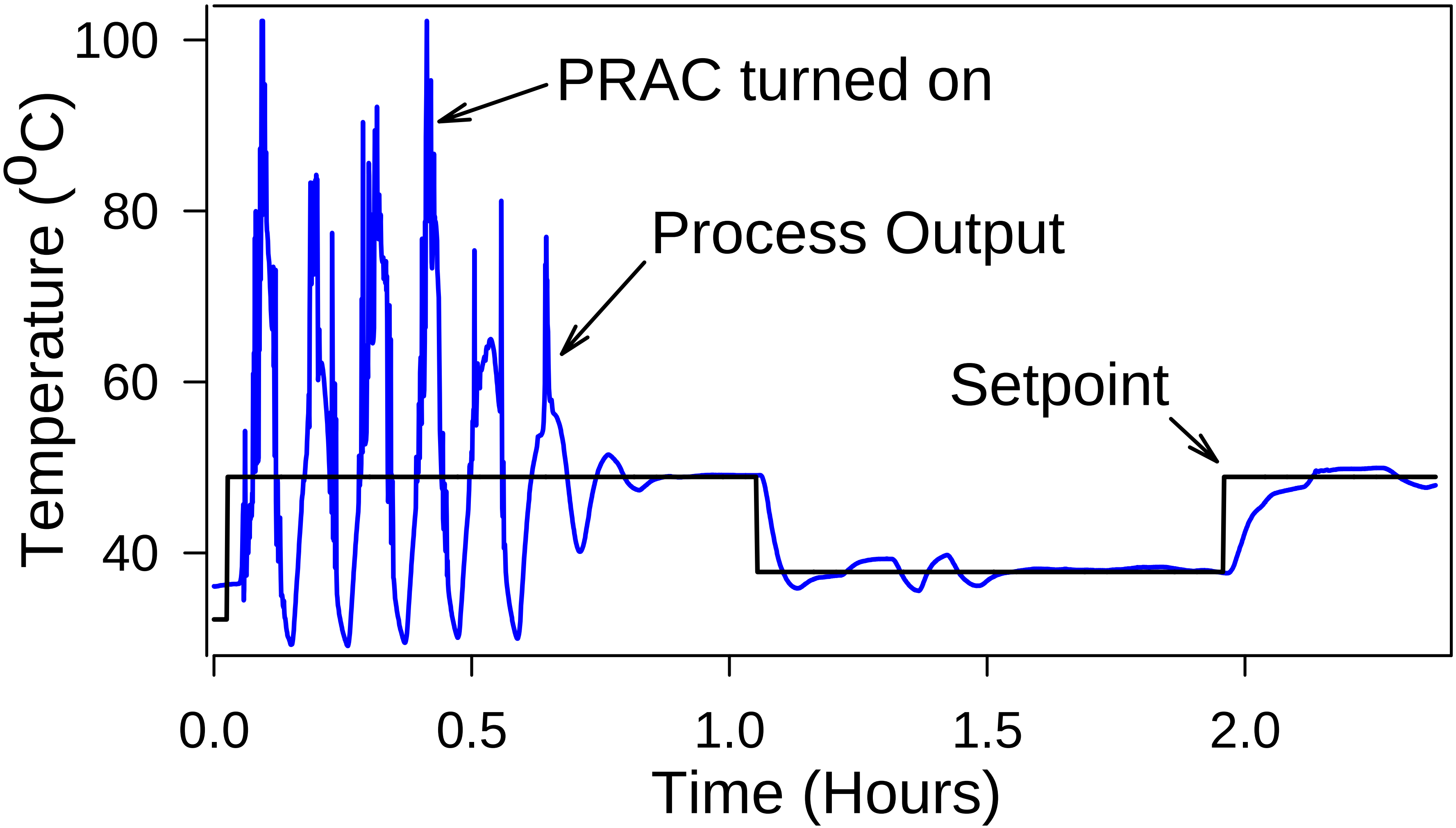
Field Test: Static Pressure



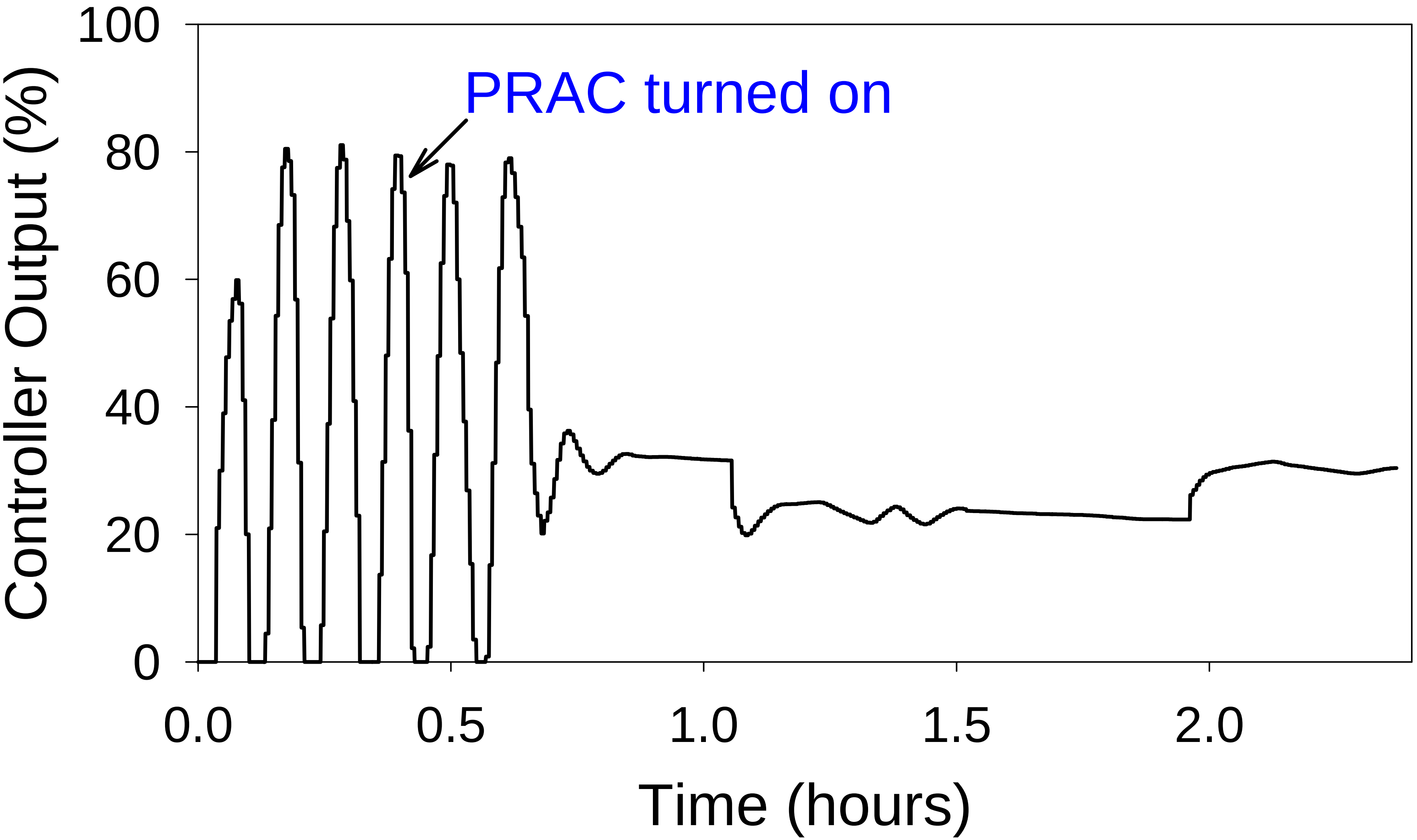
Field Test: Cooling Coil



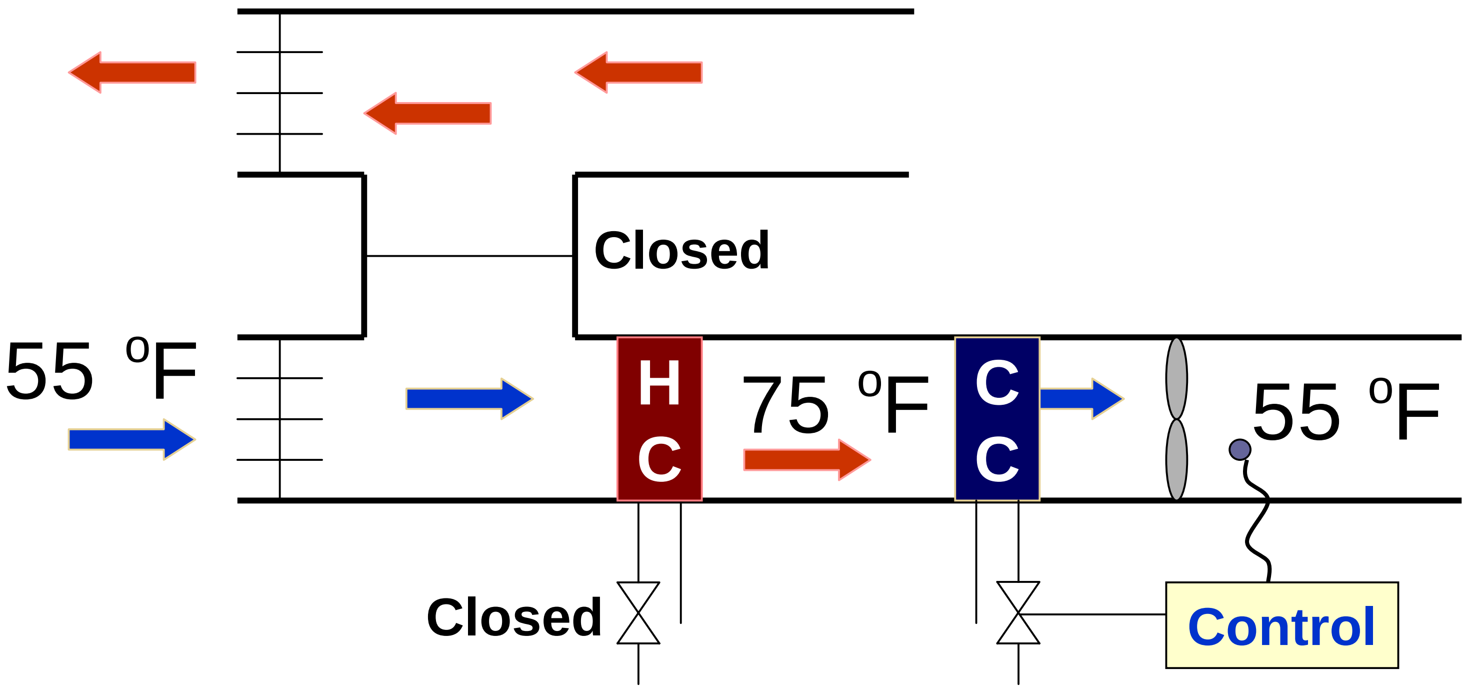
Field Test: Heating Coil



Field Test: Heating Coil



AHU Fault Detection

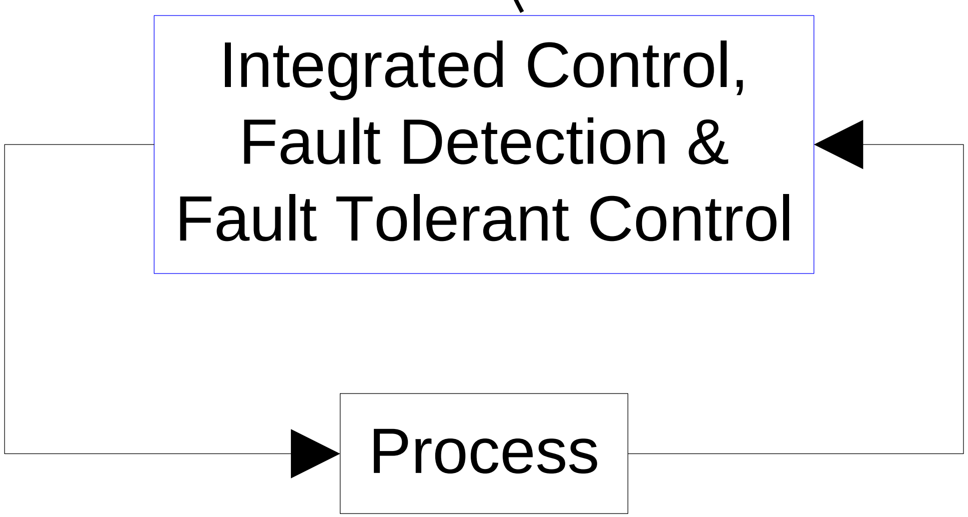


Research Objective

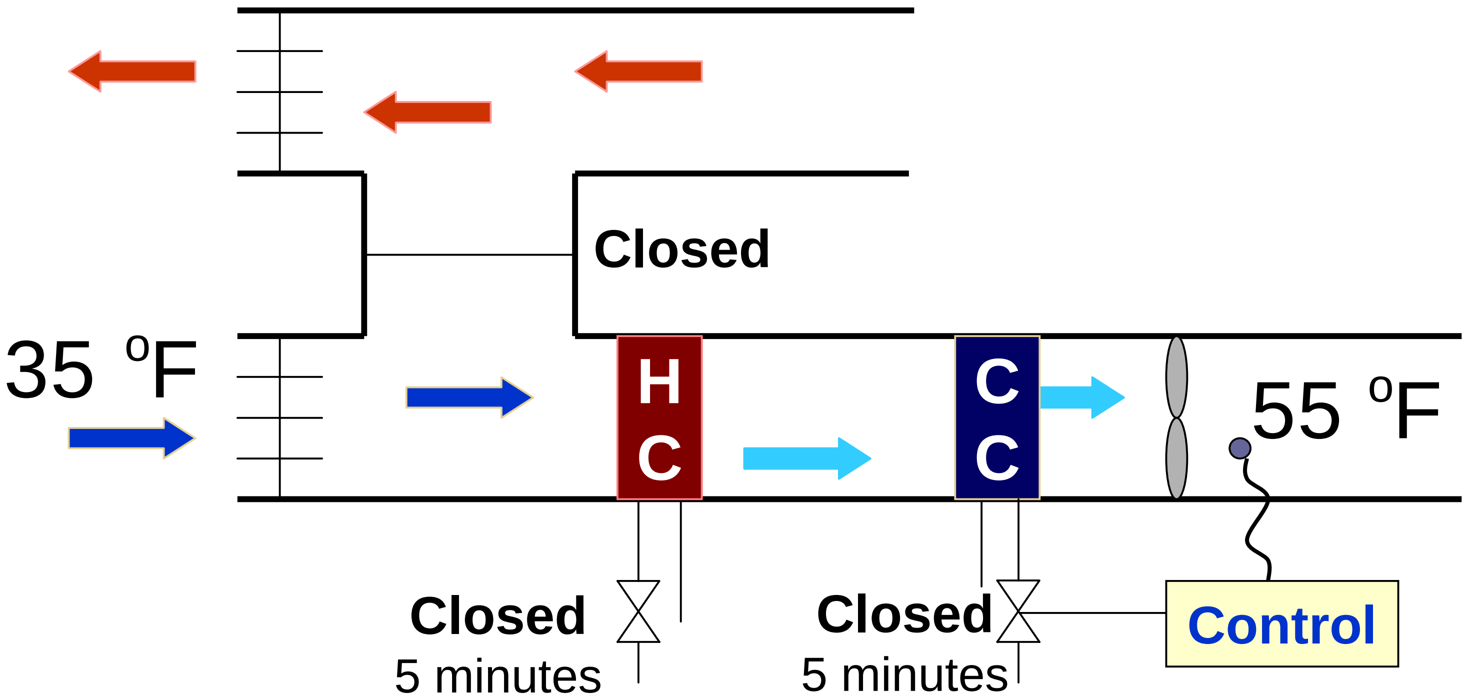
- **Detect leaky valves, stuck dampers, …**
- **No additional sensors**

Approach for AHU Fault Detection

1) State Machine
   - Mode of Operation
   - Steady-State Conditions
2) Model Based Residuals
   - Mass Balances
   - Energy Balances
3) Control Performance Indices

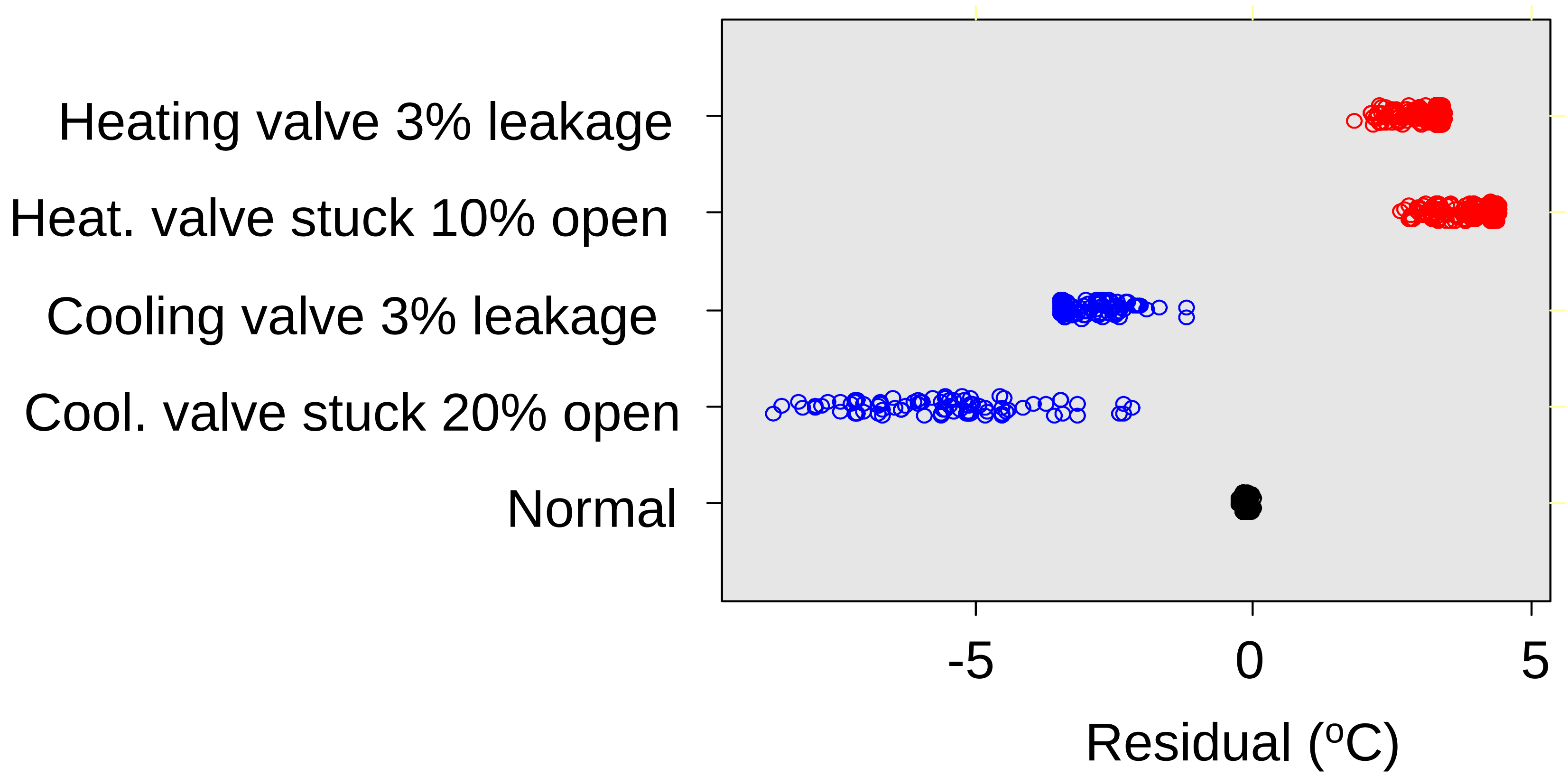


Residual Generation

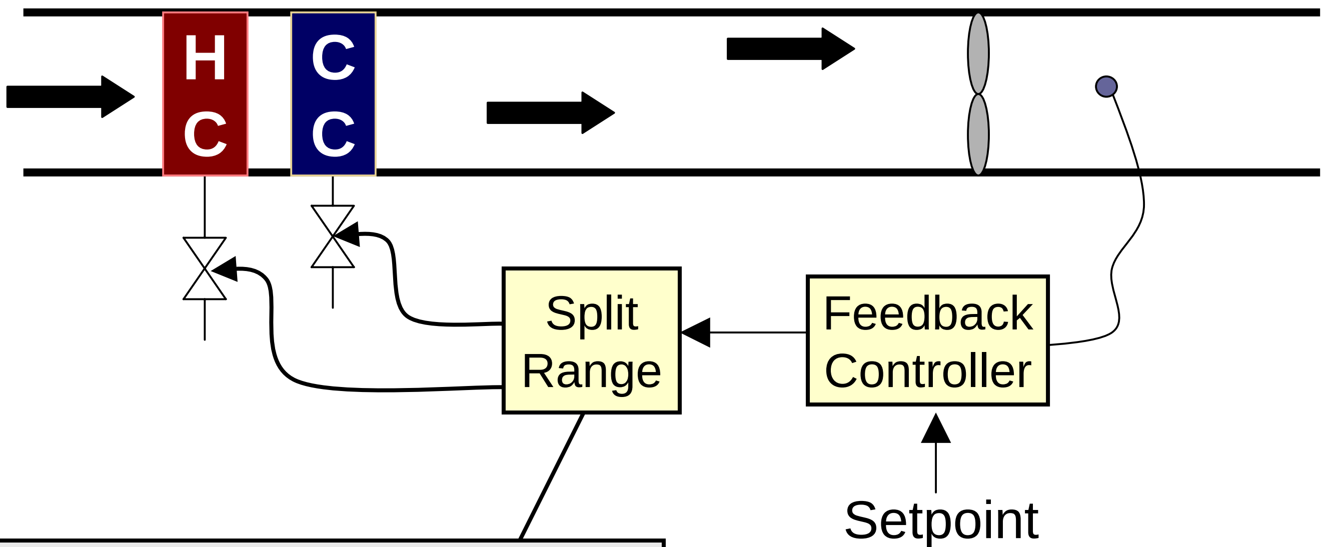


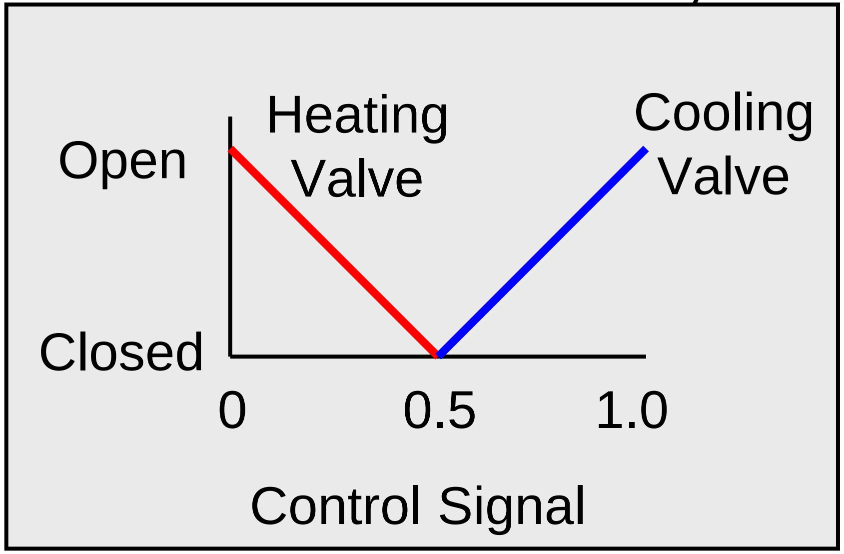
$$\text{Residual} = T_{supply} - T_{outdoor} - \hat{T}_{fan}$$
$$= 55\ ^0\text{F} - 35\ ^0\text{F} - 1\ ^0\text{F}$$
$$= 19\ ^0\text{F}$$

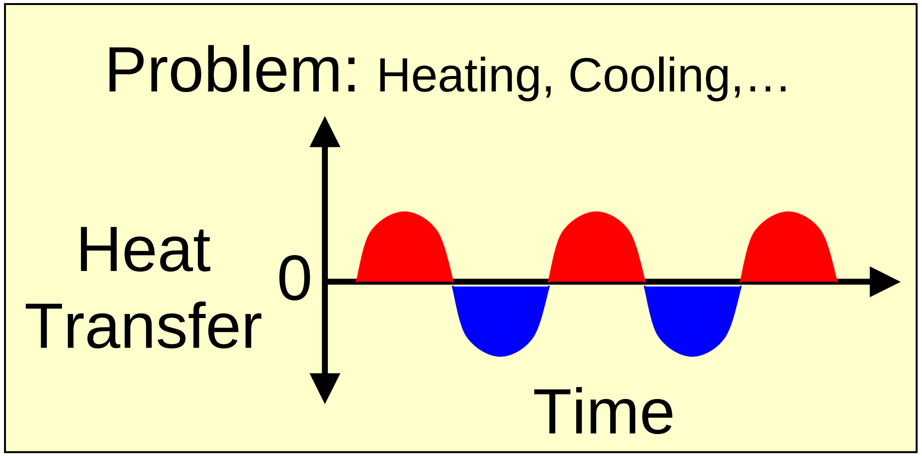
Simulation Results from Dr. John House



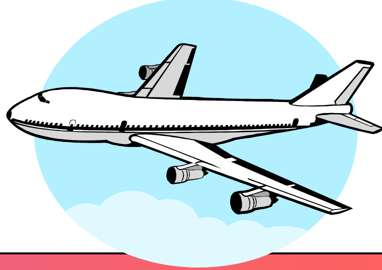
Split Range Control

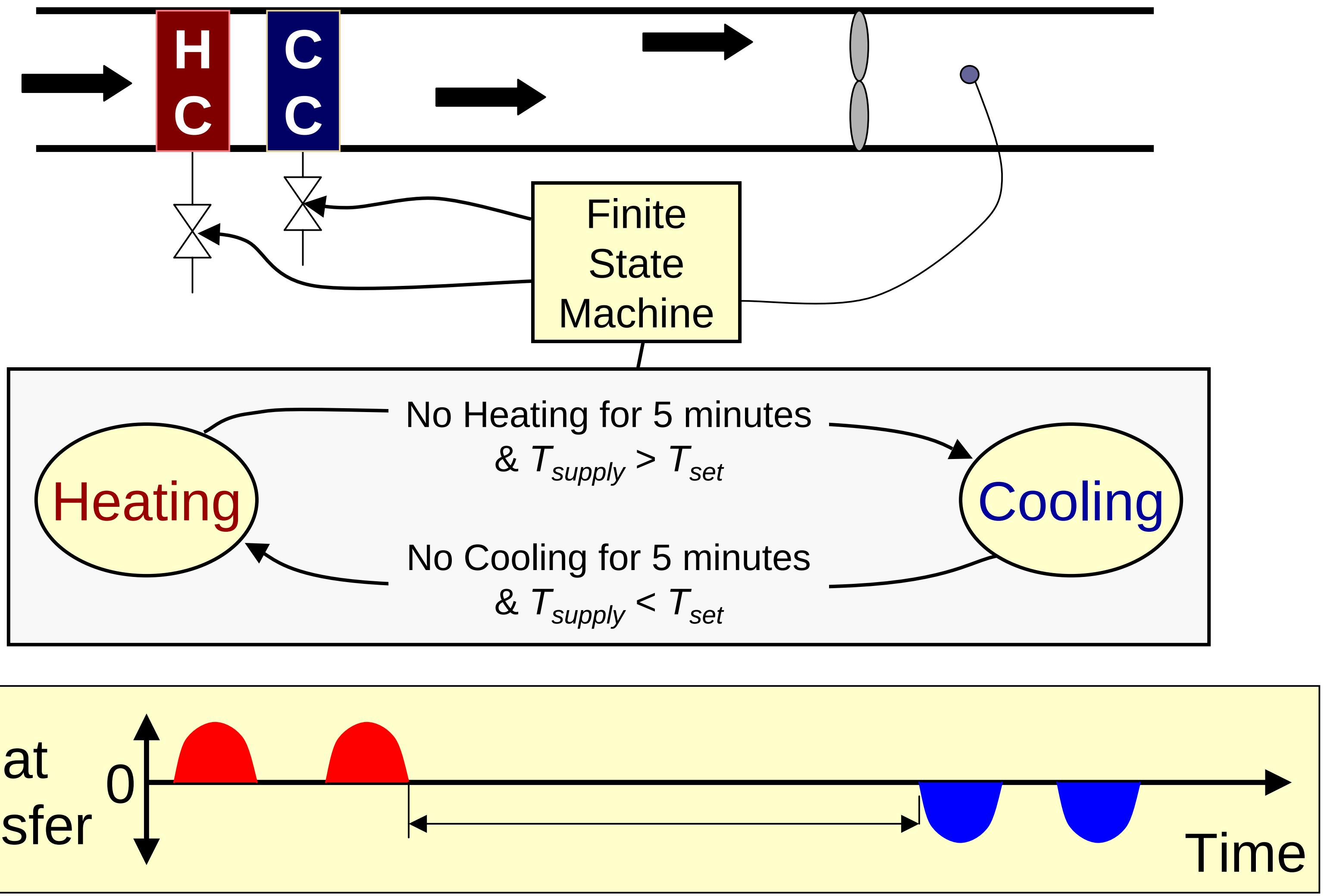




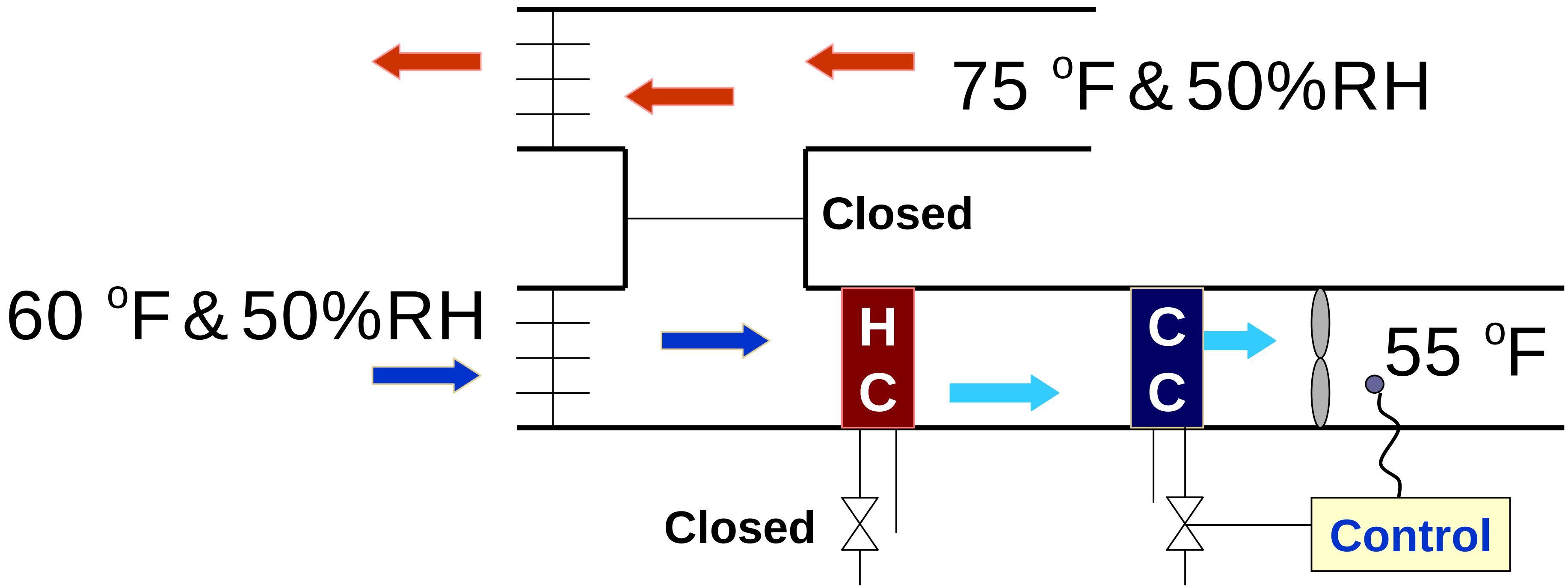


Finite State Machine

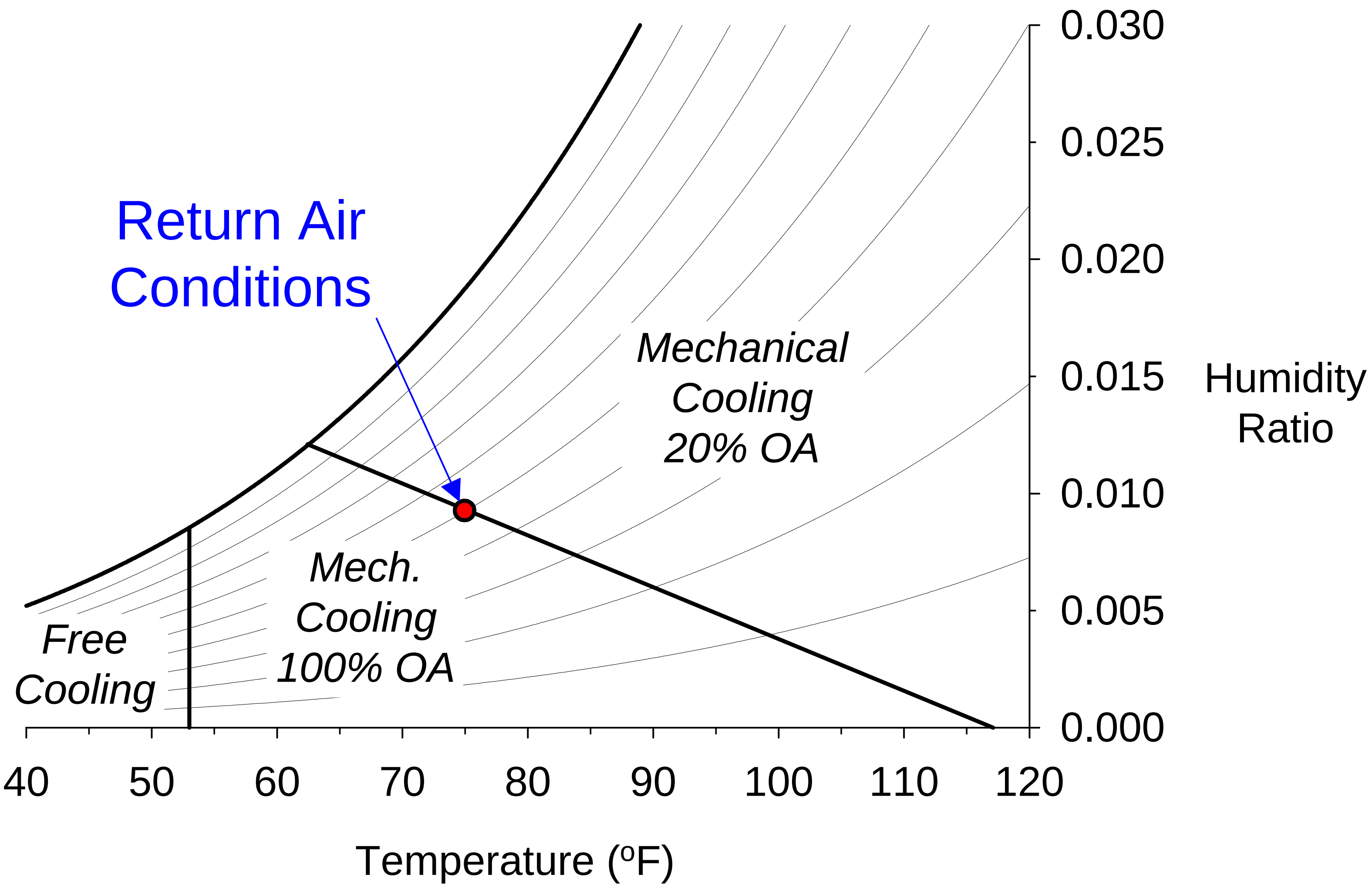




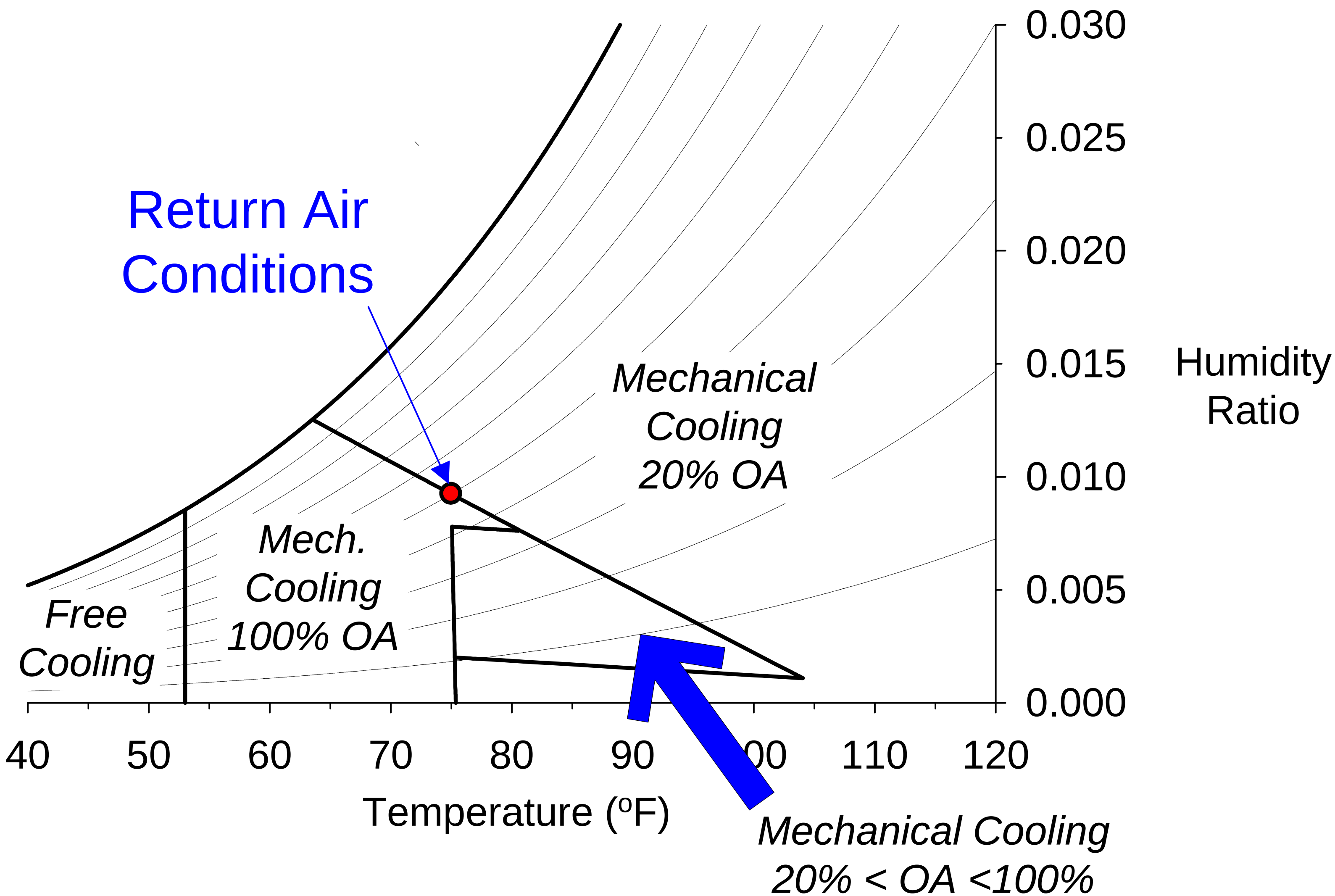
Air Side Economizer



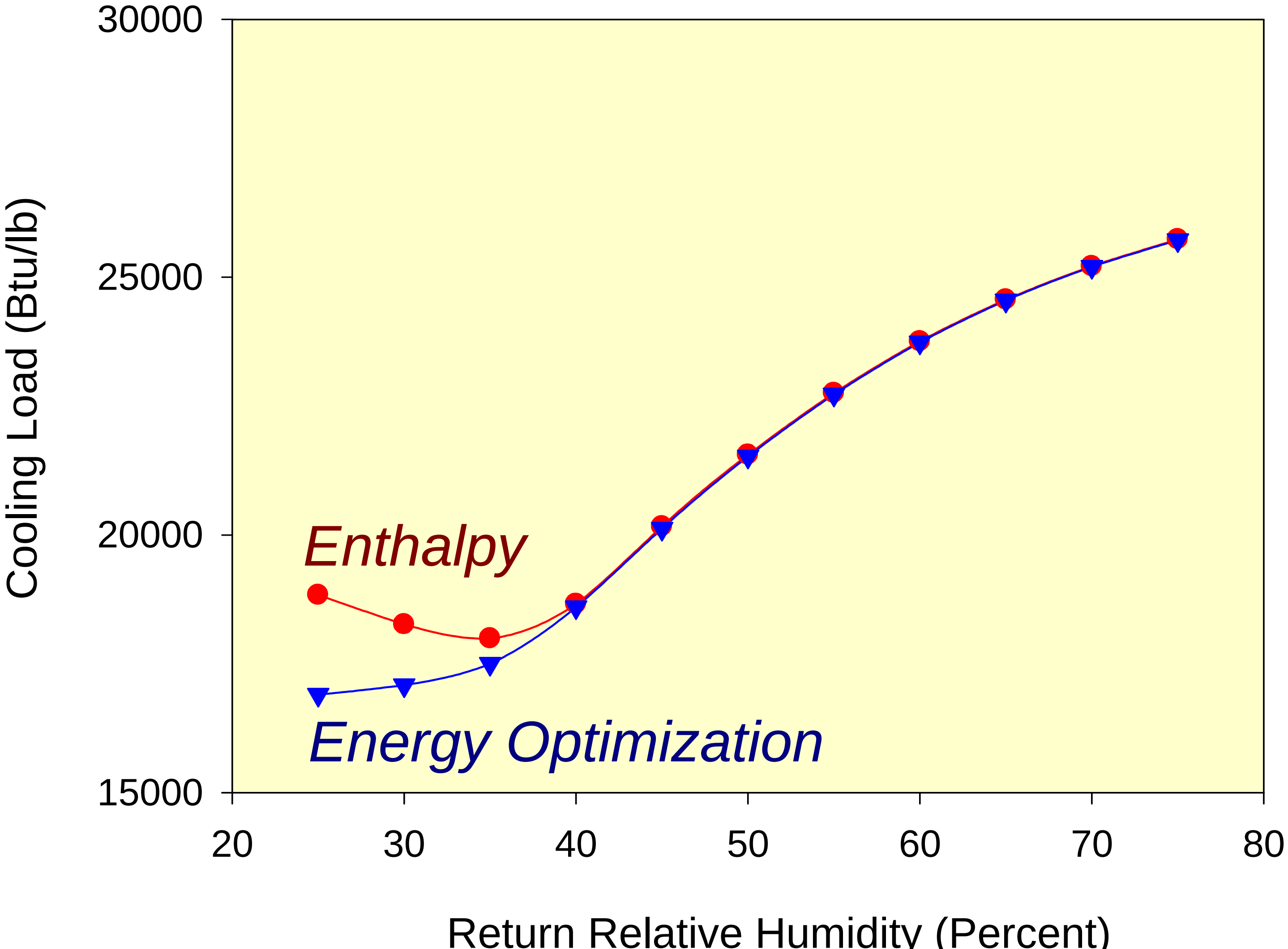
Enthalpy Economizer



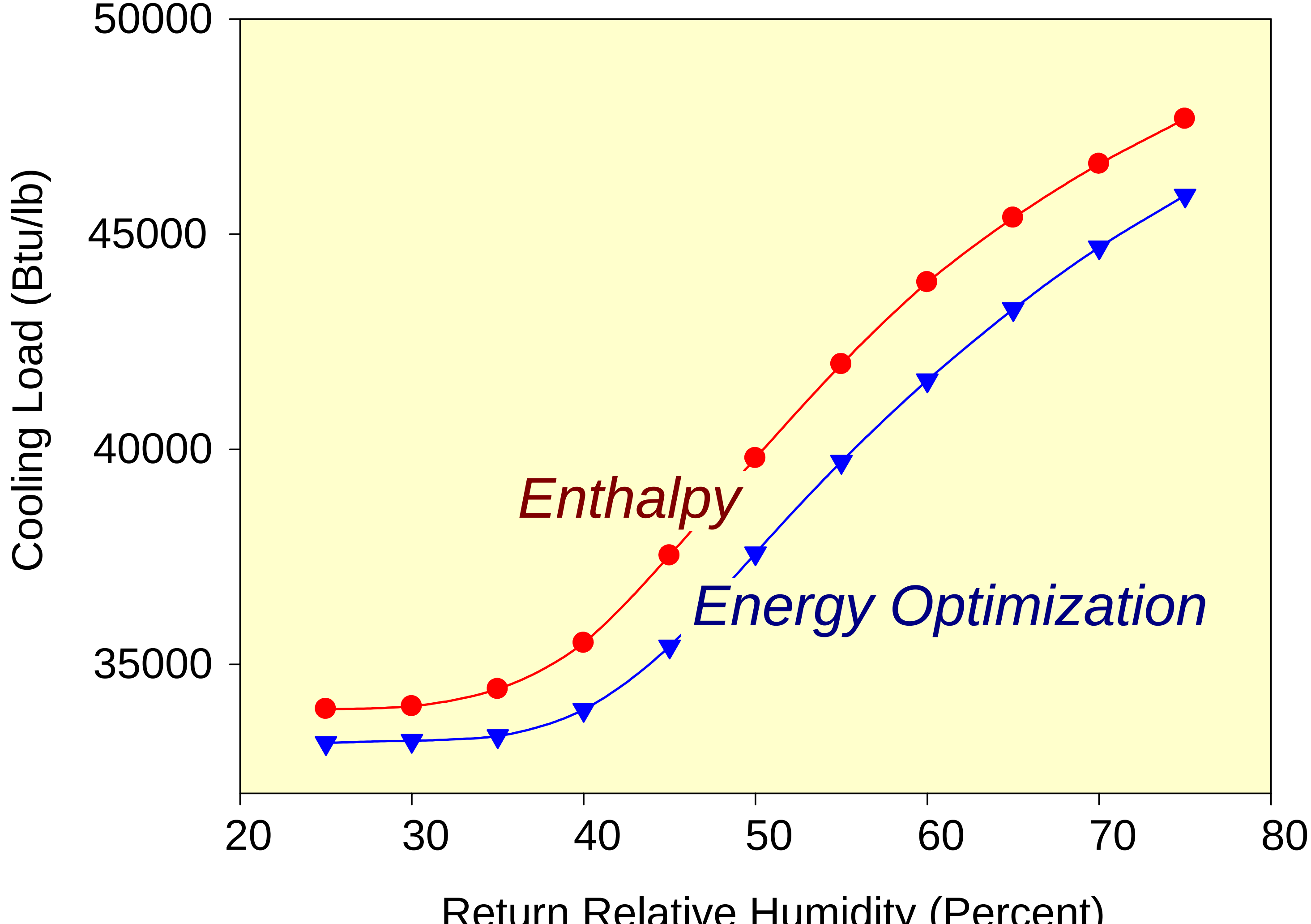
Energy Optimization Economizer



Simulation Results for New York



Simulation Results for Phoenix



Summary

- Tune feedback controllers
- Detect & fix faulty systems
- Stop fast switching: H ⇨ C ⇨ H ⇨ C ⇨ H ⇨ C
- Use energy optimization