

IT TAKES WORLDWIDE CONTINGENCY PLAN

BUILDING AUTOMATION WHATEVER IT TAKES

WHATEVER IT TAKES FACILITY OPERATIONS



TECHNICAL SUPPORT WHATEVER IT TAKES

WHATEVER IT TAKES SECURITY SOLUTIONS

DISASTER RESPONSE

JOHNSON
CONTROLS

ENERGY EFFICIENCY

Report Documentation Page

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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

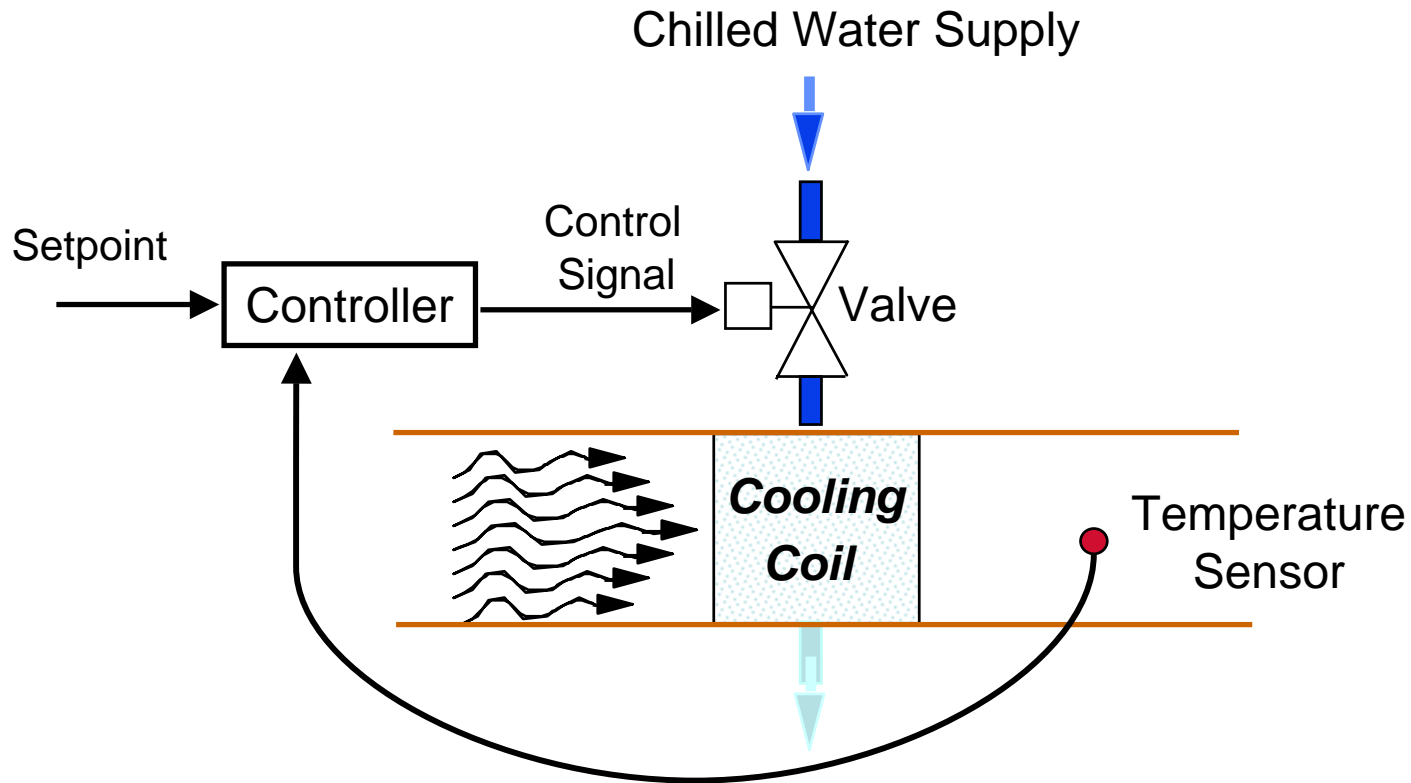
New Energy Saving Strategies for HVAC Control Systems

John E. Seem, Ph.D.

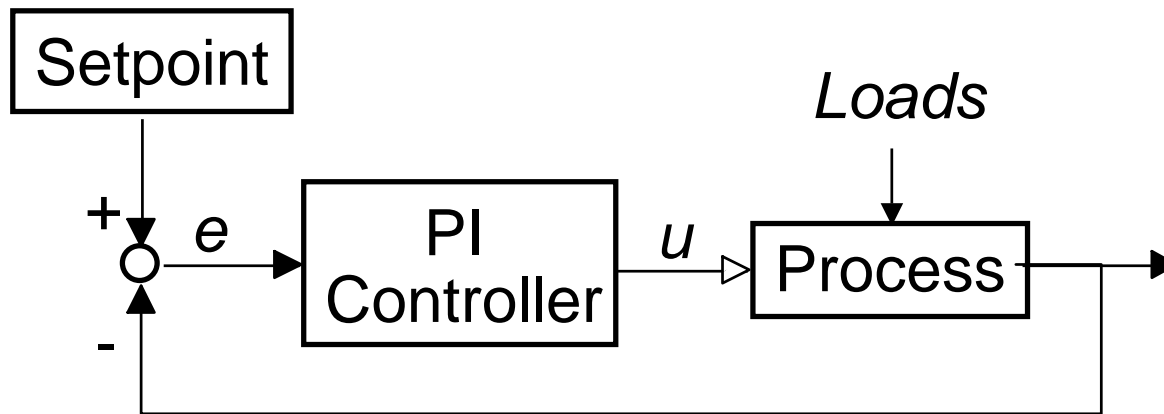
Agenda

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

Feedback Control System



PI Controller



Gain

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

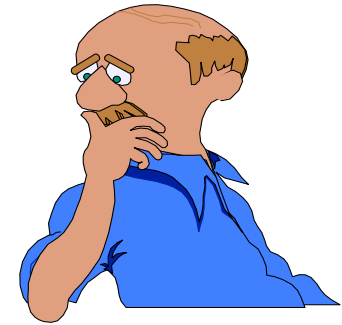
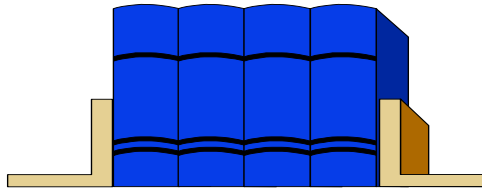
Integral Time

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

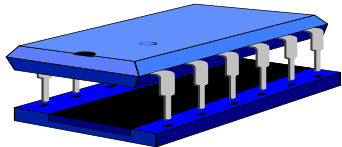
Develop Continuous Tuning Method for PI Controllers

Features

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

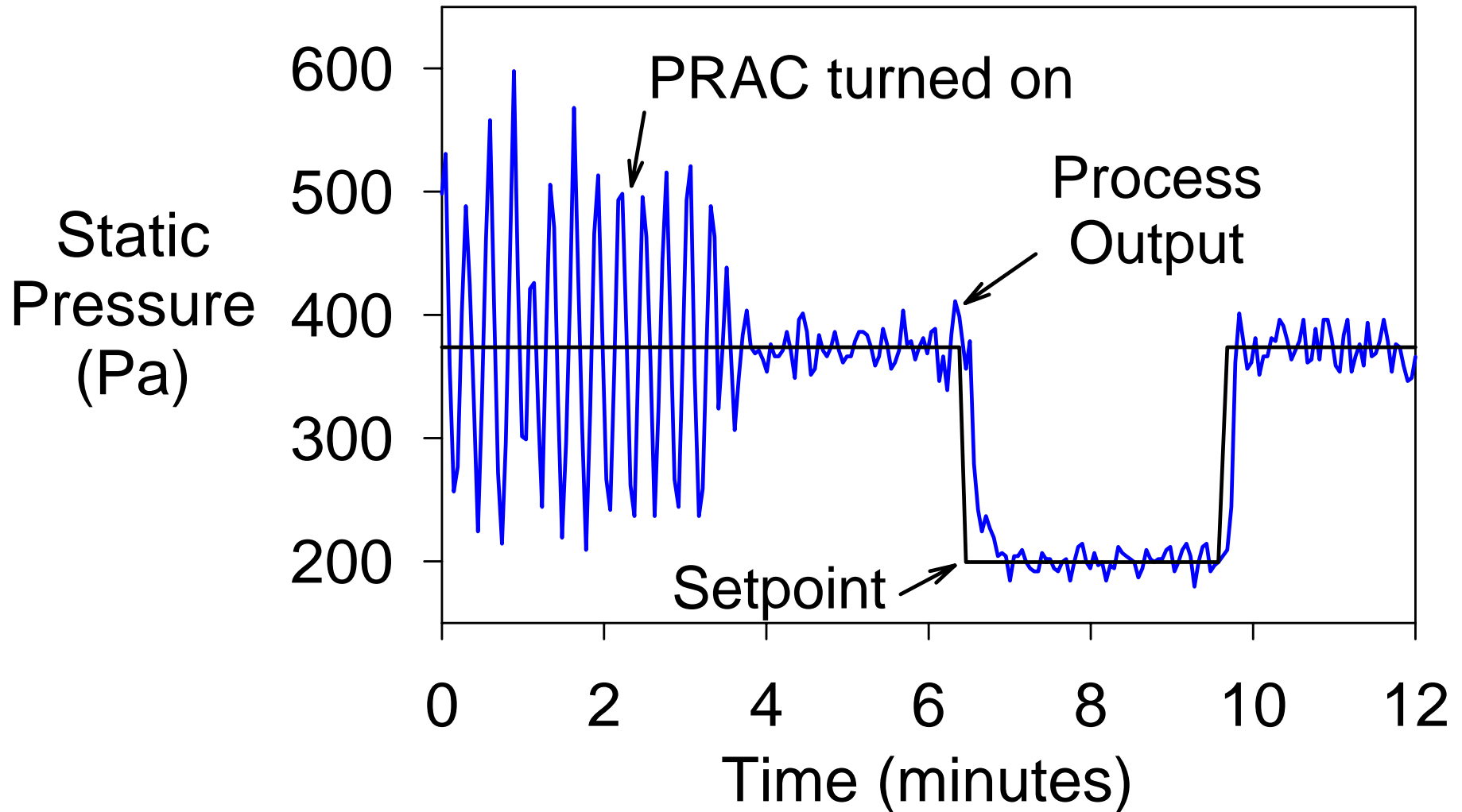
• Robust

• Low

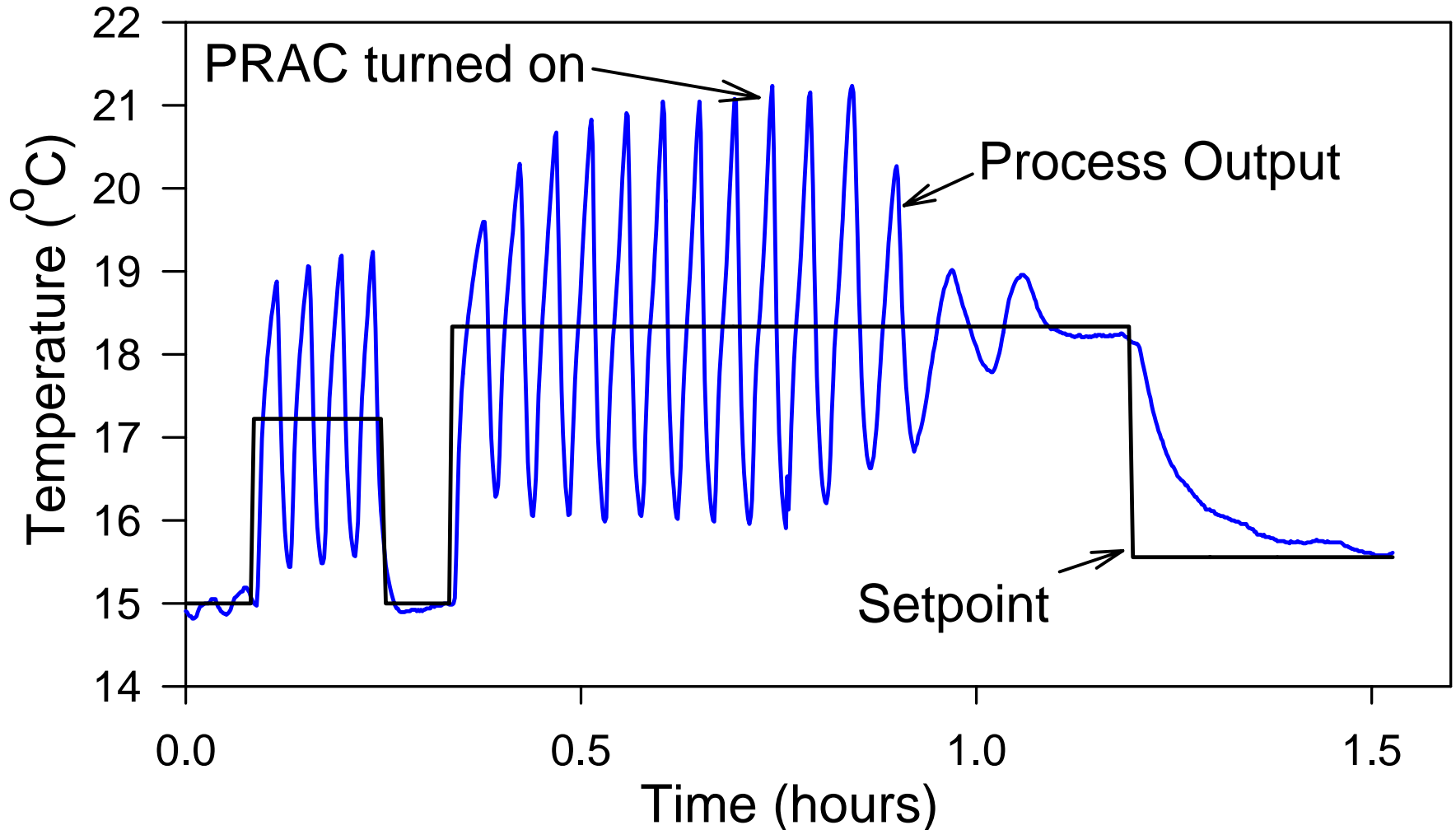


Requirements

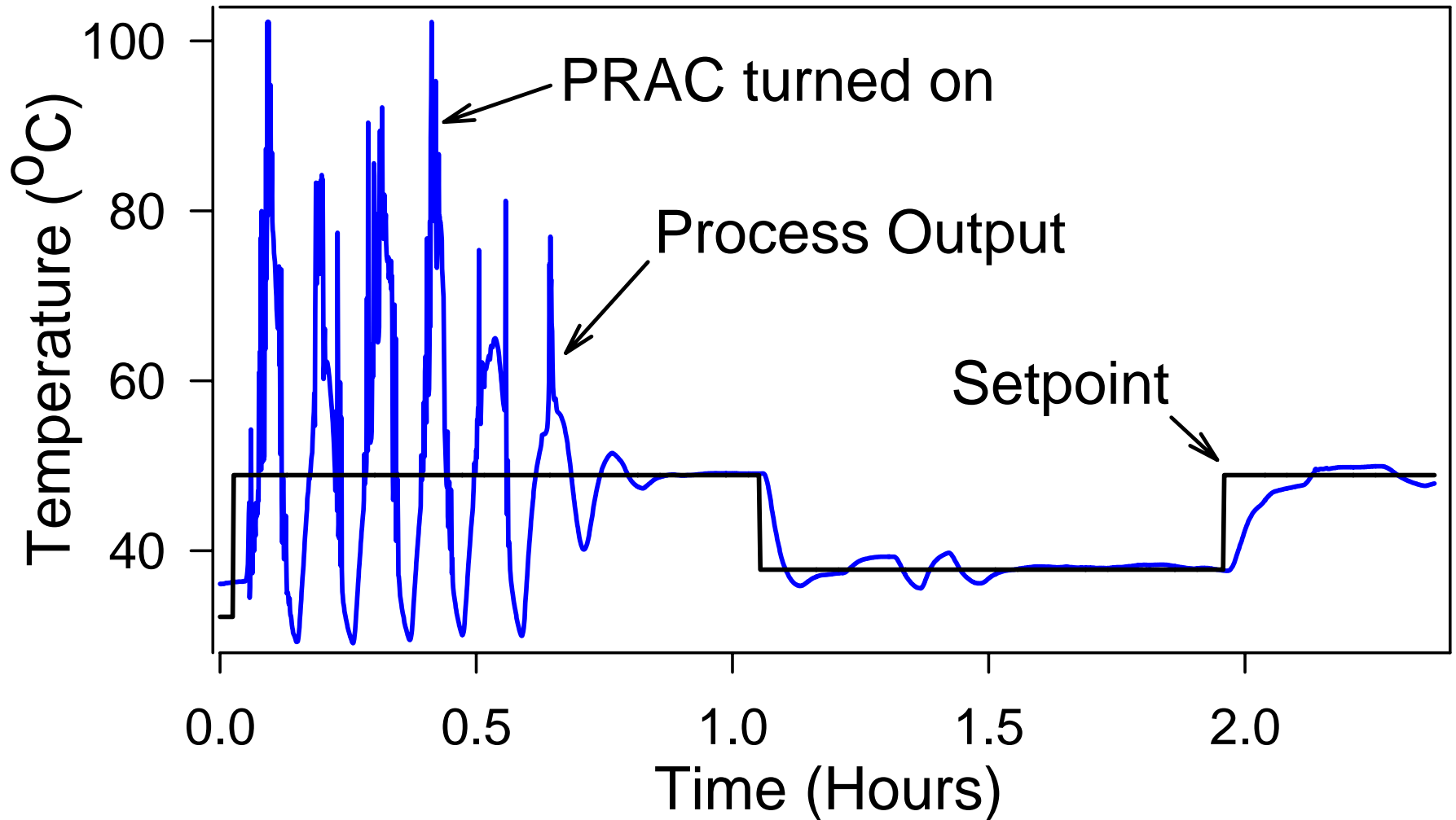
Field Test: Static Pressure



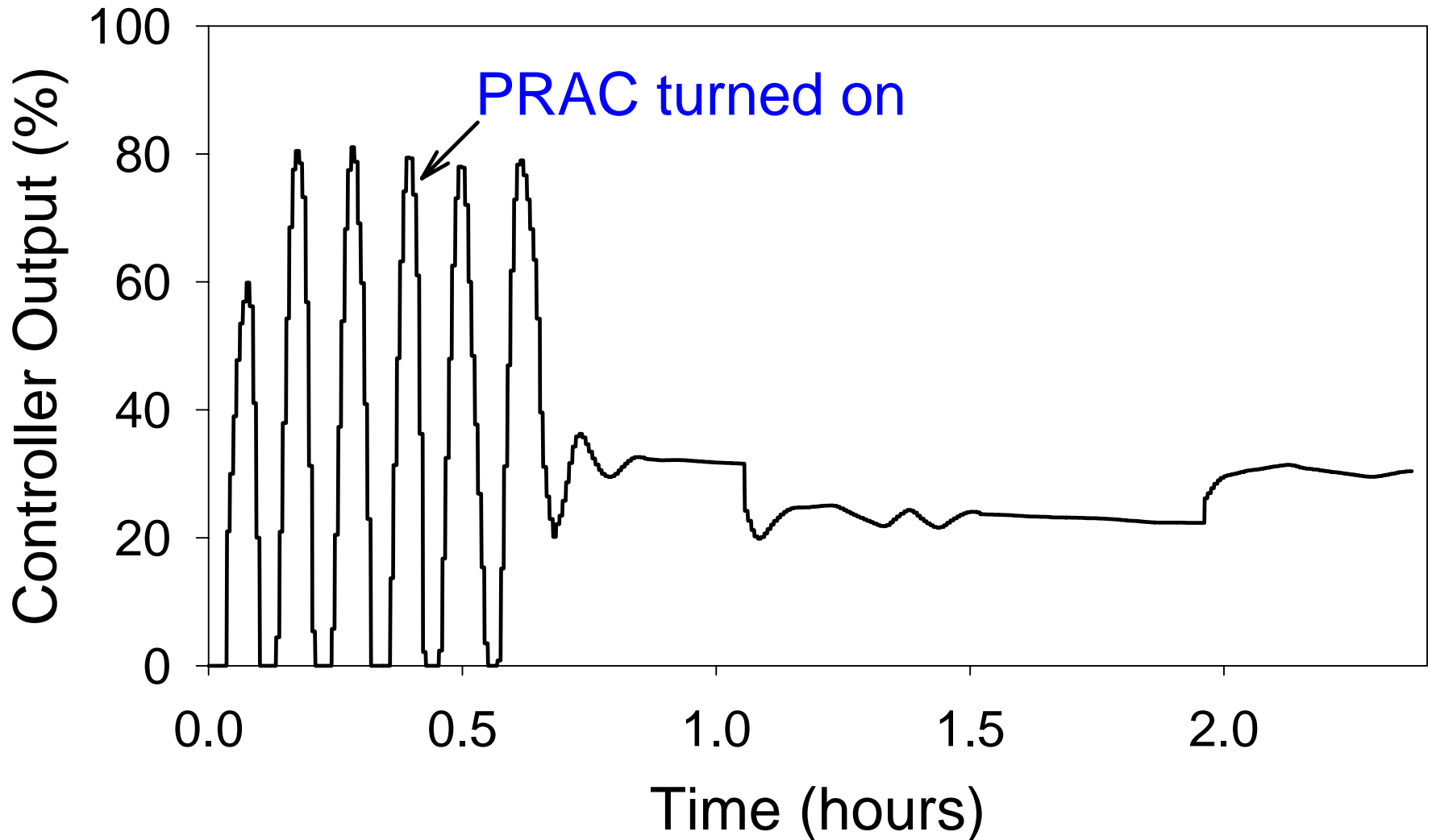
Field Test: Cooling Coil



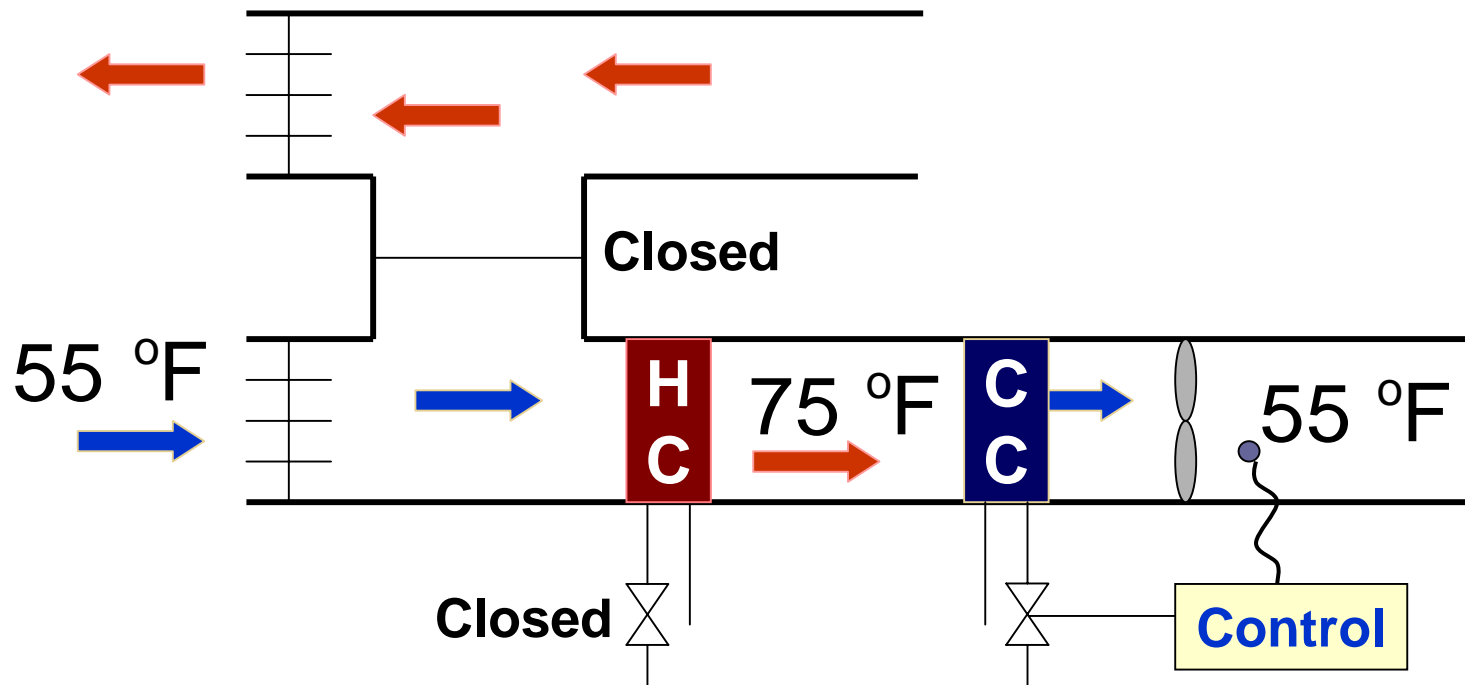
Field Test: Heating Coil



Field Test: Heating Coil



AHU Fault Detection

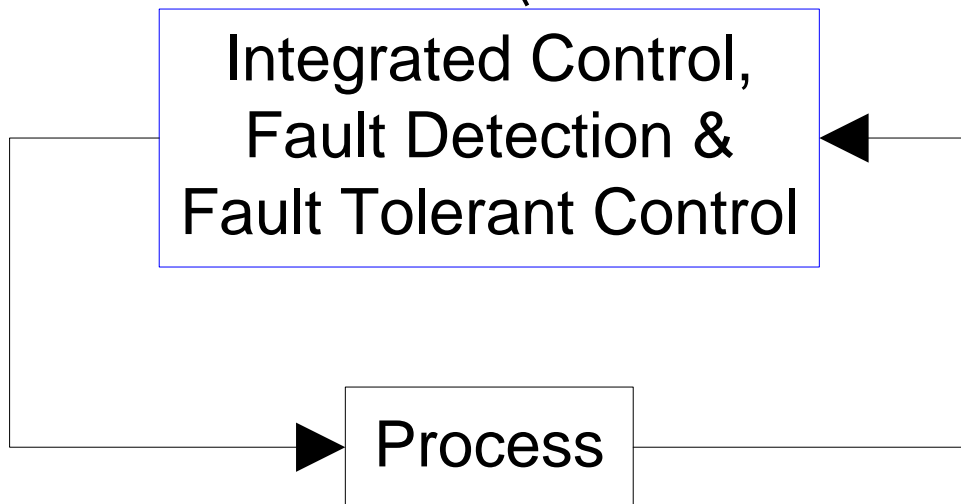


Research Objective

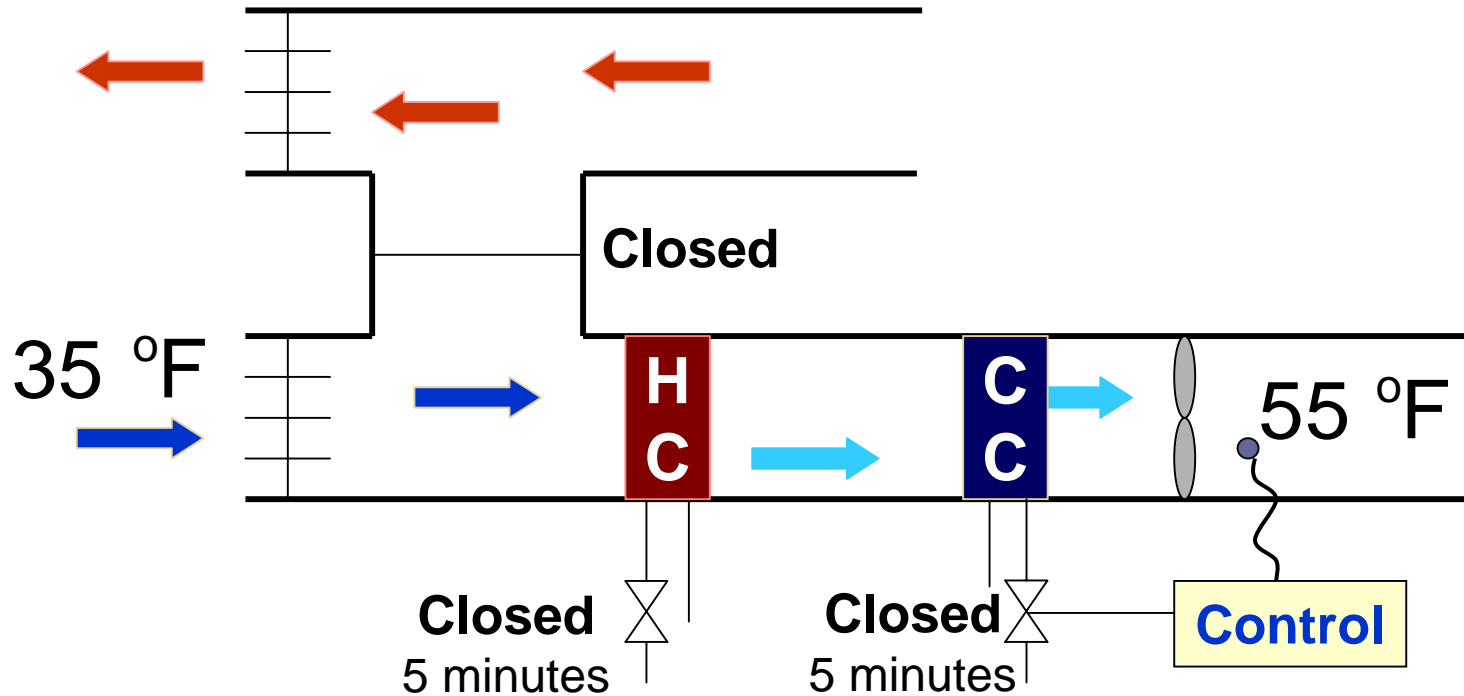
- Detect leaky valves, stuck dampers, ...
- No additional sensors

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



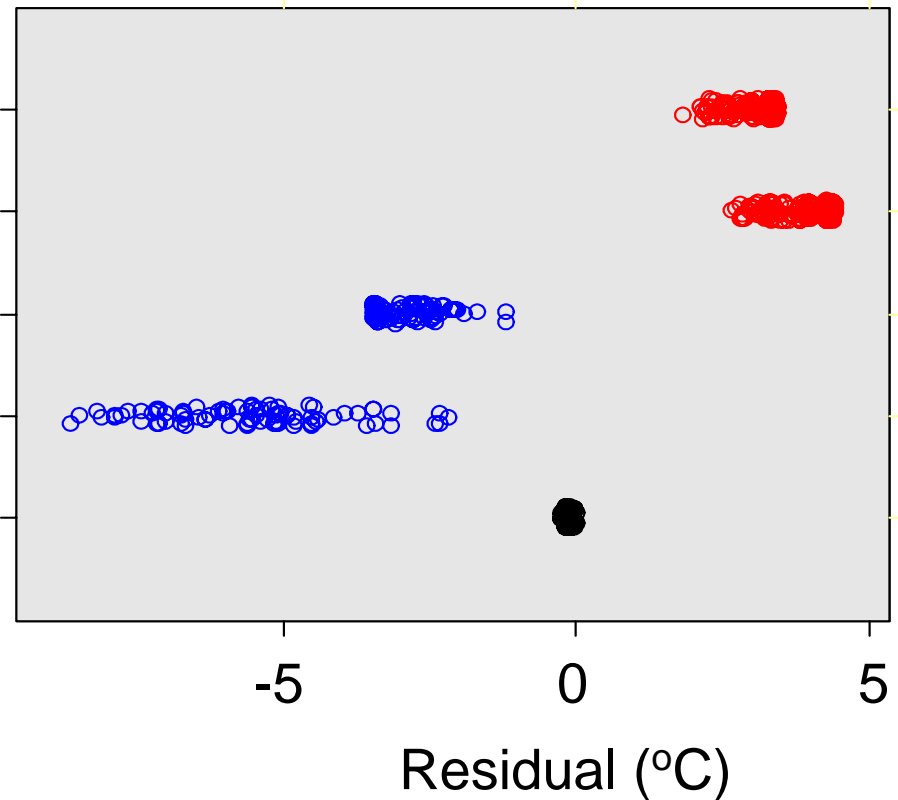
Residual Generation



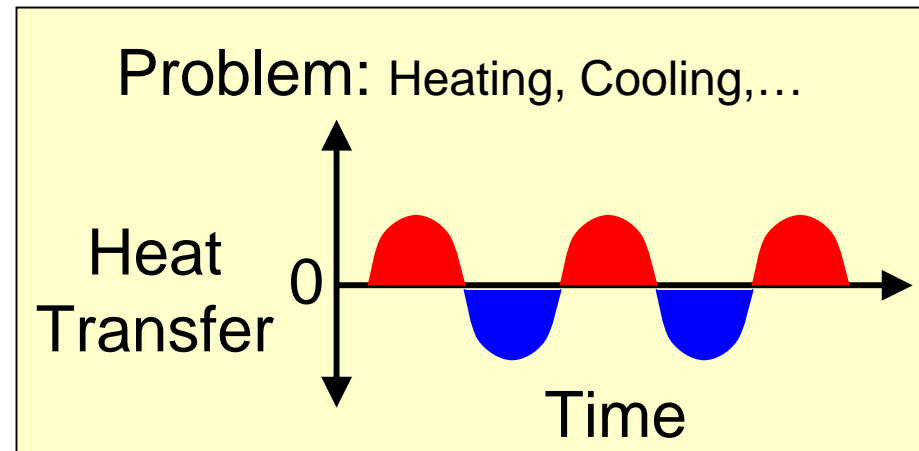
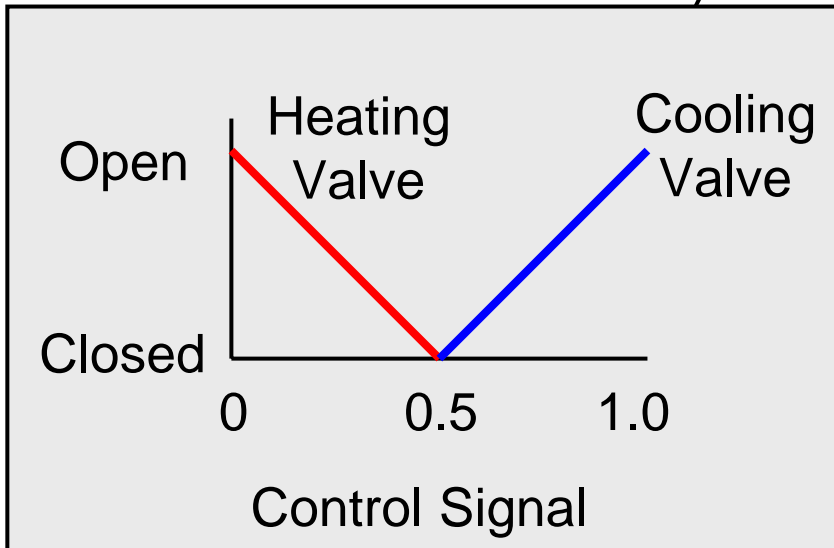
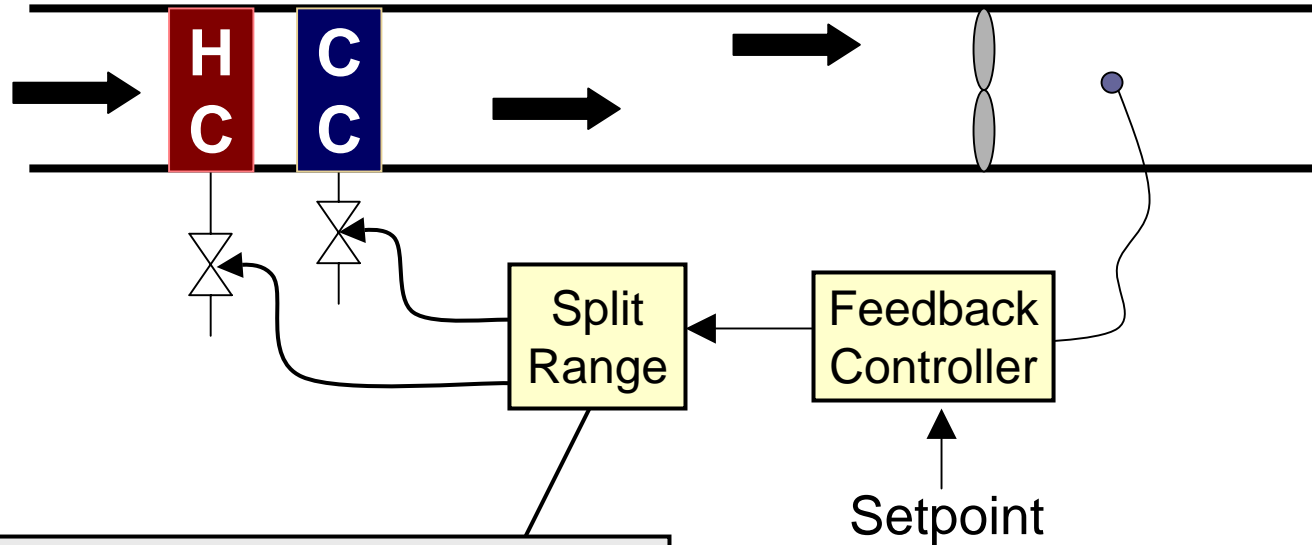
$$\begin{aligned}\text{Residual} &= T_{\text{supply}} - T_{\text{outdoor}} - \hat{T}_{\text{fan}} \\ &= 55^{\circ}\text{F} - 35^{\circ}\text{F} - 1^{\circ}\text{F} \\ &= 19^{\circ}\text{F}\end{aligned}$$

Simulation Results from Dr. John House

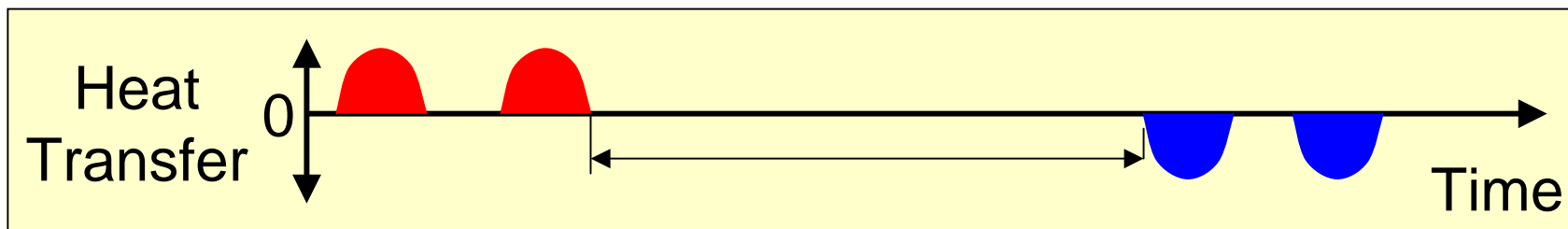
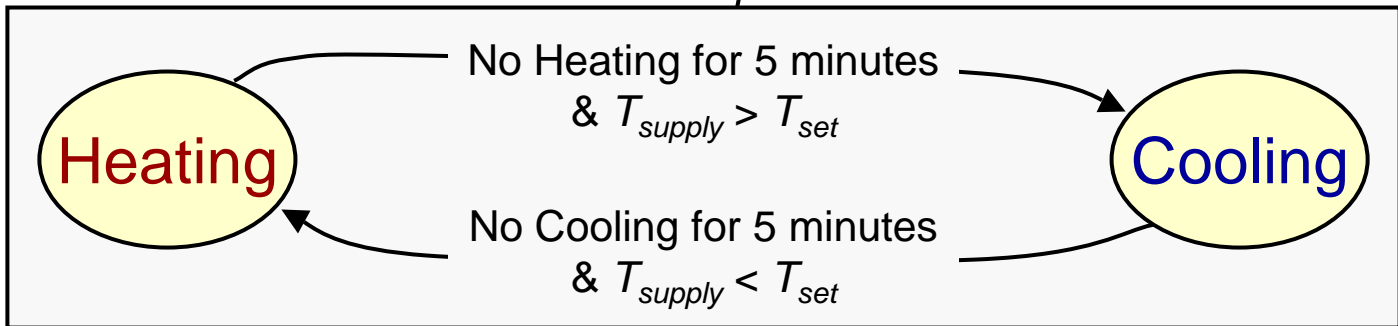
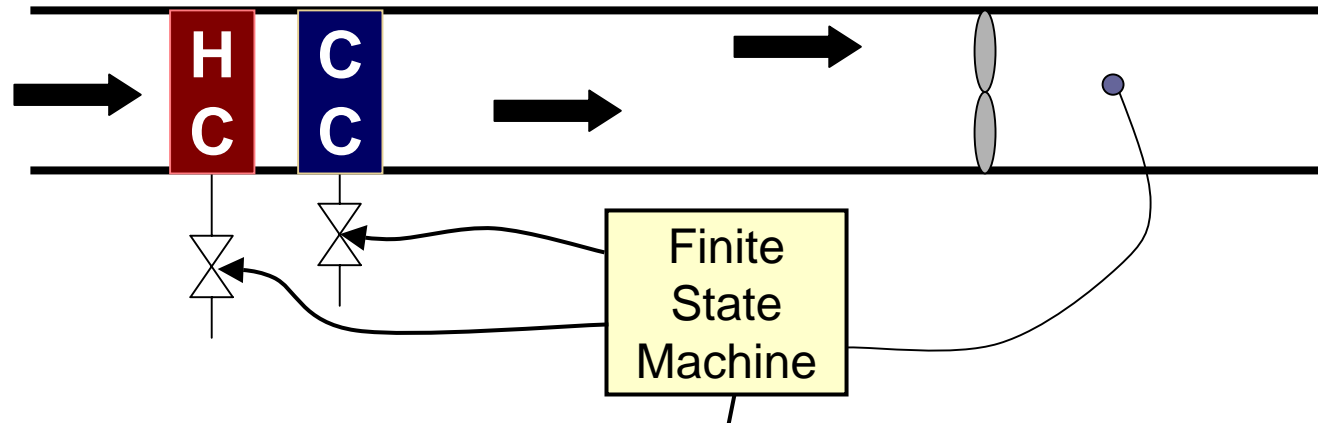
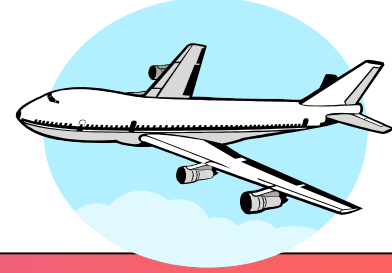
Heating valve 3% leakage
Heat. valve stuck 10% open
Cooling valve 3% leakage
Cool. valve stuck 20% open
Normal



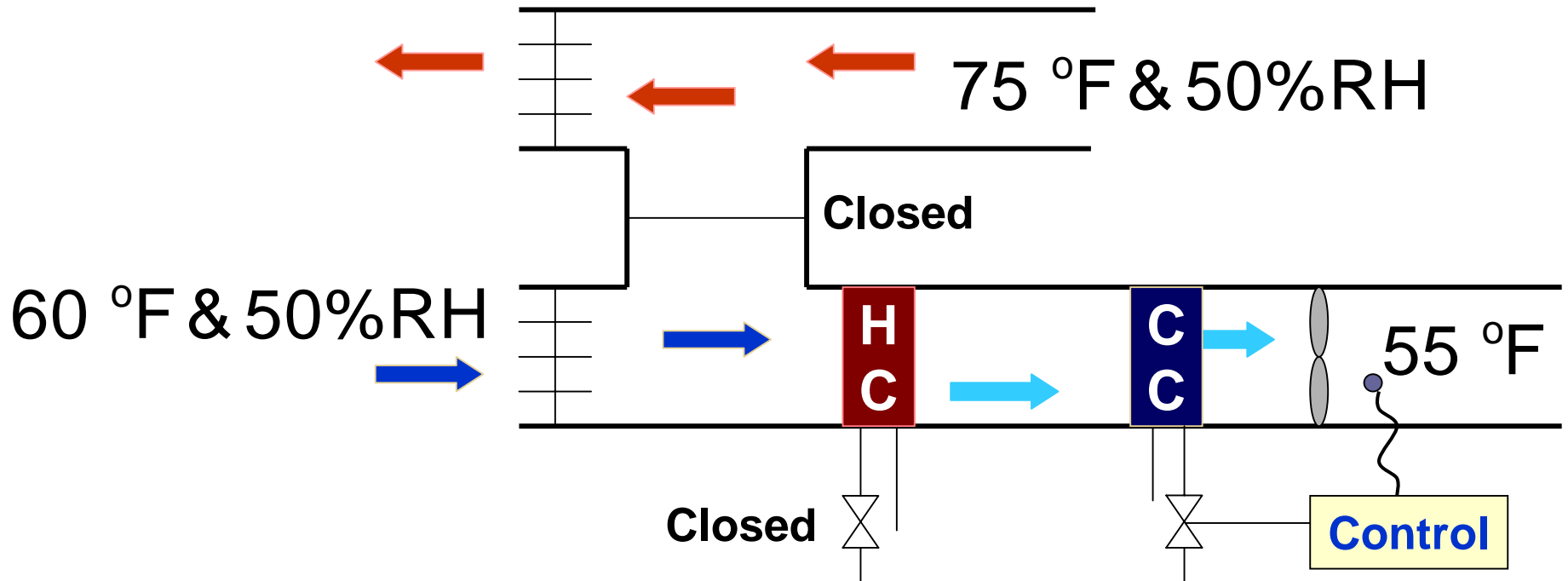
Split Range Control



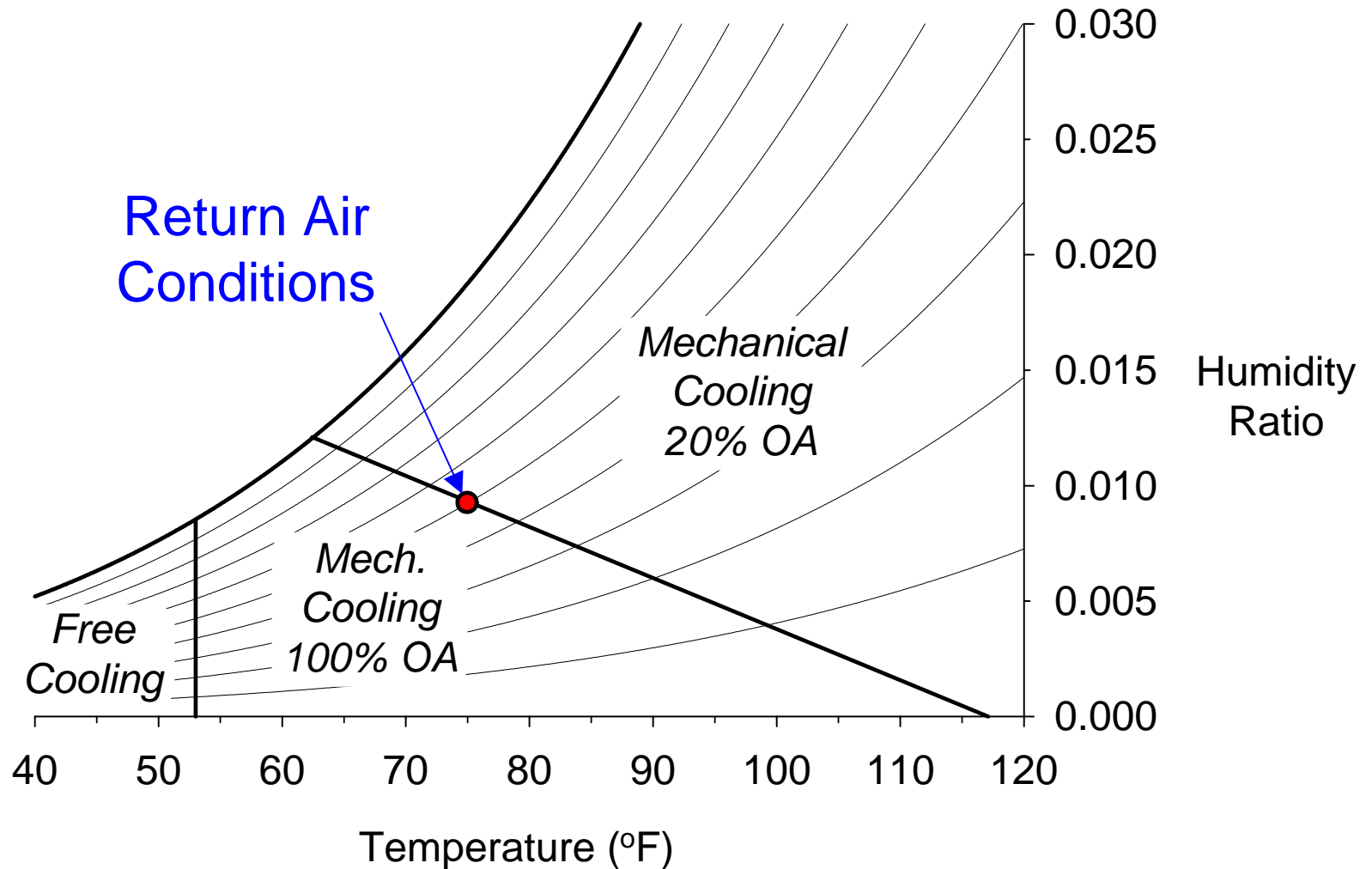
Finite State Machine



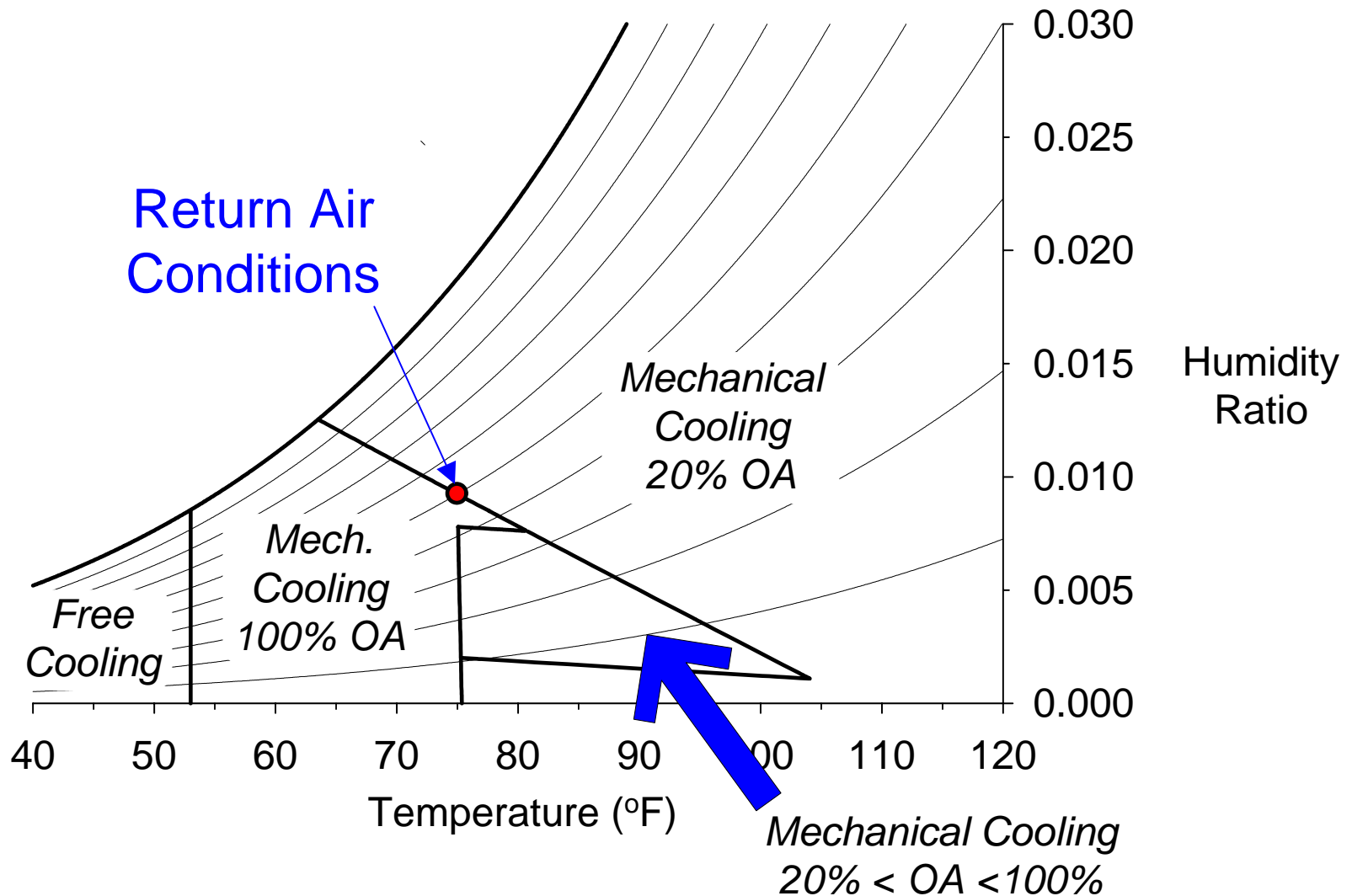
Air Side Economizer



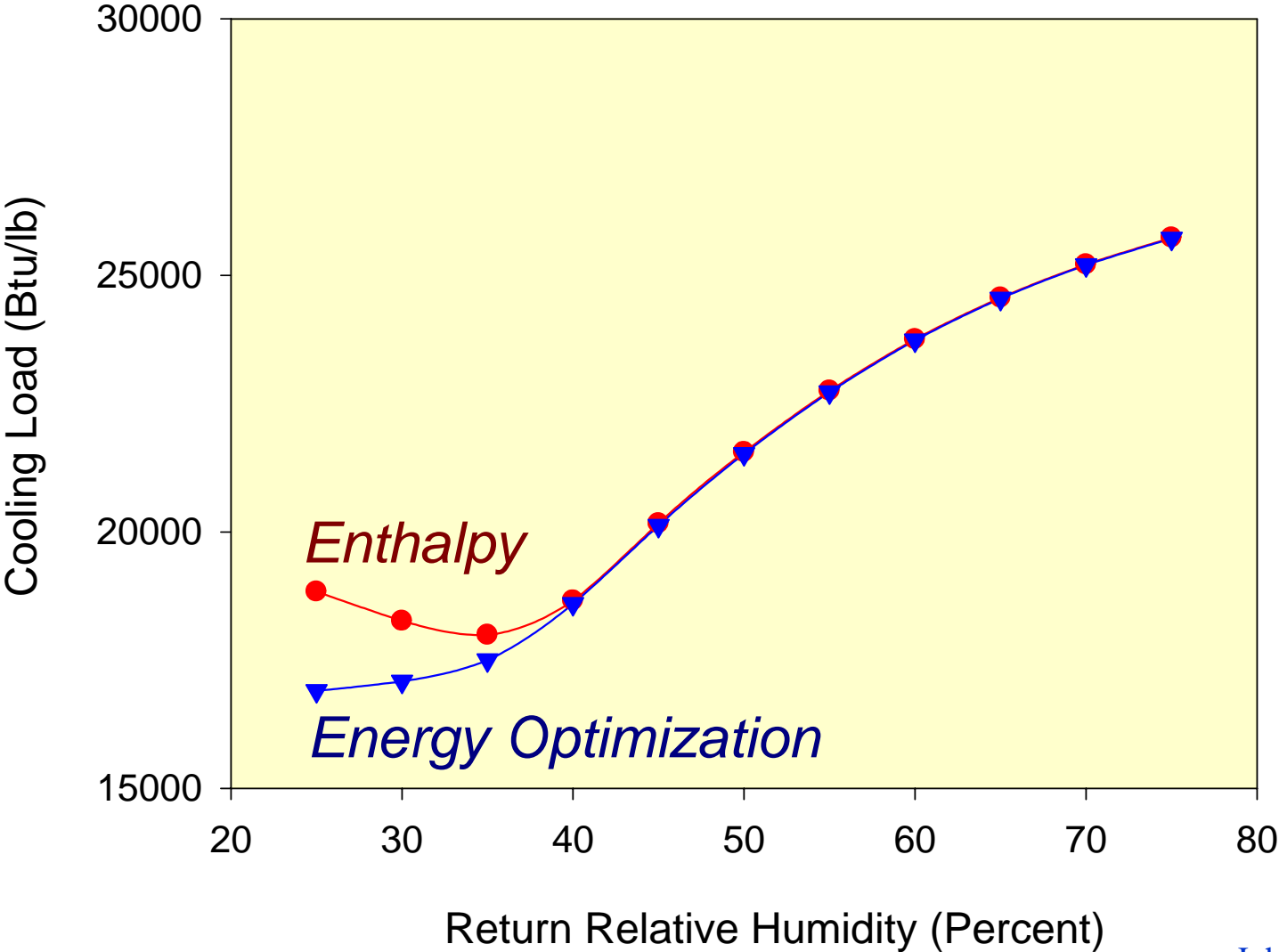
Enthalpy Economizer



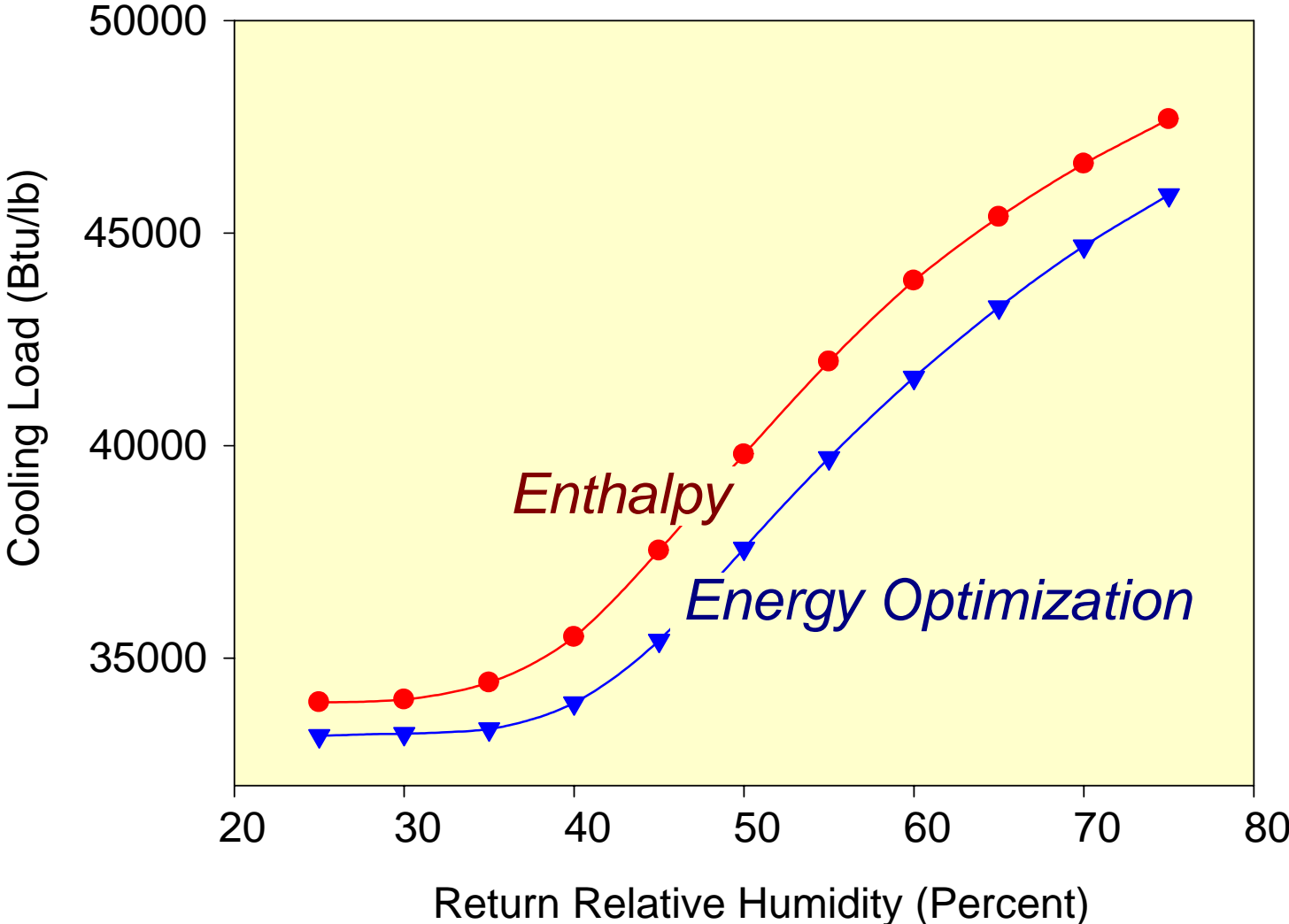
Energy Optimization Economizer



Simulation Results for New York



Simulation Results for Phoenix



Summary

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