Feedback Systems in HVAC

ASHRAE Distinguished Lecture Series

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ASHRAE, Madison Chapter

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Agenda

Definitions: feedback and closed-loop control

Types of feedback algorithms

Application: Supply Air Temperature Control
- DX cooling – staged control
- Chilled water valve – PI and PID control

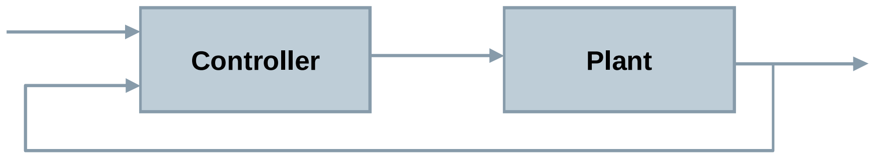
Application: Mixed Air Control
- Adaptive control

Application: Duct pressure reset

Specifying loop performance

What is a loop?

A closed loop controller responds to the results of it's own actions



Closed loop control

- temperature affects controller output
- valve curve is not crucial
- uses a temperature sensor
- delivers temperature data

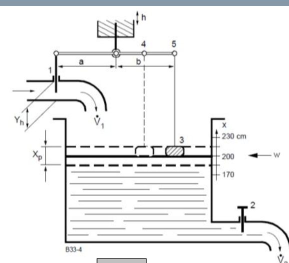
Open loop control

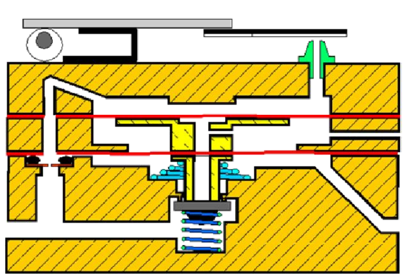
- temperature does not affect controller
- depends on known valve curve
- doesn't need a sensor
- delivers no data

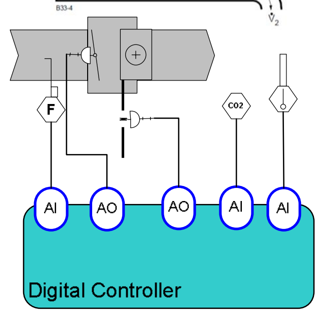
Examples of closed loop control

Many feedback technologies

- Float valve
- Bi-metal pneumatic stat
- DDC with sensor, controller, actuator







Characterizing response

Mathematical measures of:
- Speed
- Accuracy
- Stability

Apply feedback theory to get the behavior we want

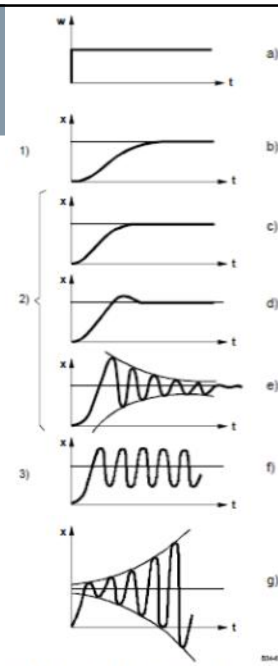
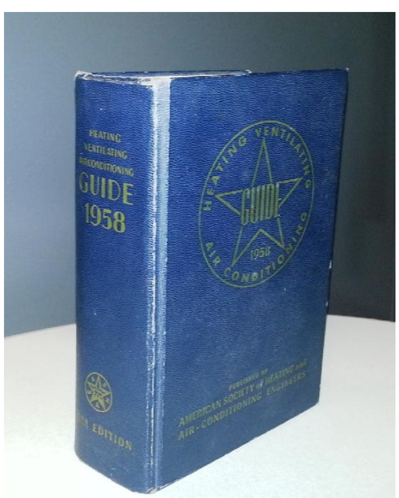


Fig. 4-6 Different transient responses

Diagram from: Control Technology
Siemens Switzerland, 2013

Some things stay true, 1958 ASHRAE Handbook



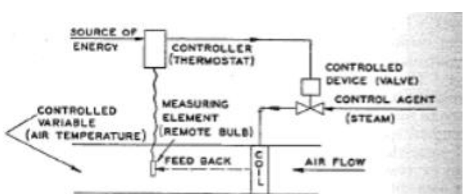


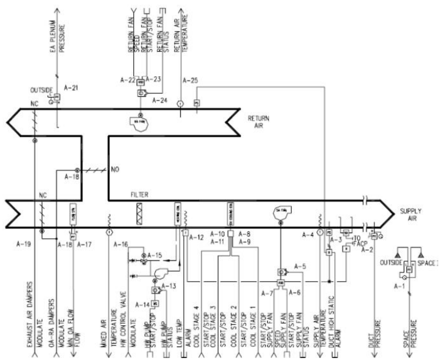
Fig. 1. Essentials of a Control System

...al Control Showing Variations in Controlled Variable as Load Changes

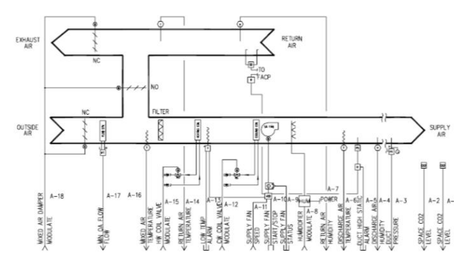
AHU Supply Air Temperature Control

Consider the cooling loop in 2 similar air handlers

- 4-stage DX unit

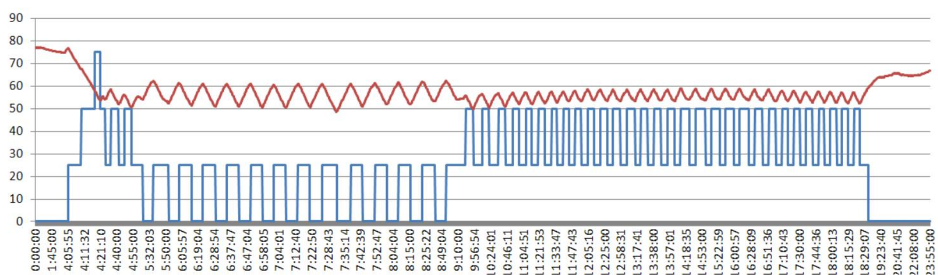


- Chilled water coil and modulating valve



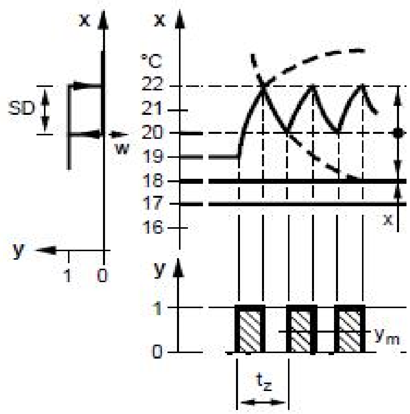
Diagrams from:
Sequences of Operation for Common HVAC Systems
ASHRAE, 2005

Staged control of DX machine



Equipment cycles on and off
Temperature rises and falls
Can reduce the size of the swing
by cycling equipment faster

Staged control of DX machine



Fixed relationship between cycle rate and size of temperature swing

Slower cycle = Bigger swing

Depends on mechanical and thermal sizing,
NOT on control calculations

Diagram adapted from: Control Technology
Siemens Switzerland, 2013

Modulating control of a Chw valve

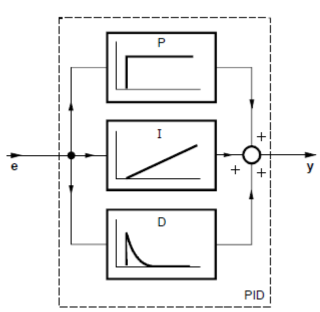


Diagram from: Control Technology
Siemens Switzerland, 2013

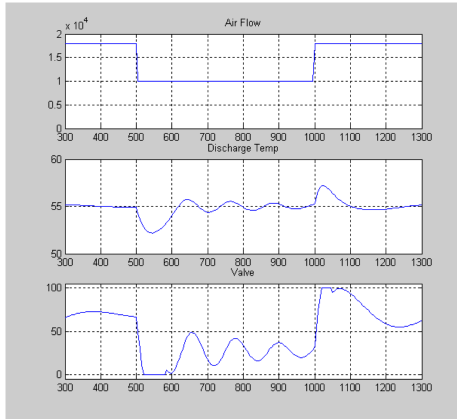
Refinement of the on/off approach
Don't just turn it on and off,
adjust for steady operation
Executed with many different technologies
Today we use DDC
Today we (usually) use PID

- Proportional
- Integral
- Derivative

We need to tune it

What is tuning?

Adjust feedback parameters for closed loop performance
Determines speed, stability and accuracy
Tuning is matching controller to the mechanical system
- Match the size of response
- Match the timing or response



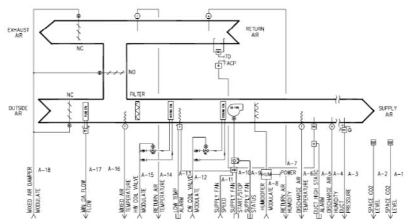
What is tuning

Matching values of the feedback parameters to the characteristics of the system under control
For PID
- Proportional band
- Integral time
- Derivative time
- Sample time

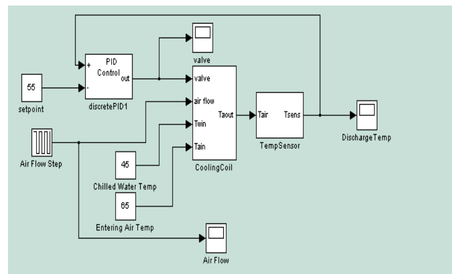
What are "characteristics"
- Physical sensitivity
- Response time

PID Operation and Tuning

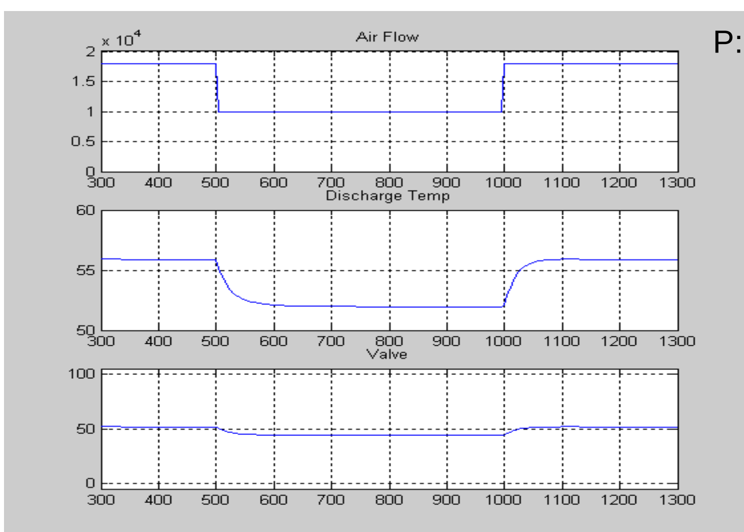
Mathematical model simulates the
cooling control process
Easy to study effects of tuning and other conditions



Schematic diagram from:
Sequences of Operation for Common HVAC Systems
ASHRAE, 2005

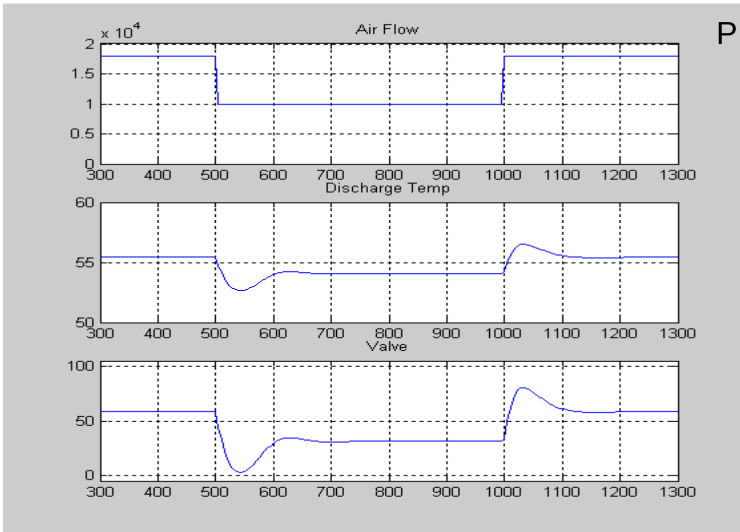


PID Operation and Tuning



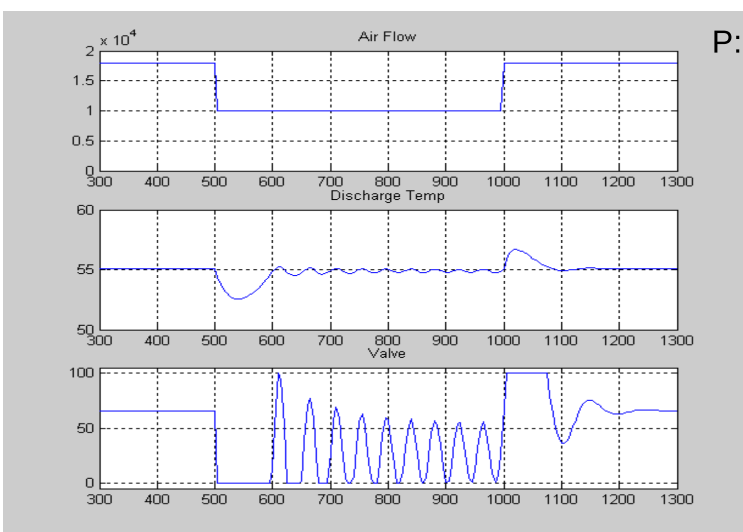
P: 50 deg

PID Operation and Tuning



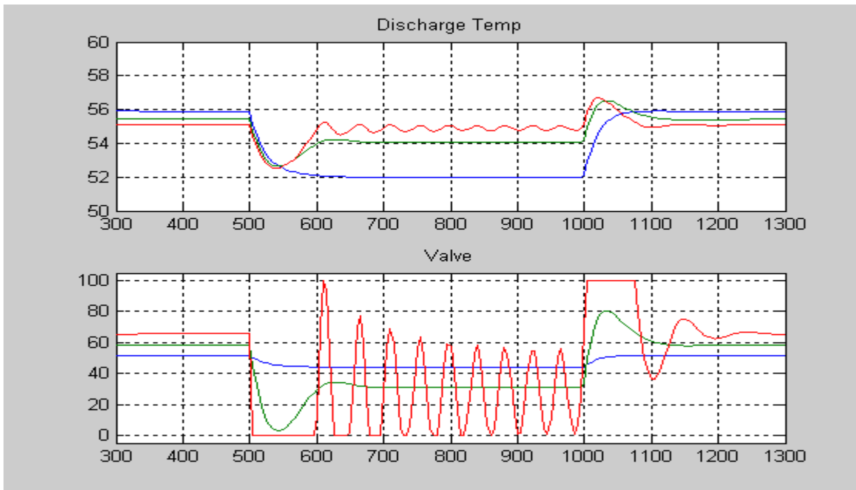
P: 5 deg

PID Operation and Tuning

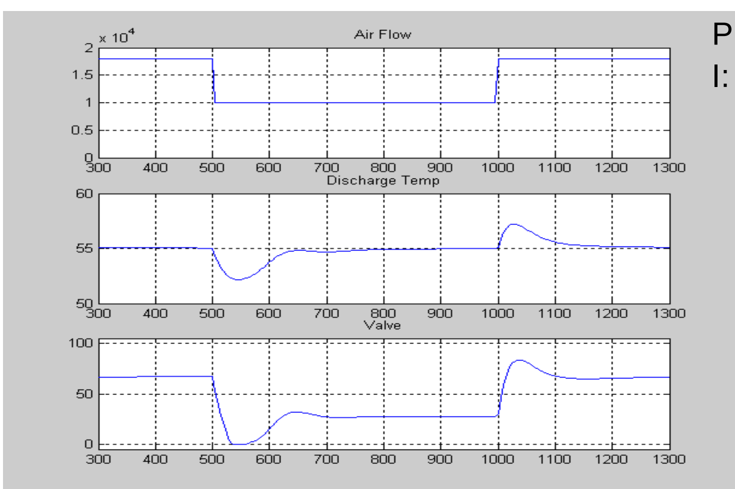


P: 0.5 deg

PID Operation and Tuning



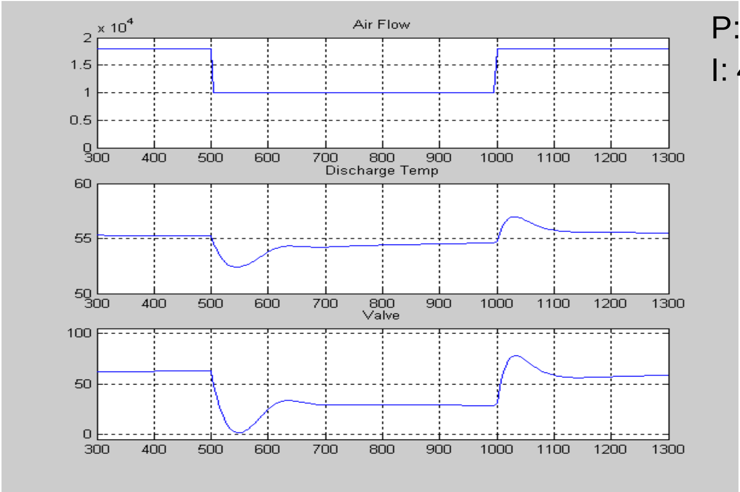
PID Operation and Tuning



P: 5 deg

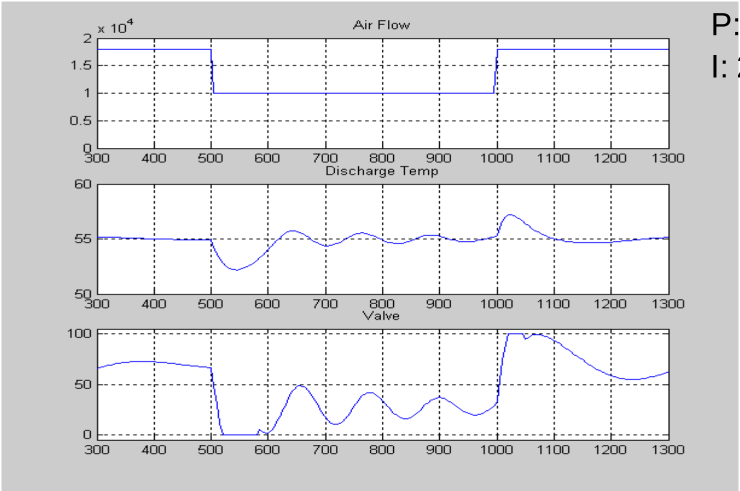
I: 100 sec

PID Operation and Tuning



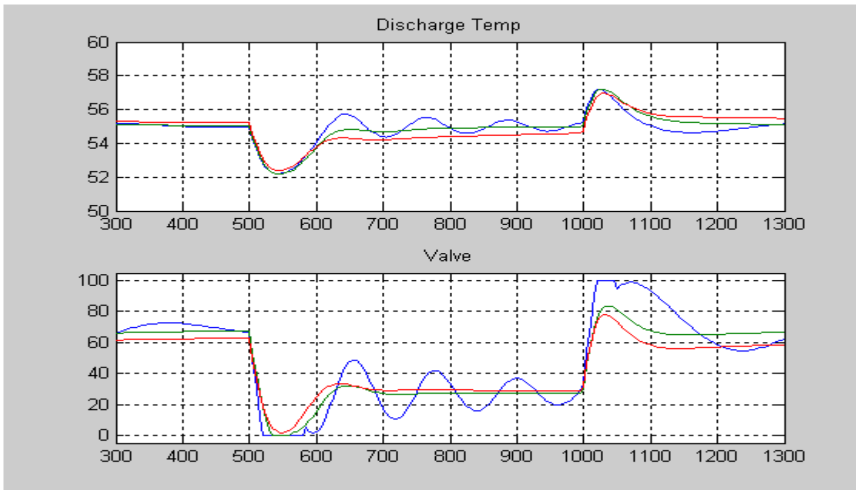
P: 5 deg
I: 400 sec

PID Operation and Tuning



P: 5 deg
I: 20 sec

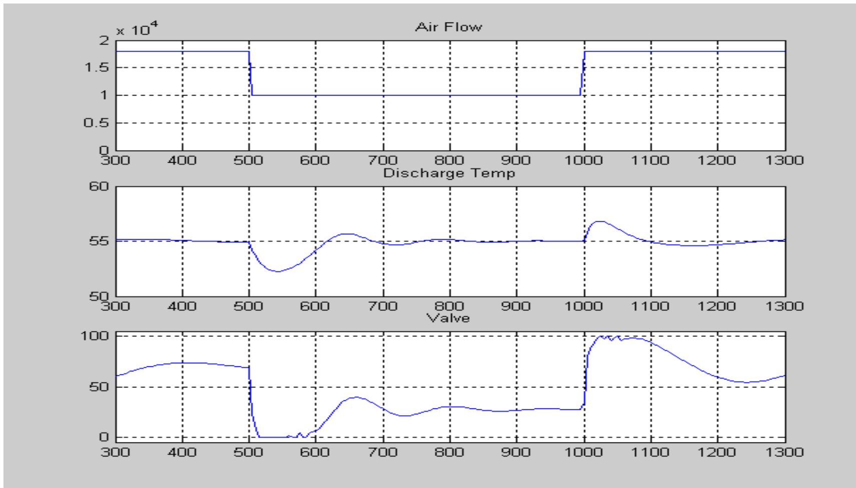
PID Operation and Tuning



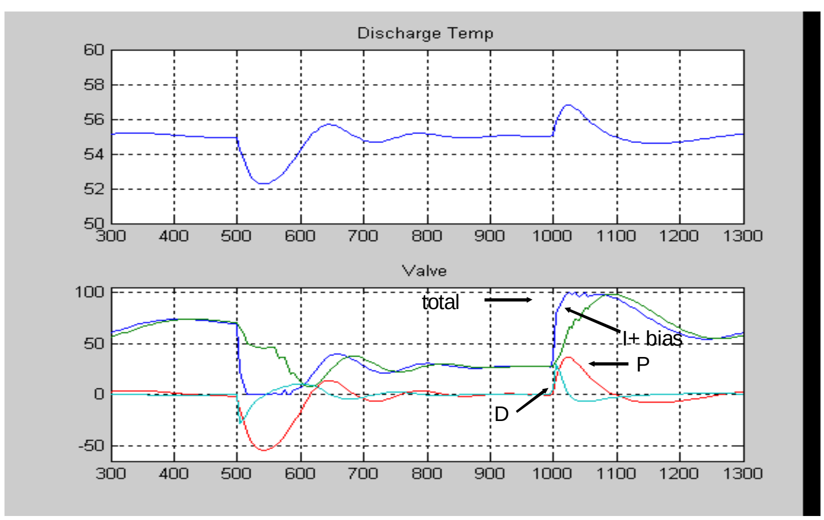
PI vs PID?

- Tuning presents range of acceptable performance
  - trade-off of speed vs. stability
- PID (rather than PI) can extend the range
  - allowing a better trade-off
- Occasionally valuable

PID Operation and Tuning



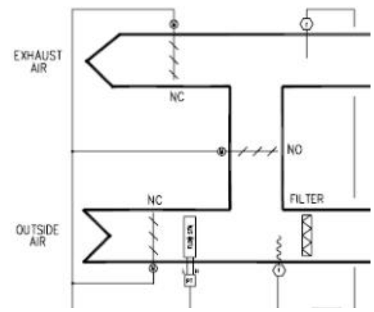
PID Operation and Tuning



Second Application: Mixed air loop

Q: What is the sensitivity of the process?
A: Difference between temperature inside and out
Weather changes, loop behavior changes too
Options:

- Tune for stability in cold, accept slow response in warm weather
- Recalculate gains based on OAT
- Apply adaptive control



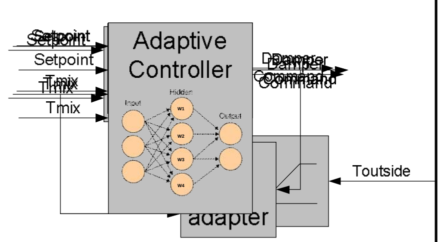
`Diagram from:
Sequences of Operation for Common HVAC Systems
ASHRAE, 2005

Adaptive Control

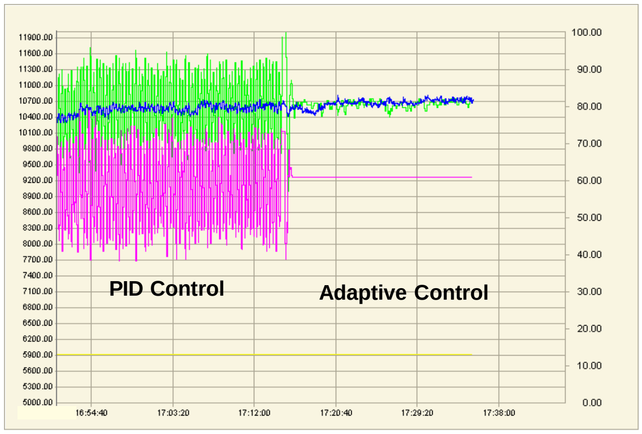
Approaches to the varying physical system

- Calculate varying gain for PID from known conditions
- Apply generic PID gain adjusting algorithm
- Apply alternate, non-linear adaptive technology

Adaptive controllers are available in the market today

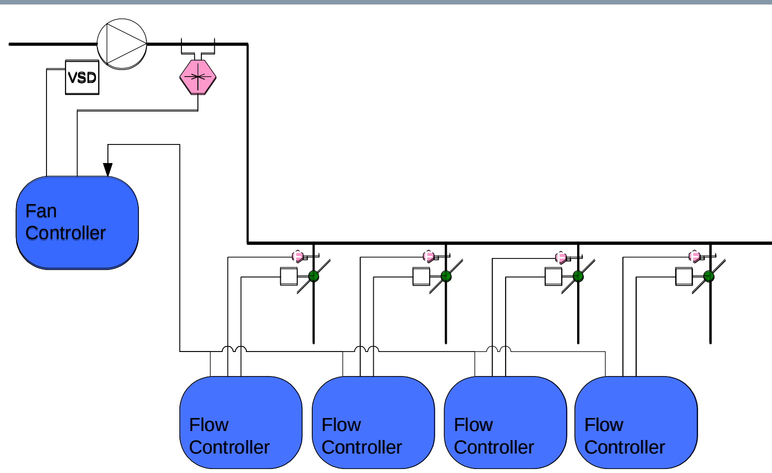


Return Air Tracking Loop with Adaptive Control



Pink – VFD
Blue – Supply Air
Green – Return Air

Duct Pressure Control



Duct Pressure Control, Duct Pressure Reset

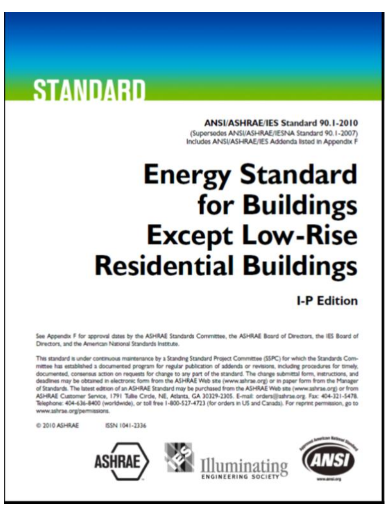
Duct pressure loop is usually not very difficult

- System can oscillate
- De-coupling is the key

Duct pressure reset can be tricky

Pressure is “reset until one zone damper is nearly wide open”

ASHRAE Energy Standard



Setpoint Reset. For systems with direct digital control of individual zone boxes reporting to the central control panel, static **pressure setpoint shall be reset** based on the *zone* requiring the most pressure; i.e., the setpoint is reset lower **until one *zone* damper is nearly wide open**.

Duct Pressure Reset

“reset until one zone damper is nearly wide open”

What control algorithm?

Some use open loop

Some use PID

- What is the controlled variable?
- What is the setpoint?

Some use ad hoc feedback (“trim and respond”)

Specifying loop performance

Already discussed loop behavior

Already characterized responses

Should be easy to define performance requirements

Difficult because it’s hard to nail down test condition

Behavior defined in math world

Test occurs in real world

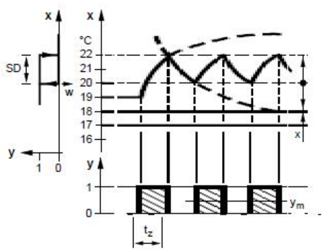
Standard 195 defines flow control performance test

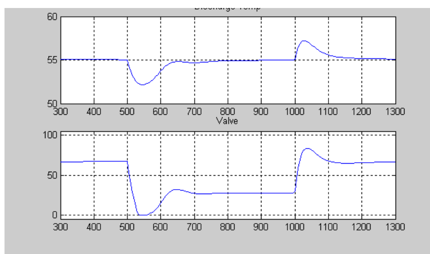
Intended as a product qualification test, not a commissioning procedure

Summary

Closed-loop control concepts
2-state control
Modulating control and PID
Tuning and performance
Advanced approaches

Questions?





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