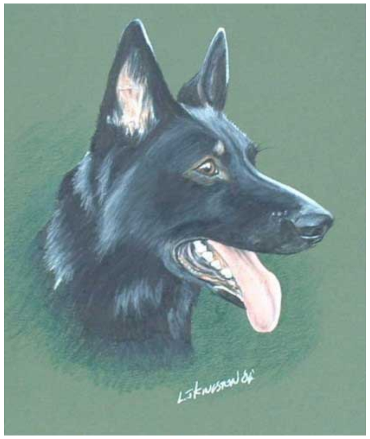
Control 201
Approaches to Process Control

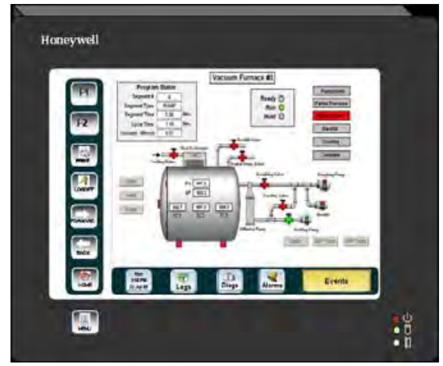


Dan Weise, presenting

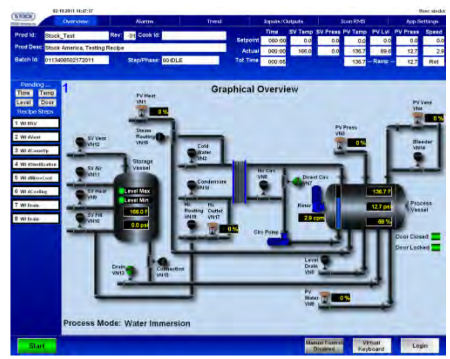
HMI (Human Machine Interface)

I use the word ‘HMI’ three ways

- Any display of data – an operator user interface



- A graphical display of data on a panel mounted video display: a hardware GUI



- ‘HMI software’: a category of software that does
  - Supervisory control
  - Graphical display of process data
  - Data acquisition and historian database
  - Examples – Factory Talk, Wonderware, WinCC, Plantscape

Program vs Configure

- Program
  - Develop a program from a blank slate
  - Uses a ‘language’; set of rules/syntax
  - Logic/flow charts/comments
  - Example: “Structured Text”

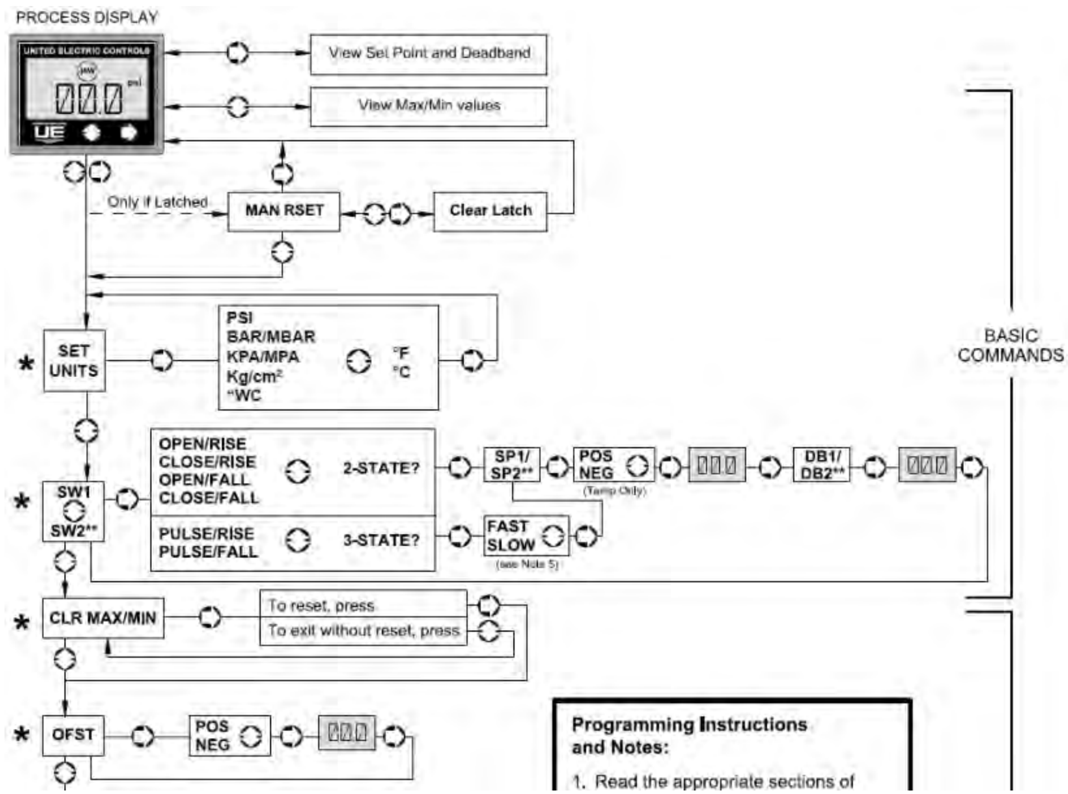
```
//========================================
// Function Block Timed Counter :  Incren
//========================================
FUNCTION_BLOCK FB_Timed_Counter
    VAR_INPUT
        Execute          : BOOL := FALSE;
        Time_Increment   : REAL := 1.25;
        Count_Cycles     : INT  := 20;
    END_VAR

    VAR_OUTPUT
        Timer_Done_Bit   : BOOL := FALSE;
        Count_Complete   : BOOL := FALSE;
        Current_Count    : INT  := 0;
    END_VAR

    VAR
        CycleTimer       : TON;
        CycleCounter     : CTU;
        TimerPreset      : TIME;
    END_VAR
```

Program vs Configure

- Configure
  - Always has a menu (of sorts)
  - Choices limited to menu selection
    - Can't program what isn't a menu selection
  - Navigate the menu with keys/buttons
  - 'menu based'



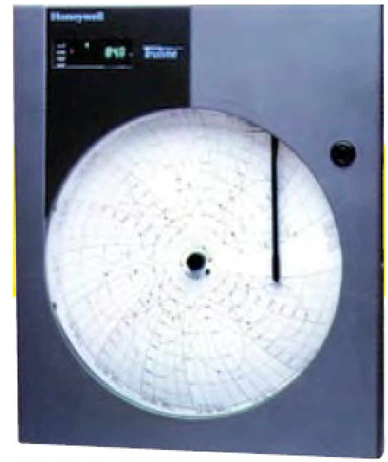
Program vs Configure

- Why does this distinction matter?
- Control strategies can use either programming or configuration (some mix the two)
- Skill set
  - Programming is decidedly higher skill set than configuration
  - Lots of organizations have people who can configure, but lack someone who can program
  - Tech support usually assists in menu selections, not in programming
  - Programming skills can be brought to the party – systems integrators do it for a living
- Trade-off in control strategy selection

Program vs Configure

Example

- 1992 prediction: “Recorder market will shrivel to zero by year 2000”
  - PC based HMIs and SCADA will do data acquisition and obsolete recorders
- In 2014, Lesman sells a several hundred recorders annually
- Why?
  - Reason #1: Don’t lie
  - Reason #2: Configure via menu selection
  - Users can make incremental changes over time without a 3rd party



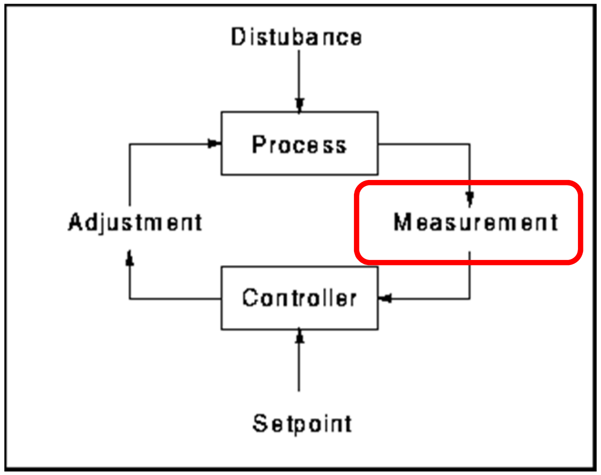
Matching your resources

- Any control strategy includes
  - Field sensors, transmitters
  - Controller hardware
    - I/O, logic and process decision makers
    - Operator interface – HMI
  - Final control elements, valves, actuators, SCRs, drives
- Driving force: be competitive, automate to cut costs
- Resources are not limitless
  - People to interface with the stuff
  - Budgets
  - Cost of ownership
- Control strategy needs to fit with the resources

Automation uses control loops

- A control loop
  - Knows where is should be (has a setpoint)
  - Measures the process
  - Makes a decision
    - I/O, logic and process decision makers
    - communications
  - Makes an output change
- To do that, it uses
  - Some means of adjusting a setpoint
  - Field instrument to measure the process variable
  - Some kind of decision maker
  - Some kind of output

Measure the process



Summarize field instruments

- Transmitters
  - Flow, temperature, pressure, level, RH
- Sensors
  - Thermocouples
  - RTDs
- Analyzer
  - Analytical, pH, conductivity, turbidity
- All produce a process variable signal
  - Mechanical – pressure channel in a regulator
  - Electronic – a 4-20mA signal

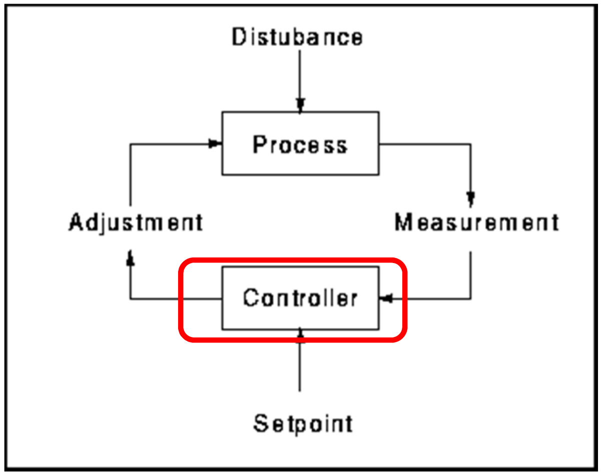
What is a process variable?

- Process Variable (abbreviated 'PV')
  - Whatever's being measured and controlled in the control loop
  - Signal coming from the field transmitter
  - Examples: Temperature, pressure, flow, level, pH, relative humidity, conductivity
- Dan calls it 'What you got'
  - 485 gpm, 1005 Deg F, 105in w.c.
- The value in the upper display
  - Happens to be labeled PV on this controller

What is a setpoint?

- Setpoint (abbreviated 'SP')
  - The desired result of control
  - It's where you set the thermostat
- Dan calls it 'What you want'
  - 500 gpm, 1000 Deg F, 8in w.c.
- The value in the lower display
  - Happens to be labeled SP on this controller
- Examples
  - Black arrow on the round thermostat
  - Machine screw on a pressure regulator
  - Digital number

The decision maker



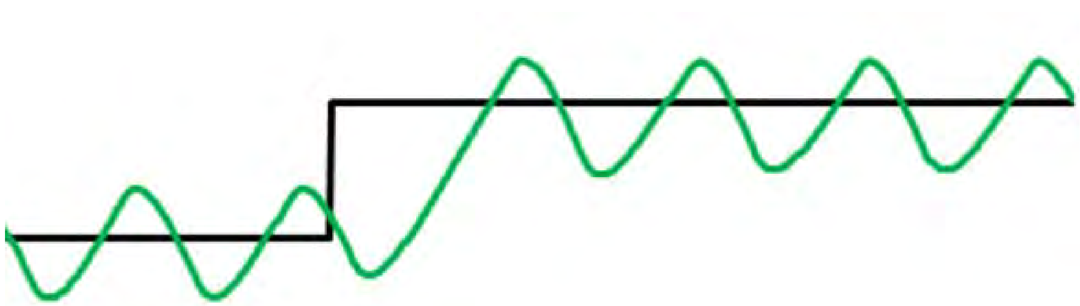
- Reads the measured Process Variable
  - What you got (PV)
- Knows what you want
  - Setpoint (SP)
- Compares what you got (PV) to what you want (SP)
- Makes a decision based on the comparison
  - Hold steady
  - Increase
  - Decrease
- Holds or changes its output
- In safety world, it's called a 'logic solver'

Process controller's output

- Signal to the final control element
- Discrete on/off output
  - Flame safety controller enables or shuts down the fuel supply
- Analog modulating output
  - Flow controller output to a modulating valve actuator/positioner/IP
  - AC drive to an electric motor

On-Off Control

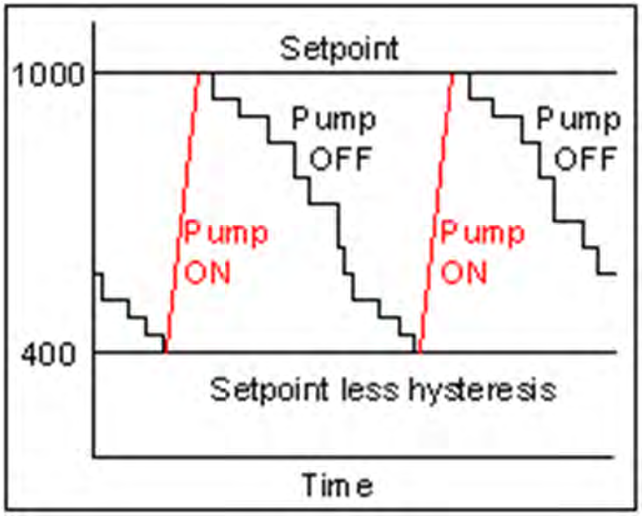
- What characterizes on-off control?
  - 2 states: either on or off
  - Simple control, no tuning
  - Sawtooth response over time – overshoot, undershoot



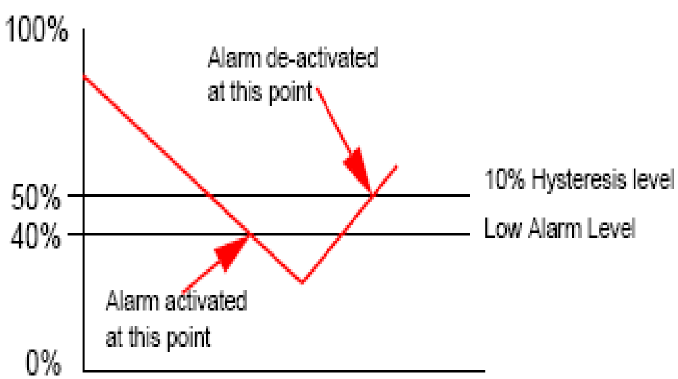
  - Hysteresis/deadband
    - Gap between when output turns on and when it turns back off again.
    - Prevents "chattering", turning on and off in quick sequence
  - 'deadband' size can be critical
    - Pump action is wide deadband, alarm action is narrow deadband

Deadband

- Wide deadband between turn-on and turn-off points for pump-up sump level control
  - Single control relay output



- Narrow deadband for alarm action



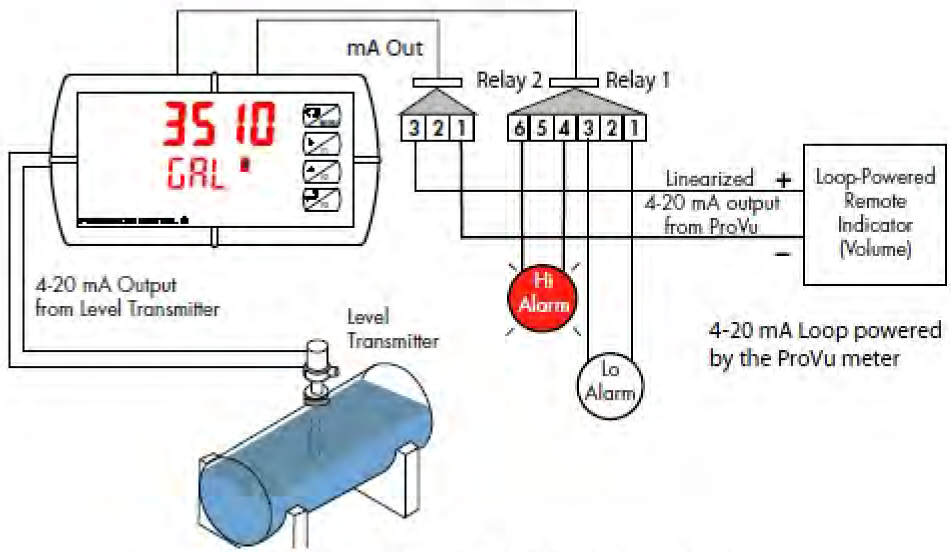
On-Off controllers

- Electromechanical temperature and pressure switches
- Thermostatic mechanical regulators
- Electronic pressure switches
- Ultrasonic level switches
- Electronic on-off controllers
- Solids level switches
- pH analytical controller

Expanded On-Off control

Precision Digital indicator/controllers

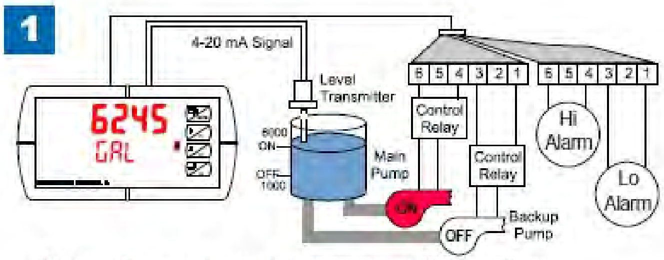
- Pump staging, alternating
- Tank level control
- Good illustrated descriptions



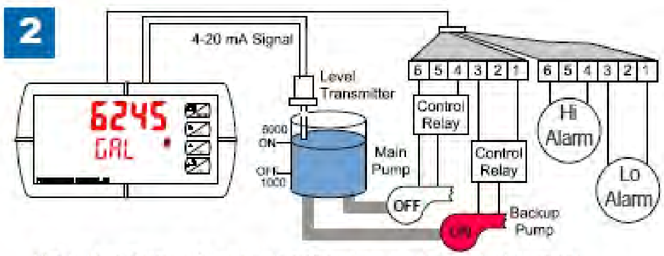
Round Horizontal Tank Math Function

MULTI-PUMP ALTERNATION

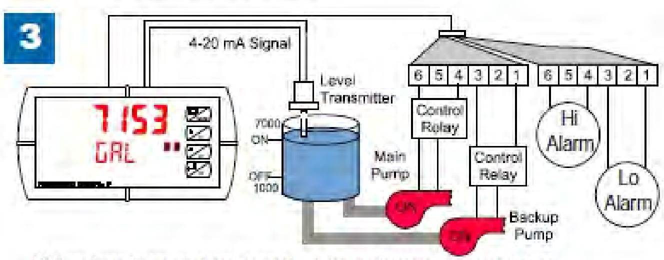
Up to 8 pumps can be alternated/sequenced.



Relay #4 turns the main pump on at 6000 gallons and turns it off at 1000 gallons.



With the Pump Alternation feature activated, the next time the level reaches 6000 gallons, relay #3 transfers and starts the backup pump.



If the backup pump is not able to keep up, and the level reaches 7000 gallons, relay #4 transfers and starts the main pump as well.

Batch Control

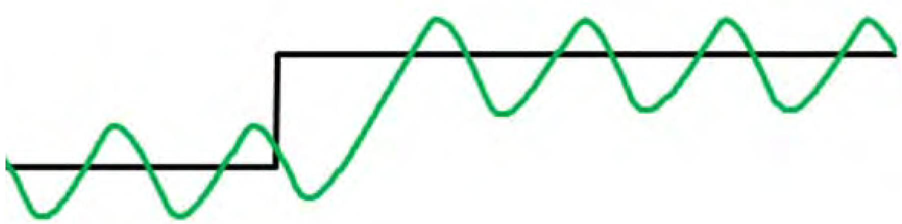
- Supplies exact amounts of material for batch
  - fill a vessel with an exact amount of materials
- Operator enters a *preset* (the setpoint) on a numerical keypad
- Hits *start* button
- Batch controller
  - reads the output of a flow meter
  - totalizes the flow
  - Shuts off when total is reached
  - Dribble or bleed option

Why do people buy batch controllers?

- Fills the bill, “Make it easy for my operators”
- Easy to train people to use it
  - Few keystrokes
- Local
  - One on every vessel
- Can be commissioned without an engineer
  - Menu selection

Why do people use On-Off Control?

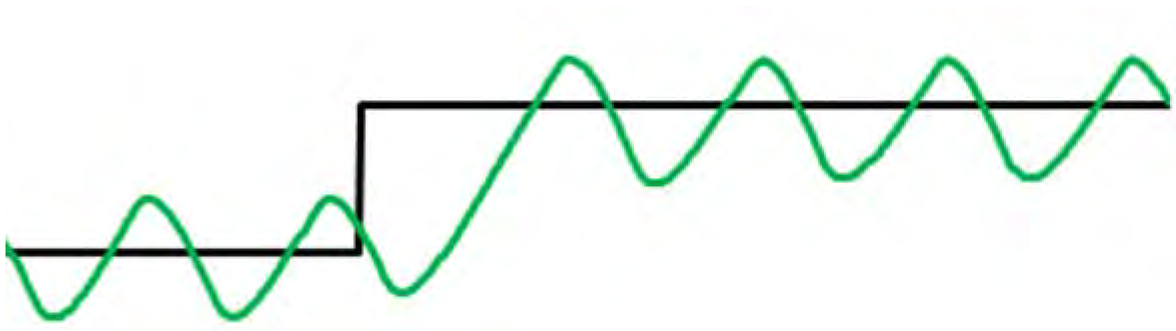
- It's simple
- On-off works well enough, like
  - A home gas furnace
  - A sump pump
  - A residential well pump with a bladder tank



- On-off generally costs less than modulating control
- On-off can be enhanced with electronic logic
  - Alternating pump control
  - Totalizing or dribble mode for batch control

On-Off Control

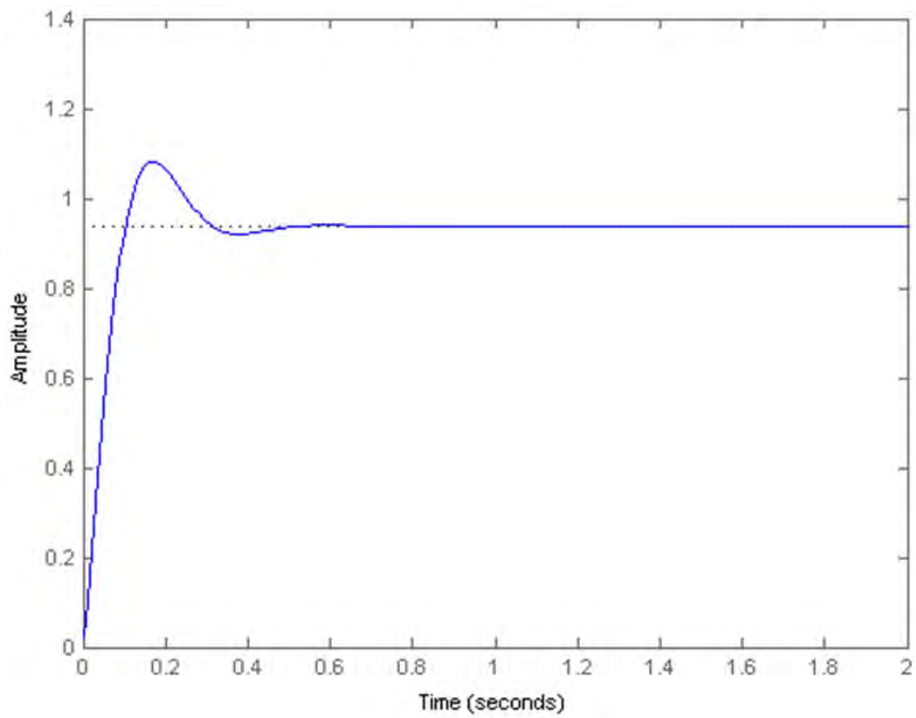
- Great, but on-off causes oscillations; sawtooth action
  - – overshoot, undershoot, overshoot, undershoot



- What if it's essential to have straight line control?

Straight Line Control

- Some processes require /straight line control
  - Not the sawtooth oscillating control inherent in on-off control
- Proportional control, known as PID, offers straight-line control

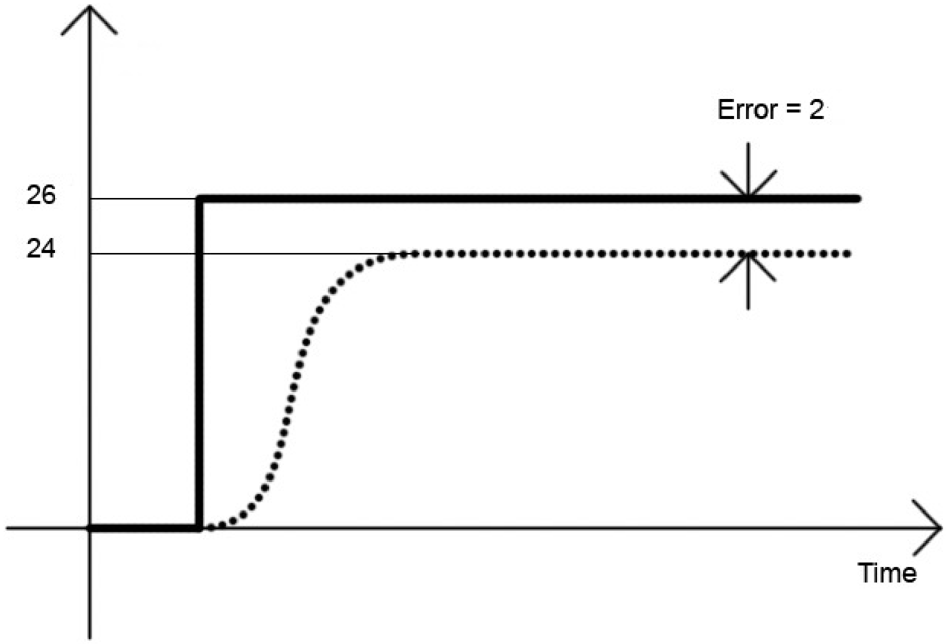


PID has Output Modulation

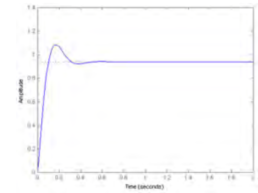
- Modulate: adjusts or regulates by incrementally varying the output
- Proportional output modulates continuously between 0% to 100%
  - not just 2 on/off states of on/off control
- An incremental response provides
  - Just the right amount
  - rather than full on (too much) or full off (too little)
- A typical modulating output is a 4-20mA signal
- Final control element (valve) provides incremental response
  - Controller output = 62% output. Valve goes to 62% open.
  - An On-off controller output is either on or off, nothing in between

How does PID work?

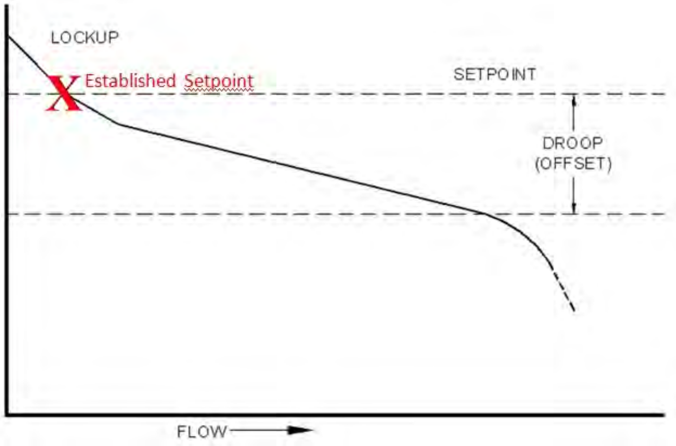
- PID looks at the *error*
- Error is difference between what you want (SP) and what you got (PV)
  - SP minus PV
- Goal is zero error, when PV = SP



How does PID work?

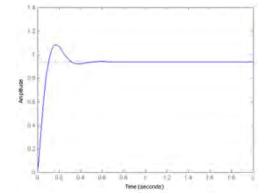


- PID has 3 modes
  - P: Proportional gain– response proportional to magnitude of error
  - I: Integral time – accounts for how long the error has existed
  - D: Derivative – accounts for how fast the error is changing
- P-only (proportional only) control
  - mechanical pressure regulator

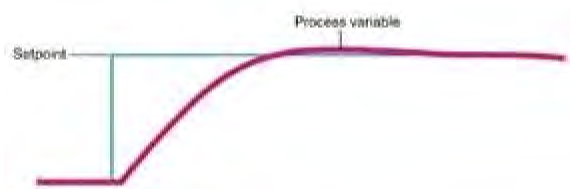


  - P-only always has ‘droop’
  - Reset (I term) corrects for droop in 2 mode PI control

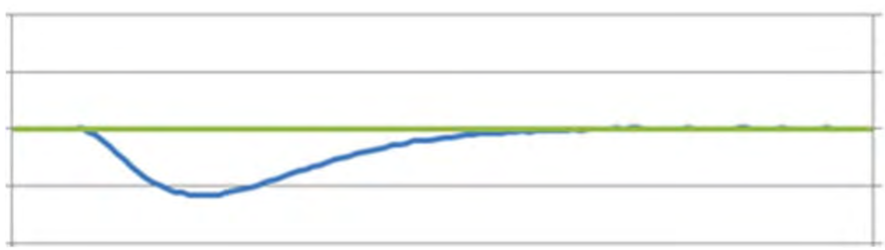
How does PID work?



- D term
  - D: Derivative – accounts for how fast the error is changing
  - Also called 'rate'
  - Backs off output more rapidly when approaching SP than P/gain

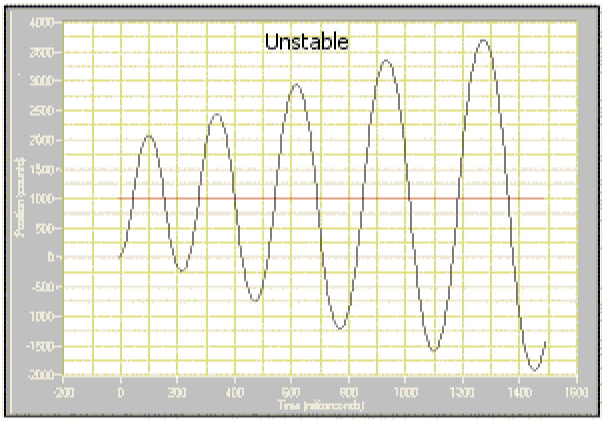


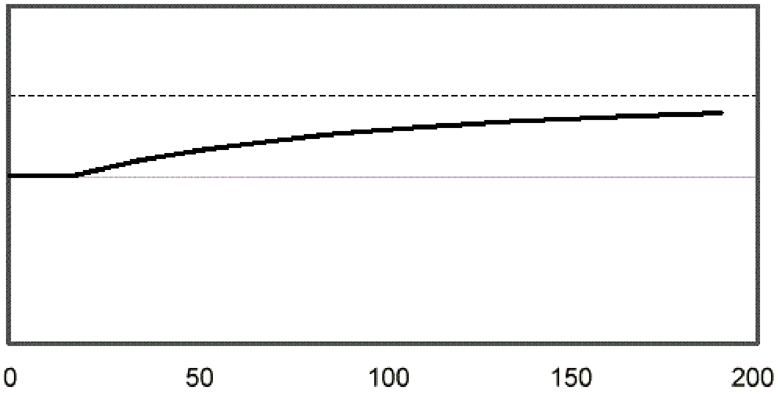
  - Adds more response when PV drops from setpoint



PID can do straight-line control (for 80%)

- Sounds great, straight line control with PID. What's the catch?
- The controller has to produce an 'appropriate' *response* to the error: not too much, not too little
- The wrong response produces fluctuations or sluggish response
  - Bad tuning can cycle worse than on-off control





Match process capacity to repsonse: tuning

- Each process load has a unique *capacity* to absorb or release energy or mass
- The task of matching the controller response to the process *capacity* is *tuning*
- Each mode, P, I, D has a numerical term associated with it
  - Tuning constants
  - Wrong tuning constants result in bad (not straight line) control
- Everyone wants to know what numbers or values to enter
  - It's different for every process
  - We're not withholding secret information, it's just that it varies from process to process

Tuning constants

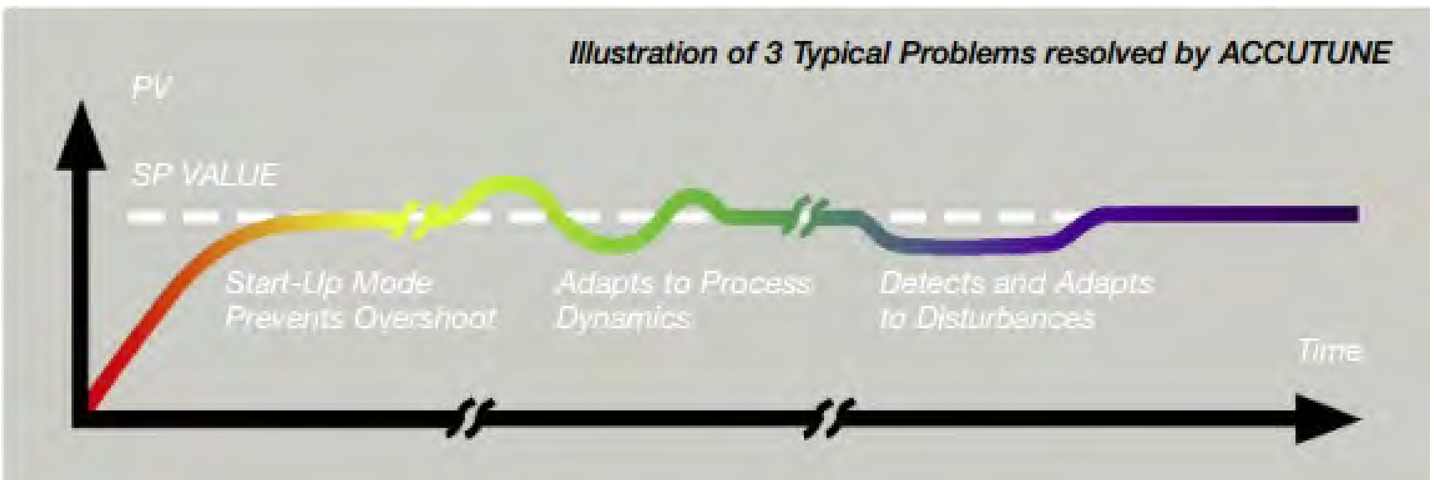
- Generally control loop types have an inherent ‘capacity’
- Tuning constant rules of thumb (based on generalities)

Control loop	*Proportional band*	*Time constant*	*Derivative*
Flow	High (250%)	Fast (1 to 15 sec)	Never
Level	Low	Capacity dependent	Rarely
Temperature	Low	Capacity dependent	Usually
Analytical	High	Usually slow	Sometimes
Pressure	Low	Usually fast	Sometimes

- But it all depends on the particulars
  - Way over-capacity gas fired temp loop with a 650% PB, 2 sec I, no D
    - Opposite of *temperature* on the chart above
- Is there an alternative to learning how to tune a loop?

Let the controller do the tuning: autotune

- PID controller runs an algorithm to determine tuning constants
- Most stand-alone PID controllers have some form of autotune
- Honeywell's Accutune:



- Demand action, manually started each time

Proportional control is the answer, what's available?

All-in-one proportional temp regulator

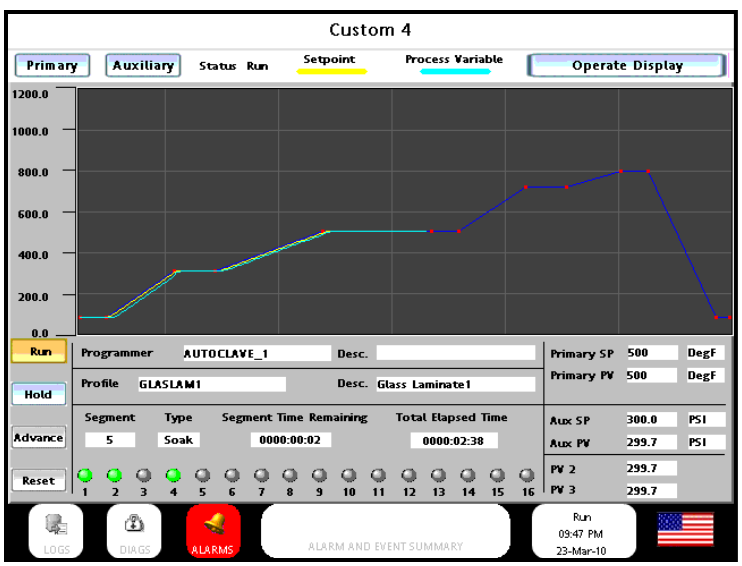
- Grandpa's technology – but it works
- Capillary bulb sensor measures PV
- Setpoint screw adjustment
- Spring and diaphragm
  make a valve stem position decision
- Integral valve controls the flow
- Modulating proportional-only control
  - Droops as flow rate increases
- Why do people buy it?
  - No electric power

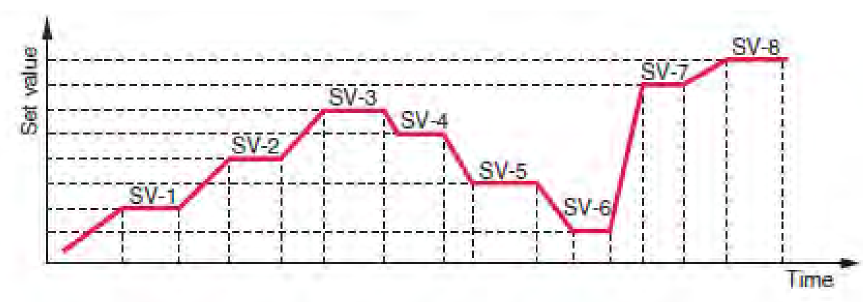
Single Loop controllers

- PID or on-off control, depends on model
- Different sizes (footprint)
- Range of capabilities
  - Temperature only to full blown process controllers
- HMI is local
  - Nothing to program
- Most are menu configured, not programmed
  - 353 process controller
    can be software programmed (0.5%)

Setpoint Programmers (SPP)

- Setpoint ramps and soaks entered, saved and recalled
  - *Profile, recipe or program*
- Continuous PID control with SPP
- Discrete output ‘Events’ synchronized to specific segments
- Improved batch processing capabilities and efficiencies





What types of control do Single Loopers handle?

- Heat/cool control
- Split range
- Position proportional (cascaded feedback actuator control)
- Ratio control
- Cascade control
- Feed forward control

Why do people buy Single Loop controllers?

- Premature death notices published in early '90s
  - PLCs will replace single loop controllers
  - Today: stand alone controller (process) and a PLC (for discrete)
- What do single loopers offer?
  - Loop control solution in a box
  - Local HMI
  - Dedicated PID control function with autotuning
  - Simple pushbutton operation
  - Universal input (T/C, RTD, 4-20mA, mV)
  - No software needed to set it up or run it or configure the HMI
  - 1-3 alarm outputs
  - All types: PID, on-off, dedicated limit control, others (previous slide)

Why use something else?

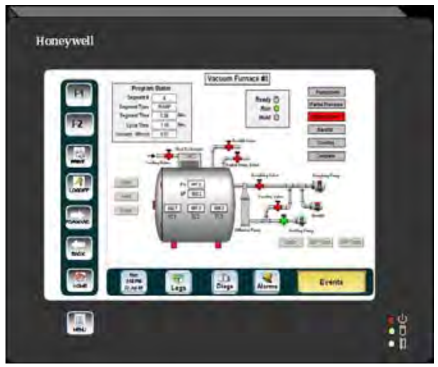
- Number of control loops
  - Not enough real estate for wiring
  - dealing with so many individual units
- Data
  - Need more data than the local display offers
  - Need more flexibility in presenting data

- What’s the step up from single loopers?

Separate the HMI from the Controller

- Control is done in a rack, typically, or panel
  - Centralize wiring (Fieldbus exception)
  - Various levels of control functionality

- Operator Interface is an HMI
  - Screen(s), panel or software on monitor
  - Configured/programmed separately from control
  - Customized display elements, graphics
    - A picture is worth 1,000 words
  - Far more flexibility in presenting data

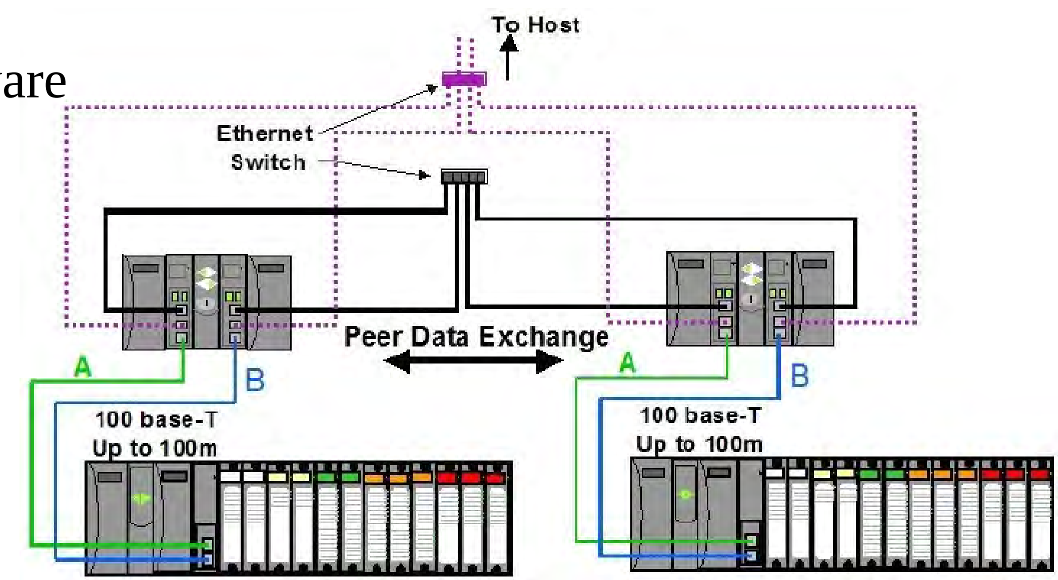


PLC control

- Originally discrete I/O, now most PLC's do analog control in some form
- Rack with modular I/O
- Blind, use separate panel HMI or HMI software
- Can be Networked
  - Gets data to and from an HMI/SCADA
- Ubiquitous (everywhere)
- Not Lesman's strength (MasterLogic PLC/LX DCS)

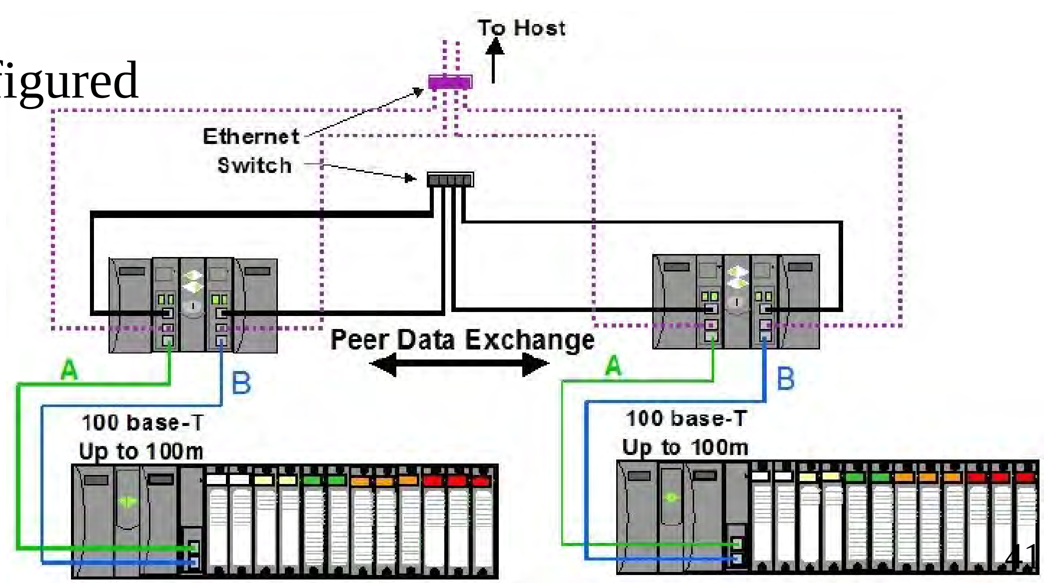
Hybrid/PAC/multiloop Control

- Process Automation Controller (PAC)
  - Modular I/O like a PLC, but process based, not discrete based
  - Slower scan time, but deterministic (fixed certainty for timed events)
  - Hundreds of I/O: AI, AO, DI, DO, frequency/pulse points
  - Can be networked
  - HMI panels or HMI software graphics
  - Redundancy
    - redundant power
    - redundant control
    - redundant networking
  - a Lesman strength – Honeywell HC-900



PLC or Hybrid/PAC/multiloop Control

- Implications of modular control
  - 2 software packages
    - control development
    - HMI development
  - Scale tips from ease-of-use to the complexity side
  - Networking skill set
  - Programmed, not configured

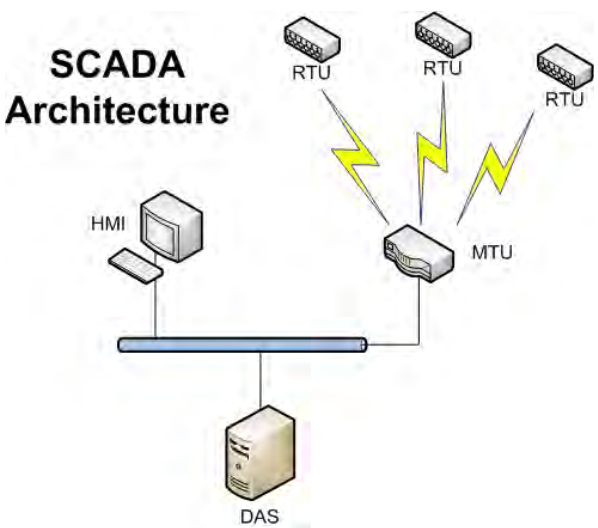


Why do people buy Hybrid/PAC/multiloop controllers?

- Too many loops for stand-alone controllers
  - Front end costs, panel, wiring, configuration are lower with consolidated rack(s)
- HMI can be customized for maximum effect
  - Graphics
  - More data available in HMI formant
    - Diagnostics
    - Recipes
    - Customized ease of use
- Because it's not a PLC
  - Autotune, SPP, actuator drive FB
- Higher level communications
- Redundancy, control, networking

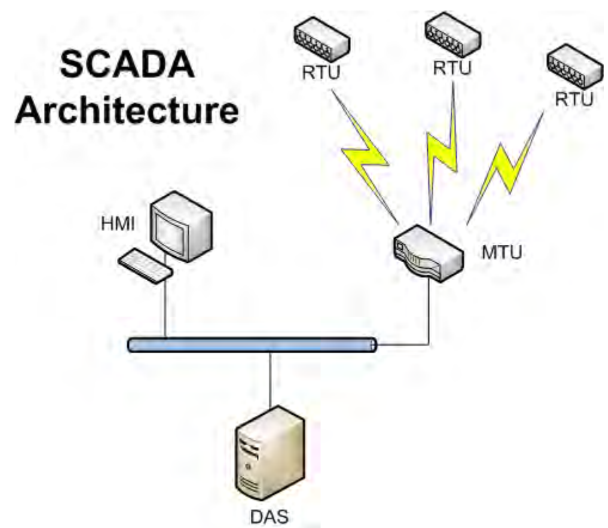
SCADA Control

- SCADA means different things to different people
  - "collect lots of remote points" from remote RTU's
  - Any data transferred over phone line, wireless or internet
  - A HMI software package with great graphics
  - A remote I/O rack that talks digital back to a local processor
  - Data Concentrator
- Today's RTUs do local control
- SCADA software is supervisory
  - Yesteryear – phone line comm
  - Today – network comm
    - VPN over internet



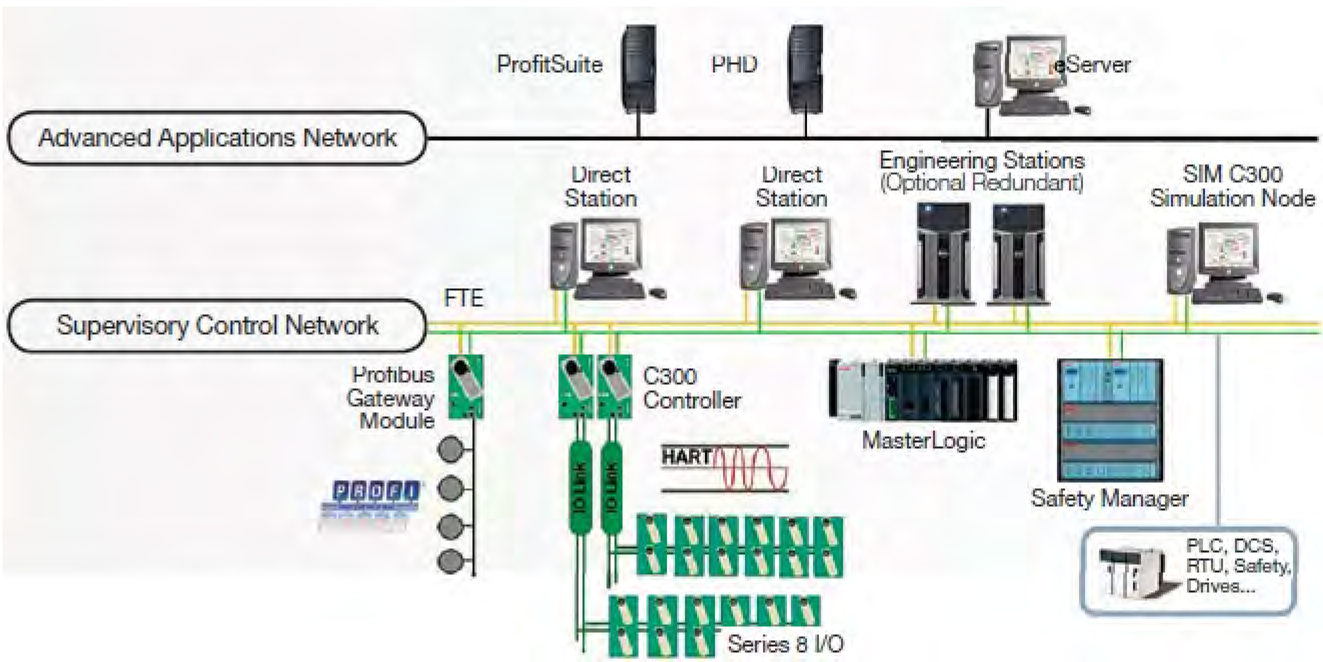
Why SCADA ?

- What's the topology ?
  - how points are spread out geographically?
  - Wide geographical spread is spelled SCADA
- Sequence of Events (SOE) alarming with mS time stamps



DCS control

- Distributed Control
  - The total integrated control solution (Not a mix & match HMI to control)
  - Server based, connects to enterprise level software
  - Advanced control algorithms, include existing PLC, SCADA, RTUs

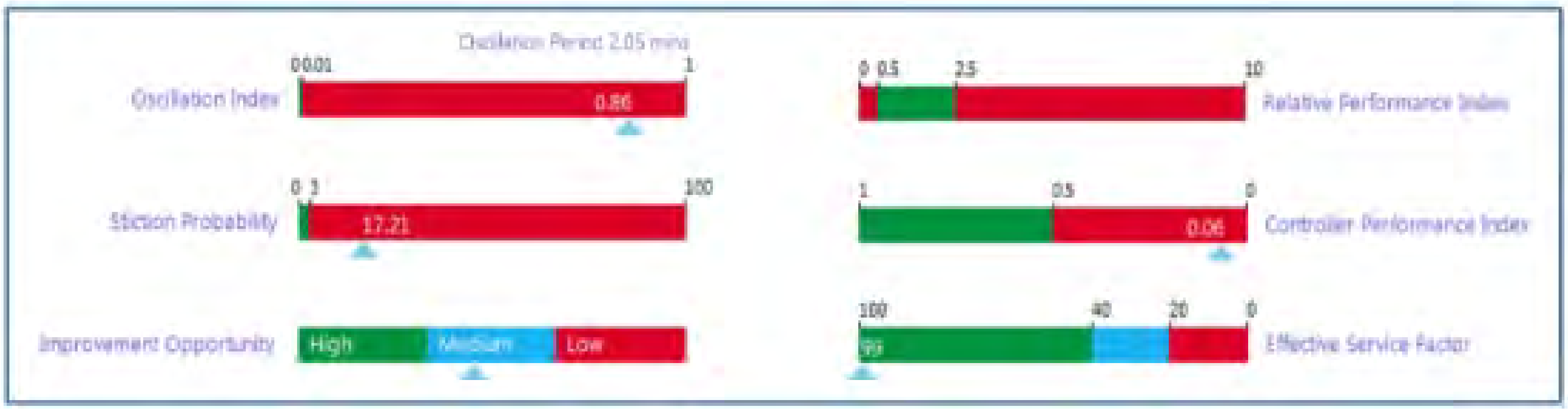


Why DCS control?

- Sophistication
- Continous process make commodities – paper, gasoline, steel
  - It's really expensive to differentiate commodities, competitiveness comes in reducing production costs.
- The software apps available at the DCS level are phenomenal
- Example: Control Performance Monitoring
  - Monitors assigned processes
  - Level 1 – raw data tabulated – performance assessment: bar graphs
  - Level 2 - prioritizes control issues AND recommends remedial action

Why DCS control?

- Example: Control Performance Assessment



Why DCS control? Expert Guidance Help

Loop Information Summary | **Loop Metrics Summary** | **Expert Guidance Help**

Loop name	CPM_COMMOSC.PIDA
Plant hierarchy	Enterprise\XML files
Loop type	Flow
Performance rating	poor
Diagnosis	Investigate more using Expert Guidance (if available).
Criticality	Normal

Oscillation period	6m 8s
OP Travel(Per hour)	63.9
OP Mean(%)	14.08
Oscillation index	0.2
Stiction probability(%)	19.9
RPI	Value is not calculated
CPI	0.42

Recommended action :

Check and repair the control valve.

Comments: When checking the control valve for stiction, make four steps up of 0.5% each followed by four steps down of 0.5% each. There should be a corresponding step in the flow for each step. The root problem could be worn stem packing, worn or dirty positioner or build up of solids around the valve trim. Some sticky valves become stuck valves that can cause a serious incident.

<< Back

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Response Summary :

Question	Your response
What is the impact of the flow variation on the process?	Significant
Is there a clear, consistent oscillation in the flow PV?	Yes
Perform manual test and choose outcome 1 or outcome 2 based on the result.	Outcome 2

Why DCS control?

- This is not raw counter data form an asset manager
  - X number of valve strokes since the counter was last reset
- Data's nice, what do you do with it?
- Subject: Control Valve cycle measurement http://www.control.com/thread/1408536240

  A manufacturer of a valve and actuator specs the life at 2 million cycles. They then define a cycle as 0-90 % movement.

  How about the case of where the valve sits all day oscillating around 50 to 60 %? What then would constitutes a cycle for preventative maintenance purposes? Should we integrate the movement over the time period and divide by 90? Would appreciate any thoughts on this.
- If you have Control Performance Monitoring, it'll recommend what to do

Communications for separated HMI/control

- Platform communications is largely Ethernet networked
  - Skill set for networking
- Fieldbus communication at the sensor or platform level can be another skill set
  - Foundation Fieldbus
  - Profibus
  - Ethernet/IP
- Skill set can be in-house or hired

Safety controls

- Standards involving safety controls
  - NFPA 85 boilers
  - NFPA 86 furnaces, heaters, kilns
  - IEC 60511 Safety Instrumented Systems for process industries
- Basic features of safety systems
  - Separate from the basic process control system
  - Do not share sensors or logic solvers (controllers)
- 3rd party agencies certify components for compliance
  - FM, TuV, Exida,

Discrete output action: failsafe or normal?

- Not a safety application, it's process control: good design
- Failsafe: coil deenergized during alarm state
  - N.C. contact is closed in alarm state, not N.O.

Table 2-3 Alarm Relay Contact Information

Unit Power	Alarm Relay Wiring	Variable NOT in Alarm State		Variable in Alarm State	
		Relay Contact	Indicators	Relay Contact	Indicators
Off	N.O.	Open	Off	Open	Off
	N.C.	Closed		Closed	
On	N.O.	Closed	Off	Open	On
	N.C.	Open		Closed	

FM Limit Control

- Limit control is a safety function
  - High Limit required by NFPA 86 (furnaces, kilns)
  - Prevents overheating and potential fire hazard
    - Safety control against run-away conditions
  - Intended to protect the heater/furnace, not the load
  - Does NOT control the process variable (temperature)
- Control output (relay) enables/disables
  - the safety shutoff valve which enables/disables the fuel supply
  - Shunt trip circuit breaker upstream of an SCR
- FM Limit controller 'latches out'
  - When tripped, requires a manual reset to re-enable the output
- Secondary, independent safety control
  - Does not share a temperature sensor (thermocouple)
  - Is separate from the primary temperature controller

BMS: Burner Management System, process

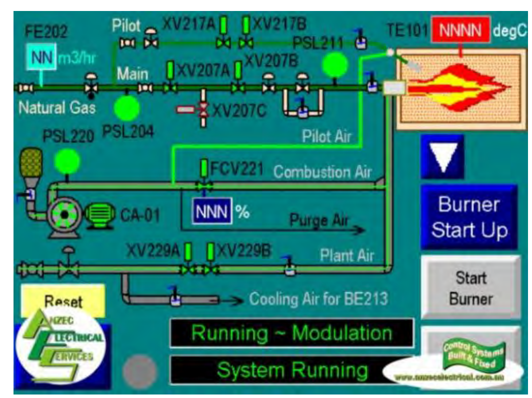
- Boiler/furnace/kiln/oven/process heater
- Process control
  - Demand firing rate to supply BTU
    - more or less heat
  - Air-fuel ratio
  - Monitor or controls excess air
- Classic control loop
  - Sensor, controller, final control: valve actuator or SCR

BMS: Burner Management System, safety

- Safety: FM approved Flame Safety components
  - Flame detection (FM)
    - UV, IR, flame rod (FM)
    - Multi-burner UV discriminator sensors (FM)
  - Single burner controls (FM)
  - Multiburner controls (FM)
  - Gas train components
    - Safety Shutoff valves (FM)
    - Vent valve, Hi/Lo pressure switches (FM)
  - Limit control (FM)

BMS: Process and safety

- Recent changes to NFPA 86
  - opened the door to SIL 2 modular BMS controllers
  - Still need the
    - FM flame detection
    - FM gas train components
  - BMS modular controller - enhanced HMI data
  - Integrate burner process control with safety
  - Significant for multiburners
    - Instead of multiple blue boxes
      it can be multiple rack modules



Safety Instrumented Systems (SIS)

- Insurance and liability is driving process loop safety design
- Standards IEC 61511 and ISA84.01 outline how to analyze, design, realize, install, commission and maintain SIS loops in the process industries.
- Risk factor for a process loop is analyzed.
  - Result is a SIL (Safety Integrity Level) rating
- *The higher the SIL* level, the greater the impact of a failure and *the lower the* failure *rate* that is acceptable
- Implementation involves concepts like
  - Analysis of past performance
  - Redundancy – multiple sensors, voting logic
  - Diversity – avoid common mode failuresby using a different technology

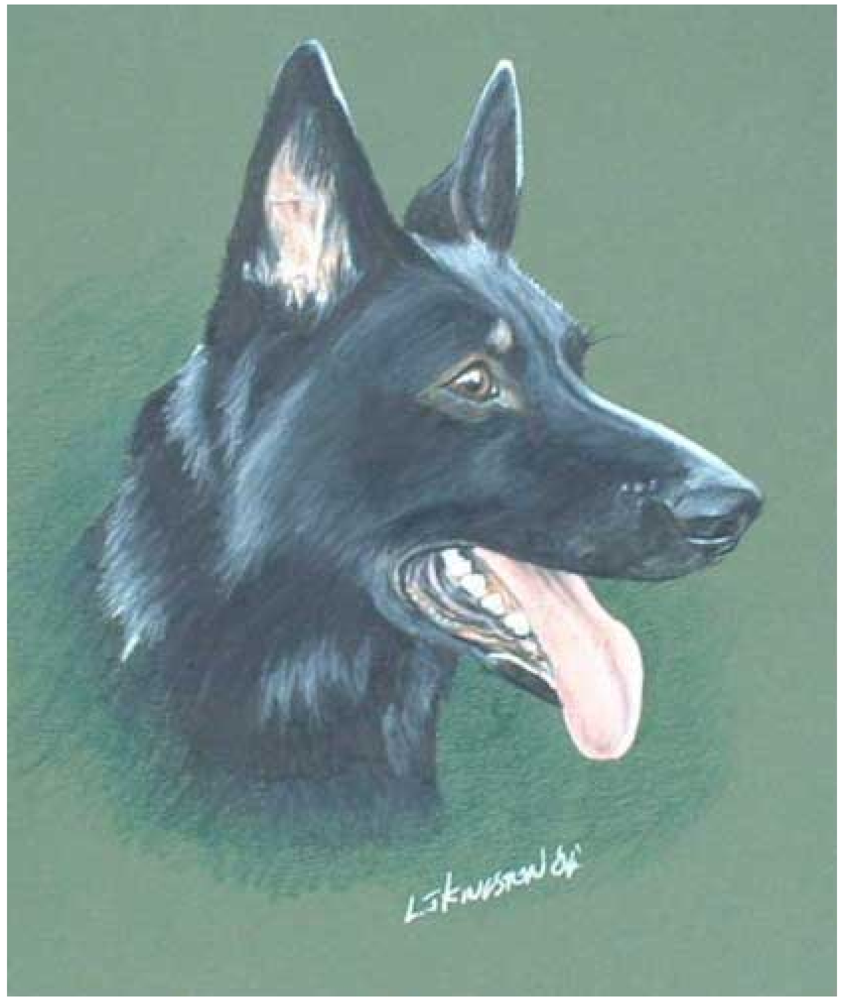
Safety Instrumented Systems

- Goal – bring the process to a safe condition
- Components can be 'proven in use' or SIL certified
- Field instruments can have SIL ratings
  - Agency certified (FM, Exida, TuV)
- A safety controller is a '*logic solver*'
  - Designed to not fail, but when it does fail, to fail predictably and safe
  - Fault tolerant
  - Incorporates fail-safe diagnostics
  - Voting logic to analyze redundant sensors
  - SIL certification (or proven-in-use)
- Recognized in chemical, gas & oil industries, moving to others

Sums up control

- Questions?

Questions?



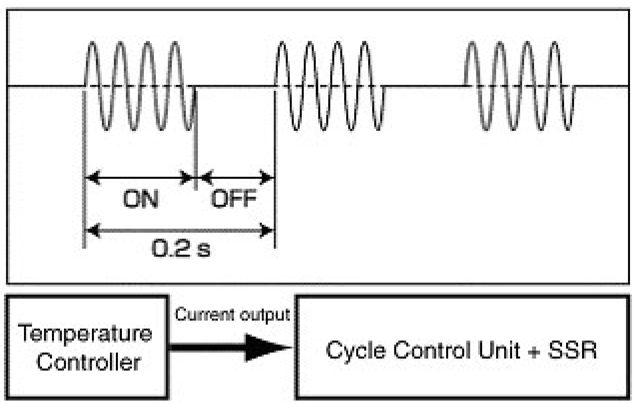
OPC – lets industrial devices communicate

History

- HMI software vendor had to write a driver for every device it talked to
- OPC comes out in mid 1990's
- Concept: OPC servers talk to OPC clients (Windows software)
- HMI software vendors integrate OPC client into their products
- Driver that talks to the device is part of an OPC server
- OPC servers are sold by 3rd party vendors or directly by mfgrs with built-in 'driver' for specific brand/model/communications protocol.
- OPC server/client speeds up the task of interfacing devices
- 85% of OPC users have no idea that they're using OPC
- OPC UA (2nd generation) is coming out as we speak
- Modbus is a standard OPC protocol

Time proportional control

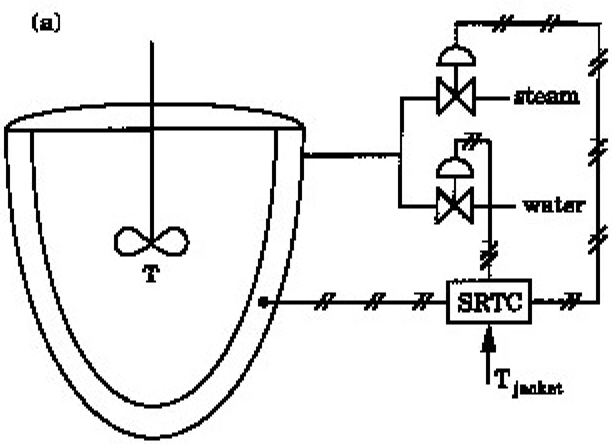
- Packaged SCR/thyristor controllers
- Control input 4-20mA
- Package switches the high voltage, high current



- Choice of zero cross or phase angle
  - Phase angle chops each cycle (noise/harmonics)
  - Zero cross turns on or off when cycle starts at 0 or ends at 0 (little noise/harmonics)
- Sometimes referred to a PWM, or Pulse Width Modulation

Heat/Cool control

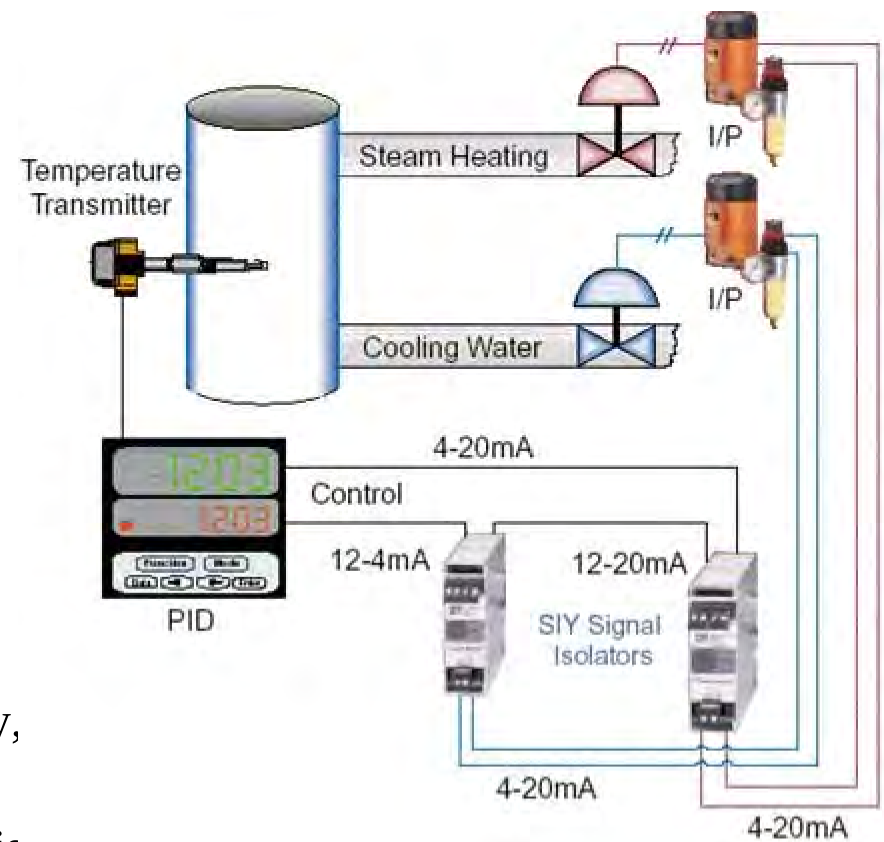
- A controller that automatically switches between heating and cooling
- Heat-cool controllers: 1 loop with 2 control outputs
  - Only one control loop (only one output is active at a time)
  - One output for heat
  - One output for cooling
  - Home thermostat has to be manually switched from heat to cool
- Jacketed vessel



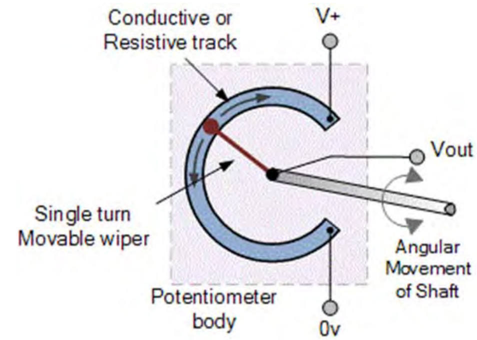
Split Range control

Split Range control

- Single 4-20mA output splits to two final control elements (FCE)
  - Sometimes single operation (heat/cool)
  - Other times, staged operation
- Need
  - PID Controller with 1 linear output
  - Two final control elements (valves with positioners or E/I/P)
  - I/P or positioners ranged differently, 3-9 and 9-15 psi
  - Sometimes a loop repeater/splitter is needed (diagram) due to positioner loading



Position Proportional Control



- Position Proportional Output
  - Output to drive a electric actuator
  - Slidewire feedback for precision positioning
    - Slidewire tracks the rotation position of the motor shaft
  - Controller output, 2 relays
    - One relay drives motor Clockwise (CW)
    - Other relay drives motor counter-clockwise (CCW)
    - Slidewire feedback tells controller when to stop driving
  - Requires 6 wires CW, CCW, common, 3 wires for slidewire
    - Controller uses slidewire card
  - Adapter modules convert 4-20mA to position prop
  - Controllers: UDC3200, Truline, HC-900

Three Position Step Control (TPSC)

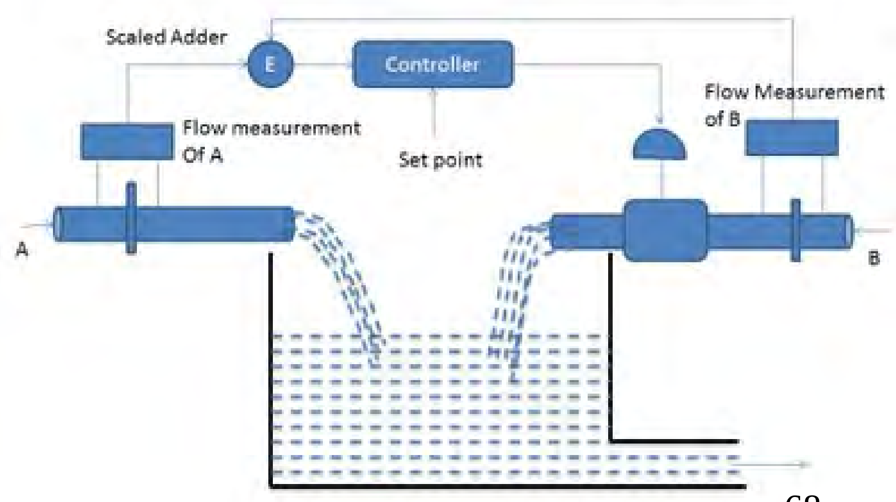
- Position Proportional minus the slidewire
  - Slidewire is the weak link, breaks first
  - Open feedback control, no slideware feedback
  - Uses the 2 relay, CW, CCW action
  - Times the duration the drive motor is on
  - Initializes first time by stroking full open, full closed
  - West calls is VMD (valve motor drive)
  - Requires setting the stop-to-stop time (30 seconds, 90 seconds)
  - UDC: can be configured and used when the slidewire fails
    - Relay output wiring is identical to position proportional
  - Costs less then Pos Prop (no slidewire card)
  - Better reliability (no slidewire to fail)
  - Assumes PI integral action makes up for minor position error

Ratio Control

Typical ratio control application - blending

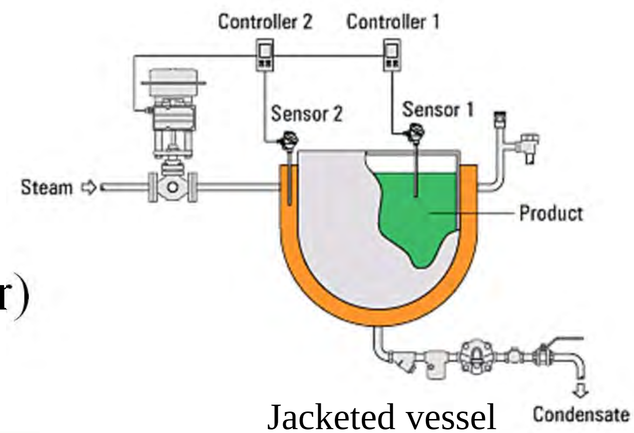
- Single ratio controller
  - 2 PV inputs, wild flow and controlled flow
- Controls one flow rate as a ratio of the other
  - Wild flow X (A) (outside demand factor determines its flow rate)
  - Controlled flow (B) at x% of A

Example of Ratio Control System



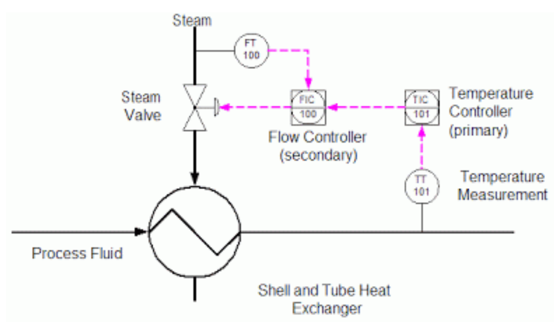
Cascade Control

- 2 interconnected control loops
  - 2 measured PVs, one for each control loop
  - Only ONE control output (4-20mA) to a final control element
  - 2nd loop's output becomes setpoint of 1st loop
- Typically used when
  - primary PV is slow responding (relatively)
  - Secondary PV is fast responding (3-10x faster)
- One sensor is typically sensing the load



Jacketed vessel

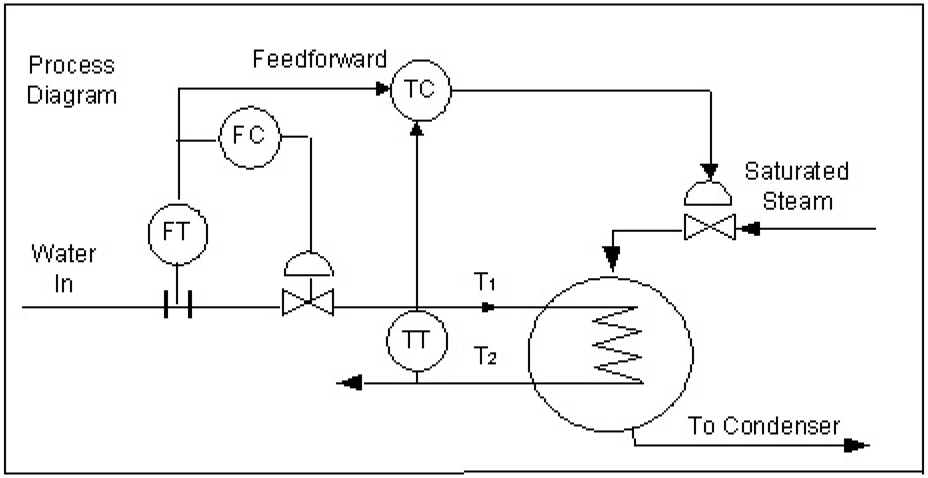
annealing



Heat Exchanger

Feed Forward Control

- Disturbance is measured (upstream flowrate)
- Feedforward bypasses PID, doesn’t wait for disturbance effect on PV and resulting ‘error’
- Ratioed disturbance value is summed into PID output
    - Feedforward component added directly to PID output
- Comprehensive understanding of disturbance required
- below: heat exchanger: inflow rate fed forward to Temp controller



2 control modes

- Manual control
  - A person
    - makes the decision
    - makes the change
- Automatic Control
  - A controller controls the process variable
    - Reads the process variable = measures
    - Compares PV to SP = compares
    - Makes a decision: how much to change or not = computes
    - Changes output (manipulated variable) = changes

Regulating a process

- Manual control
  - Manually set the light dimmer

- Automatic
  - Unattended
  - automatic correction for disturbances

Final Control Element

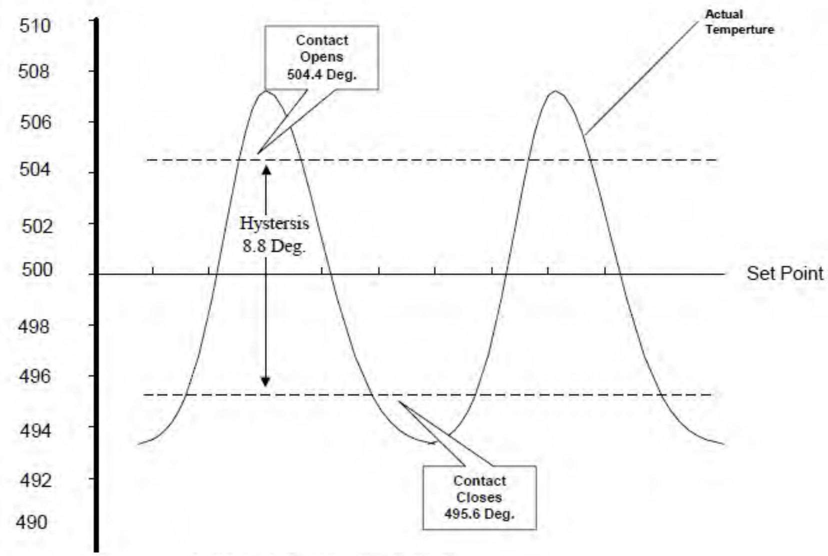
- Physically controls a desired output variable (flow, electricity)
- Puts more or less energy or more or less stuff into the process
- Controller's output signal drives a 'final control element'
  - Tells Final Control Element
    - To Turn ON
    - To Turn OFF
    - Defines the magnitude of change the final control element should make

Final Control Element

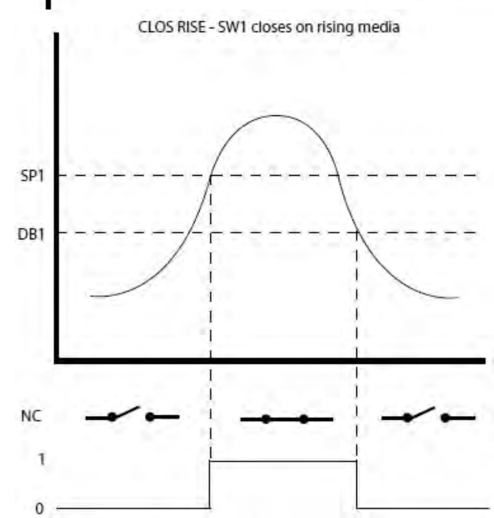
- Examples of final control elements:
  - Electrical motors driving a pump
  - Variable speed drive or variable frequency drive to an electric motor
  - Contactor which turns pump's motor on
  - Control valve
  - SCR/thyristor unit (industrial grade light dimmer)

How is deadband implemented?

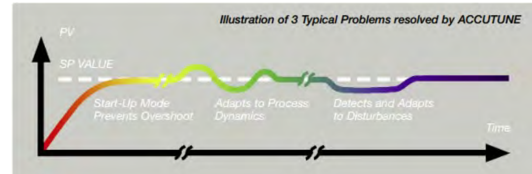
- Honeywell on-off controller:
  - splits deadband above and below the setpoint:



- UE One Series Electronic pressure switch
  - Trips exactly at SP and deadband



How does Accutune work?



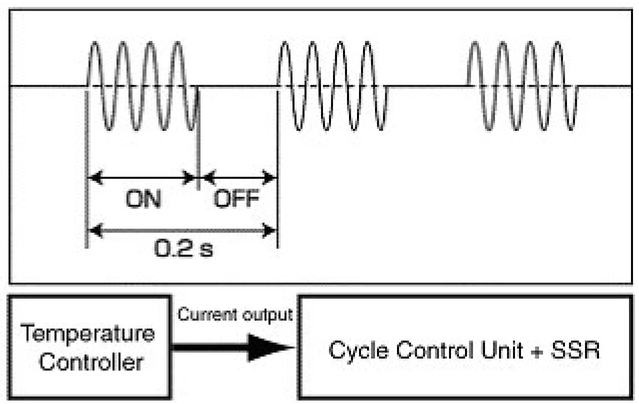
– Push a button to start it running
– Output goes to 100%, then 0%, then 100%, then 0%
  – Introduces an upset in the process
– Controller observes the response to output changes
– Determines the tuning constants from the process response
– Saves new tuning constants, exits Accutune
– Controller resumes control using new tuning constants
– Caveats
  - Load has to be typical – it does no good to tune to an uncharacteristic load
  - Output swings might damage some loads – use a dummy load

How is electricity 'modulated'?

- How is AC power modulated to electric heating elements for proportional straight line control?
- Vacuum furnaces use electric power (not gas) to keep products of combustion from polluting the load
- 3 techniques
  - Time proportional control
  - SCR/thyristor
    - Uses either time proportional or PWM
  - Variable Frequency drives

PID Time proportional control

- AC power is cycled/switched on or off over a ‘duty cycle’
- The duty cycle has a fixed time period
  - .2 seconds, 5 seconds, 20 seconds



- The On period is a proportion of the full time period
  - 0% is no power
  - 50% is power on for half the cycle, off for half the cycle
  - 100% is power on for the full time period

Separate HMI from Control

Why graphics and HMIs?

- Example:
  "We need it be at 355"
  "355 what?"
  " I don't know. It's always 355"

  It was 355 gpm, not 355 Deg C

- A graphical HMI can easily display something as simple as engineering units