A Field Perspective on Pneumatic Control and Actuation Systems

Control System Building Blocks

Presented By:
David Sellers
Senior Engineer, Facility Dynamics Engineering

A Field Perspective on Pneumatic Control and Actuation Systems

But First; The System Concept

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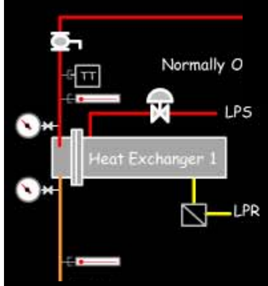
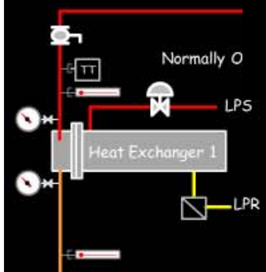
Its Not Just a Heat Exchanger …

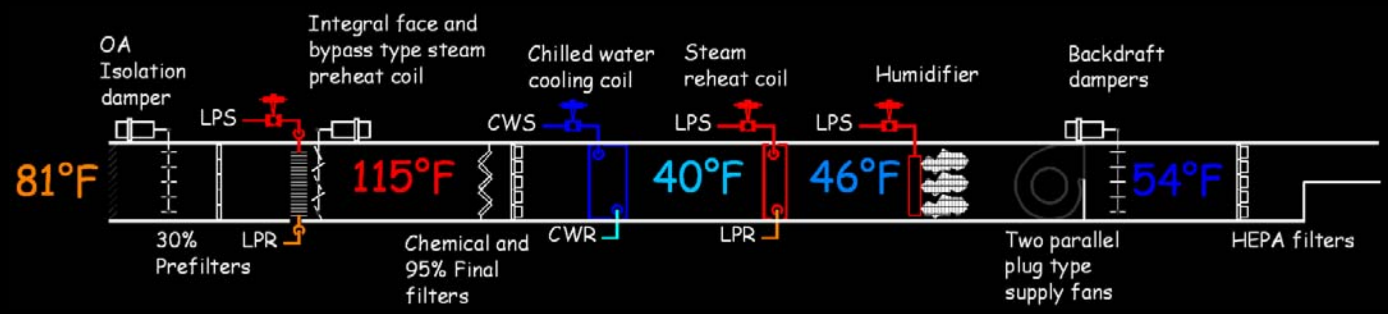


Its Not Just a Heat Exchanger …

…It's a Hot Water System



Its Not Just an Air Handling Unit …



Its Not Just an Air Handling Unit …
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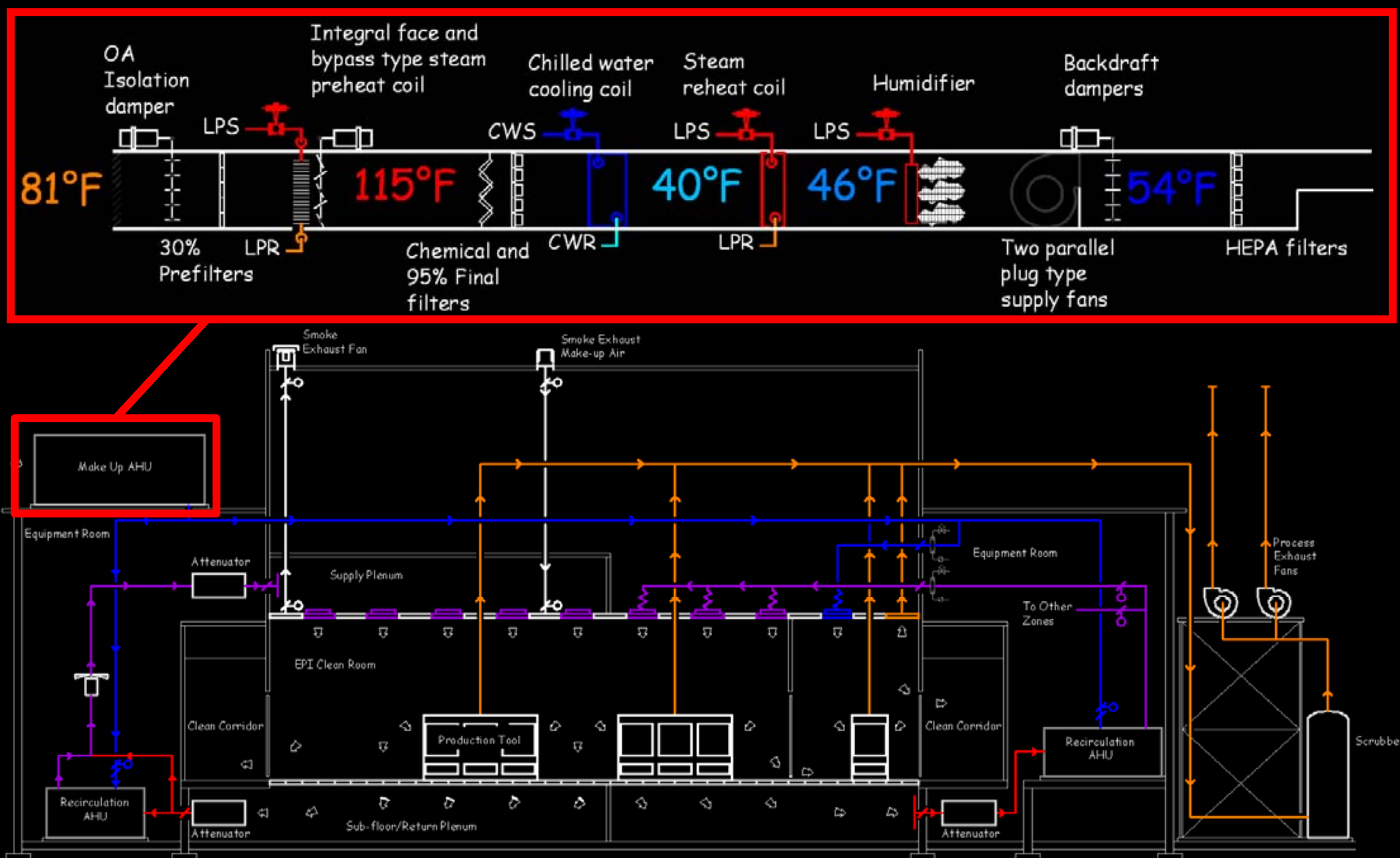
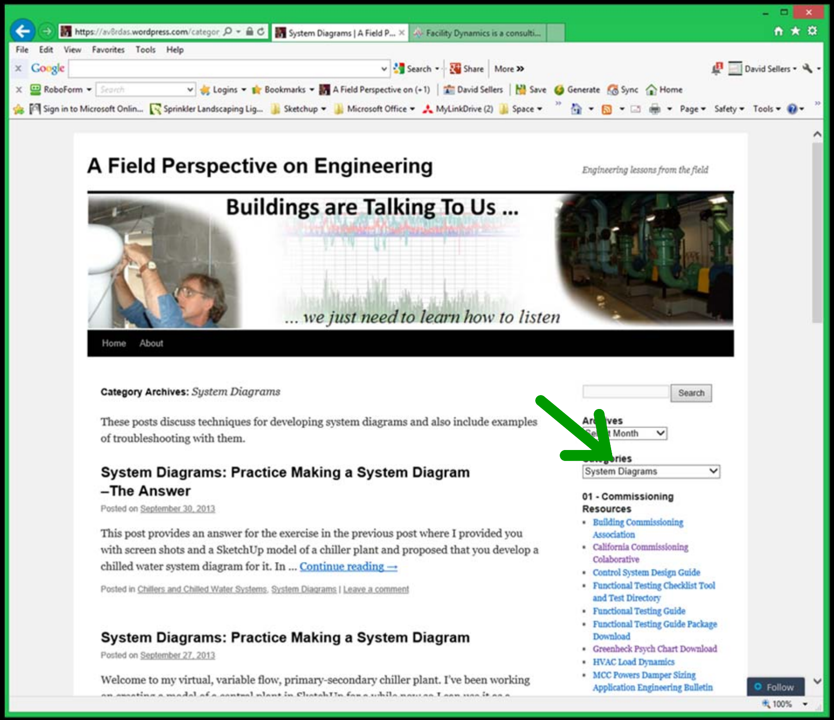


System Diagram and Concept Resources

www.Av8rdas.Wordpress.com

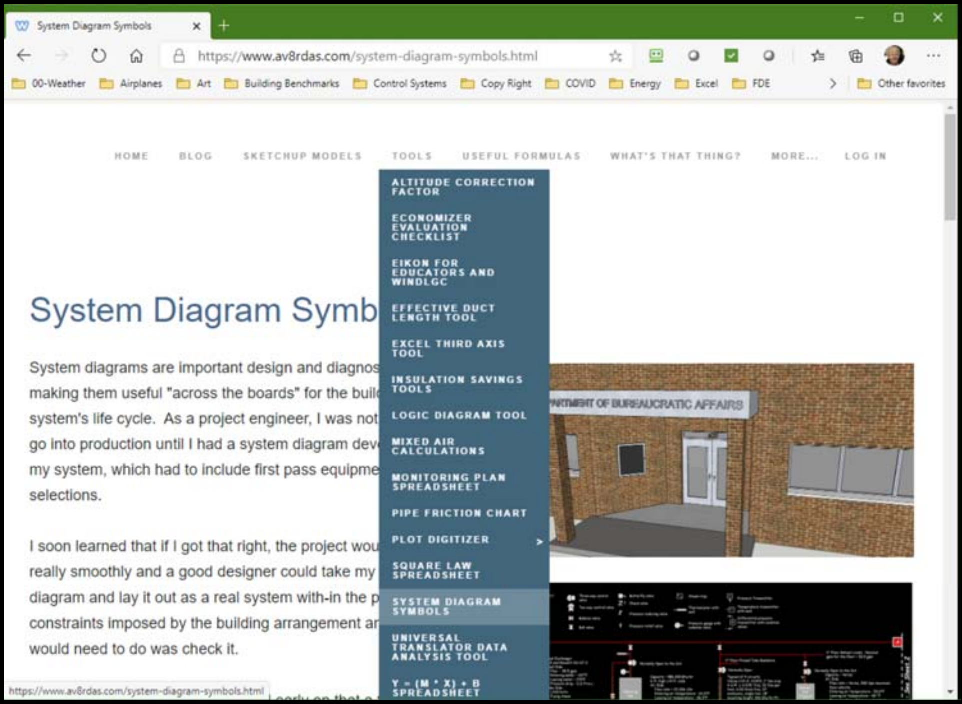
- Search for “System Diagrams: …”
- You can also filter for them with the drop-down menu
- Developing a System Diagram: Getting Started and the next few posts walk you through the process using the PEC ice storage system as an example



Resources for Details Behind this Content

https://www.av8rdas.com/system-diagram-symbols.html

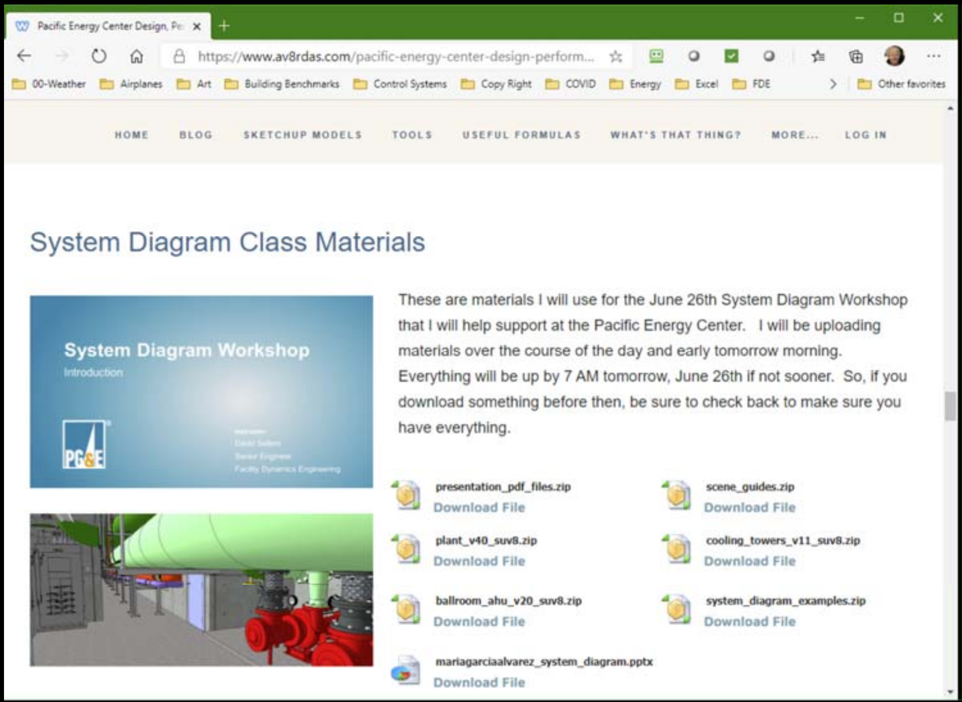
- PowerPoint based tool and symbol library
- AutoCAD symbol library
- Examples in AutoCAD and PowerPoint



Resources for Details Behind this Content

https://www.av8rdas.com/pacific-energy-center-design-performance-and-commissioning-issues-classes.html#System

- Full day workshop content
- Multiple examples in multiple formats



Control System Building Blocks

The Fundamental Goal of the Control System

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

The Fundamental Goal of the Control System

You can get what you want in a very inefficient manner

The Fundamental Goal of the Control System

You can get what you want in a very inefficient manner

See *Commissioning to Meet Space Qualification Criteria vs. Energy Consumption Optimization Focused Commissioning* for details

The Holistic (Green) Goal of the Control System

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control as efficiently and sustainably as possible

The “Three R’s”

• Repeatable	• To make, do, or perform (an action) again (and again, and again, and again ….)
• Reliable	• Giving the same result on successive trials
• Robust	• Sturdy; capable of performing without failure under a wide range of conditions

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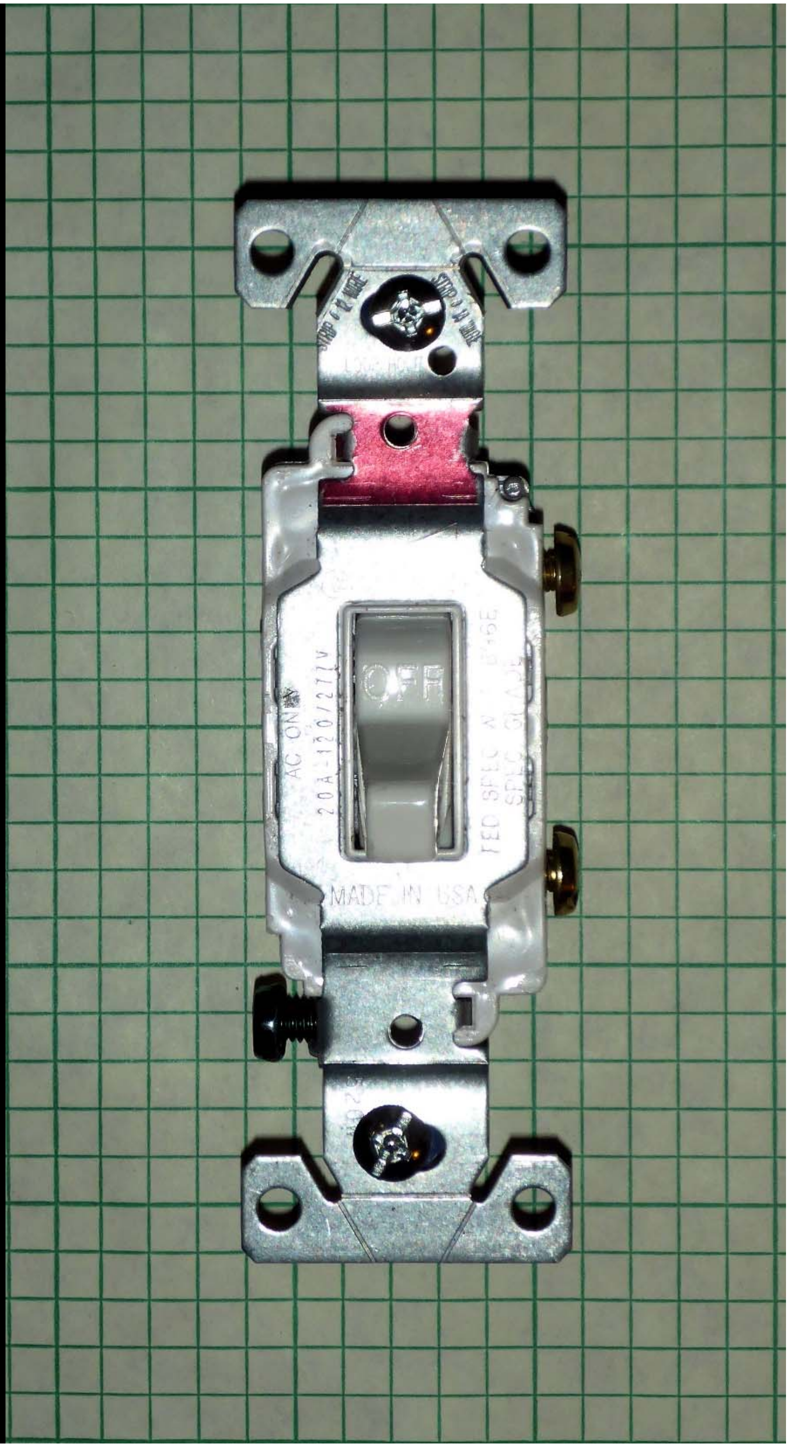
Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Inputs

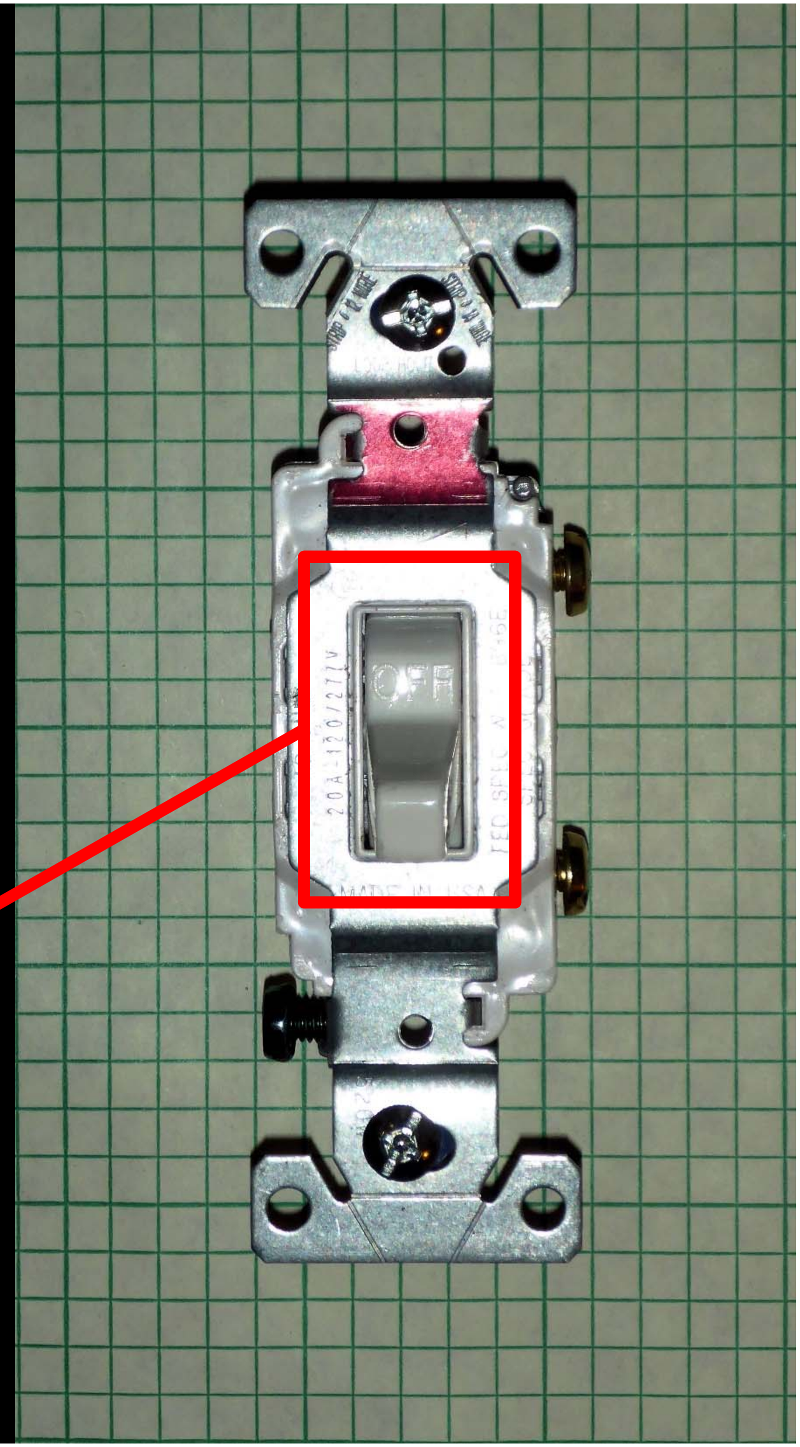
Measure the process variable

A Digital Signal



A Digital Signal

With automatic operating state indication …



A Digital Signal

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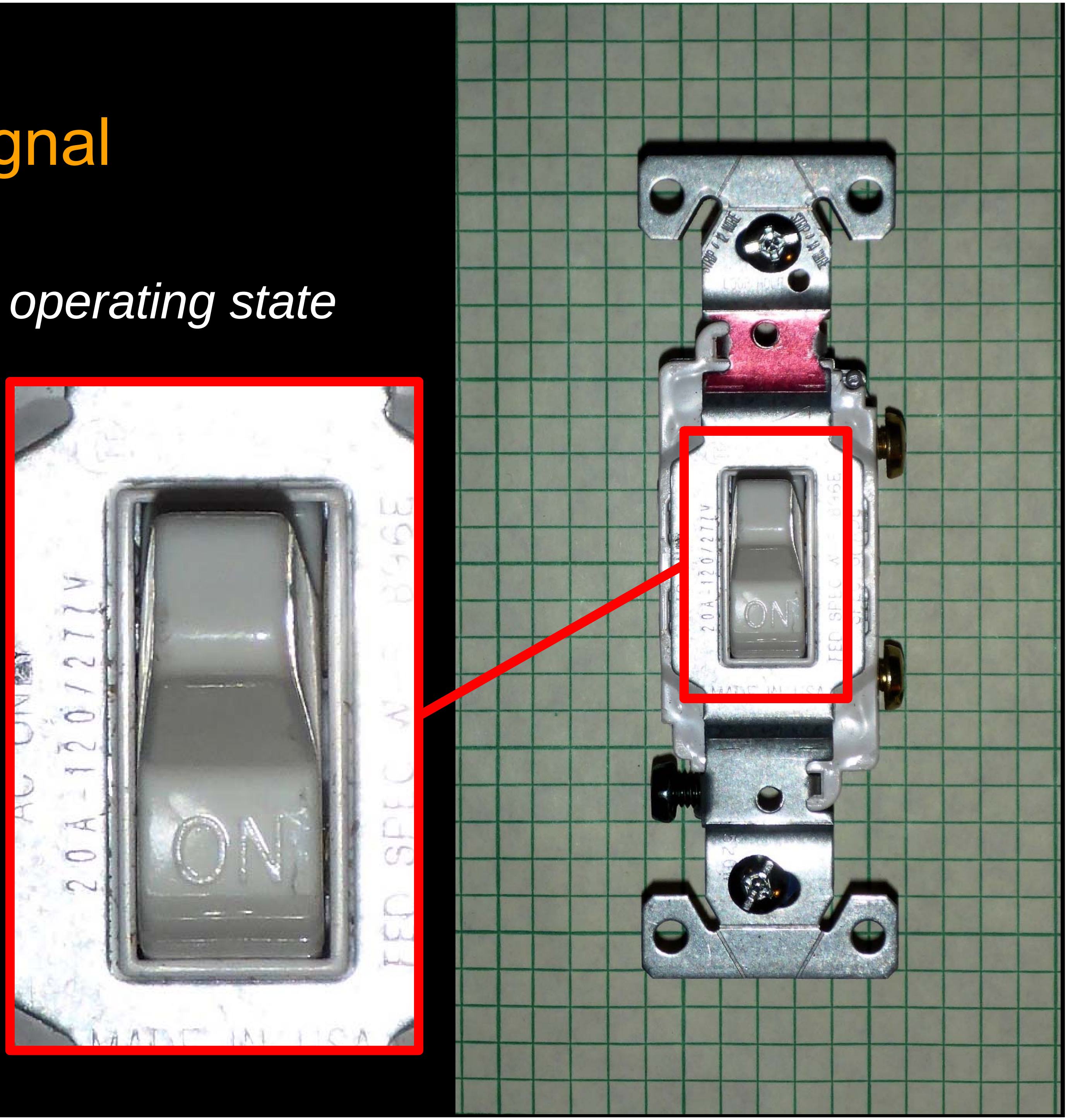
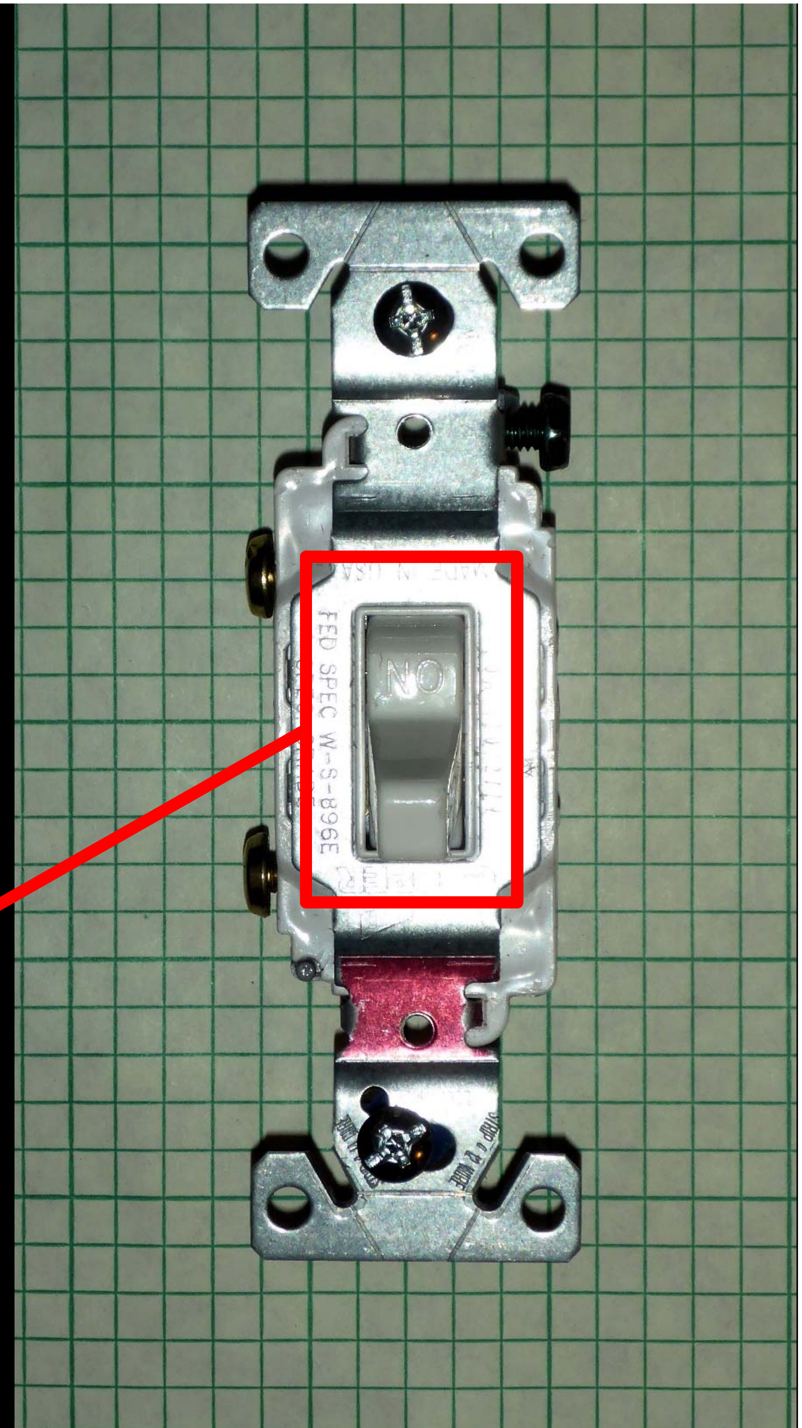


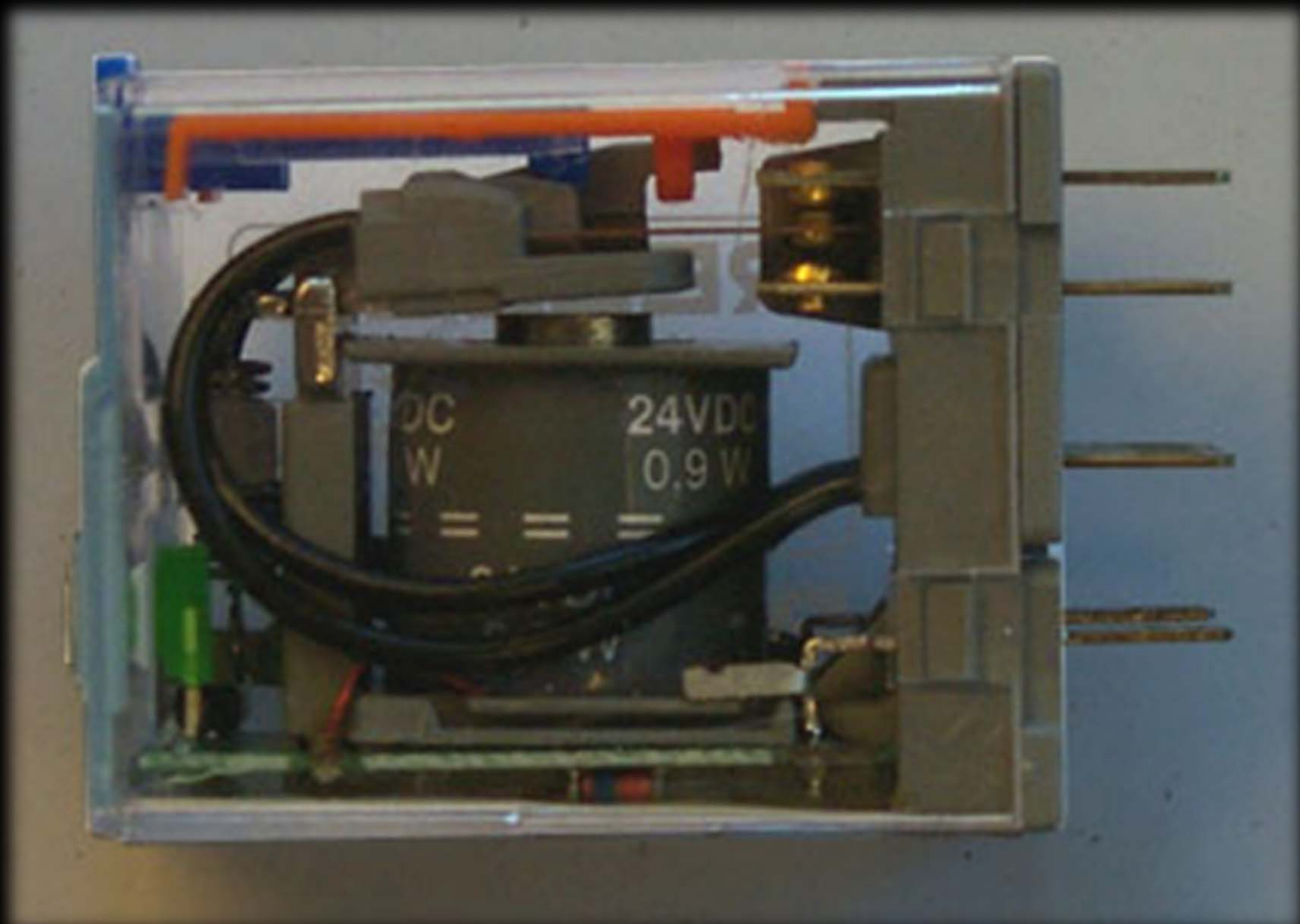
A Digital Signal

… and automated fault detection

Tom McCarthy



A Digital Signal



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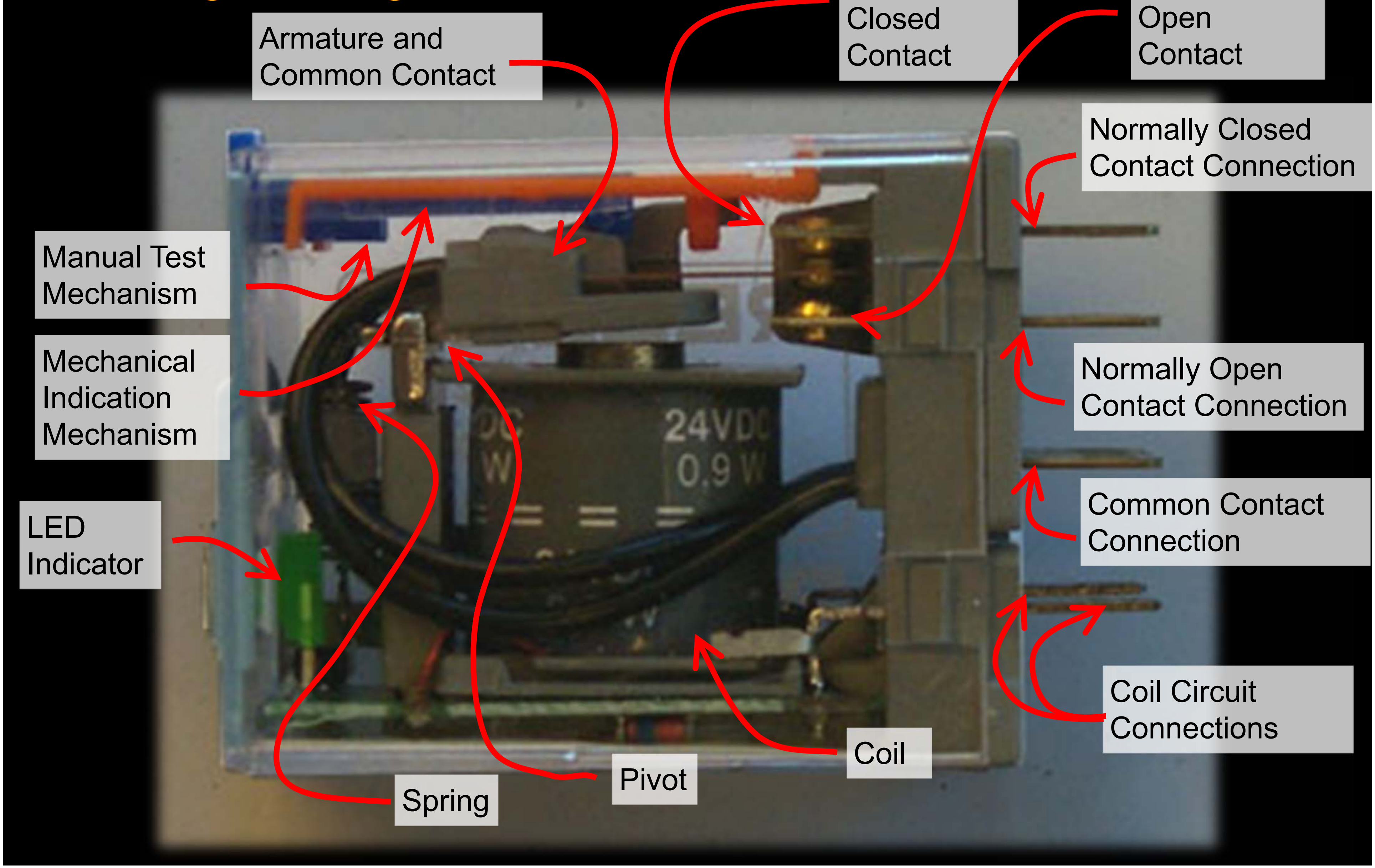
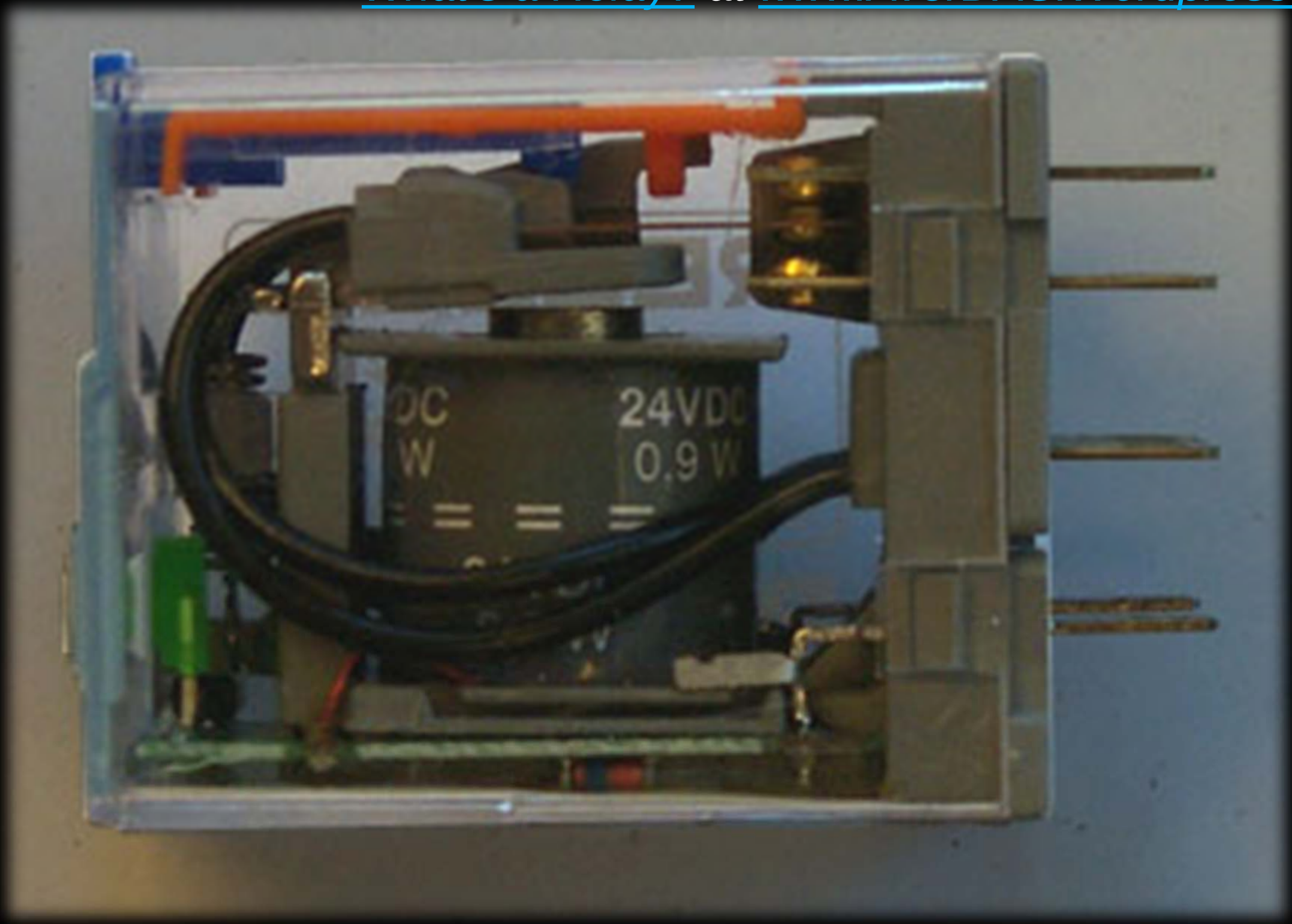


A Digital Signal

For More on Relays, see [Learning about Relay Logic; What's a Relay?]() at [www.Av8rDAS.Wordpress.com]()



A Digital Signal

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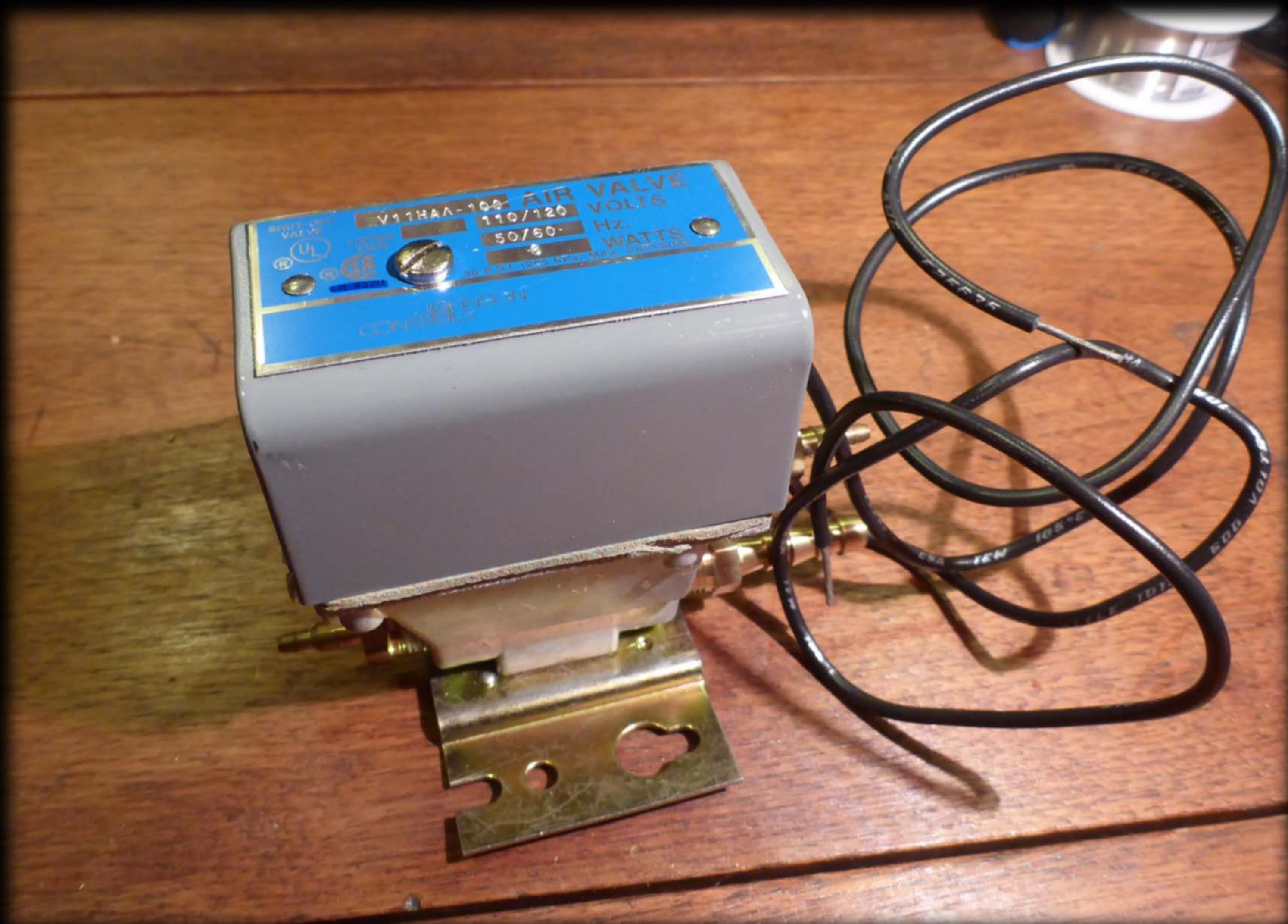
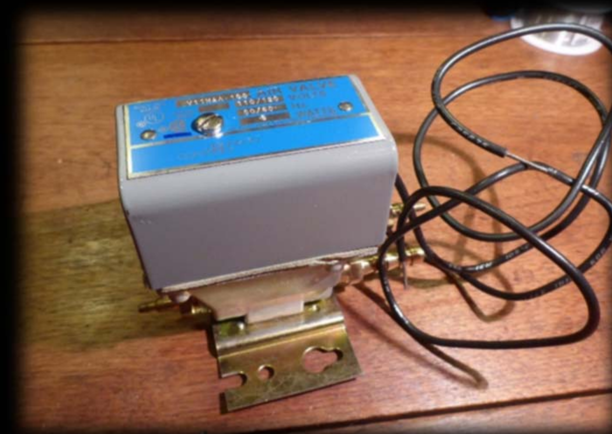
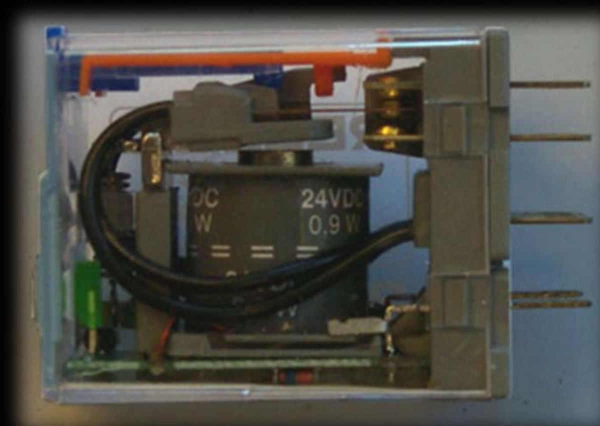


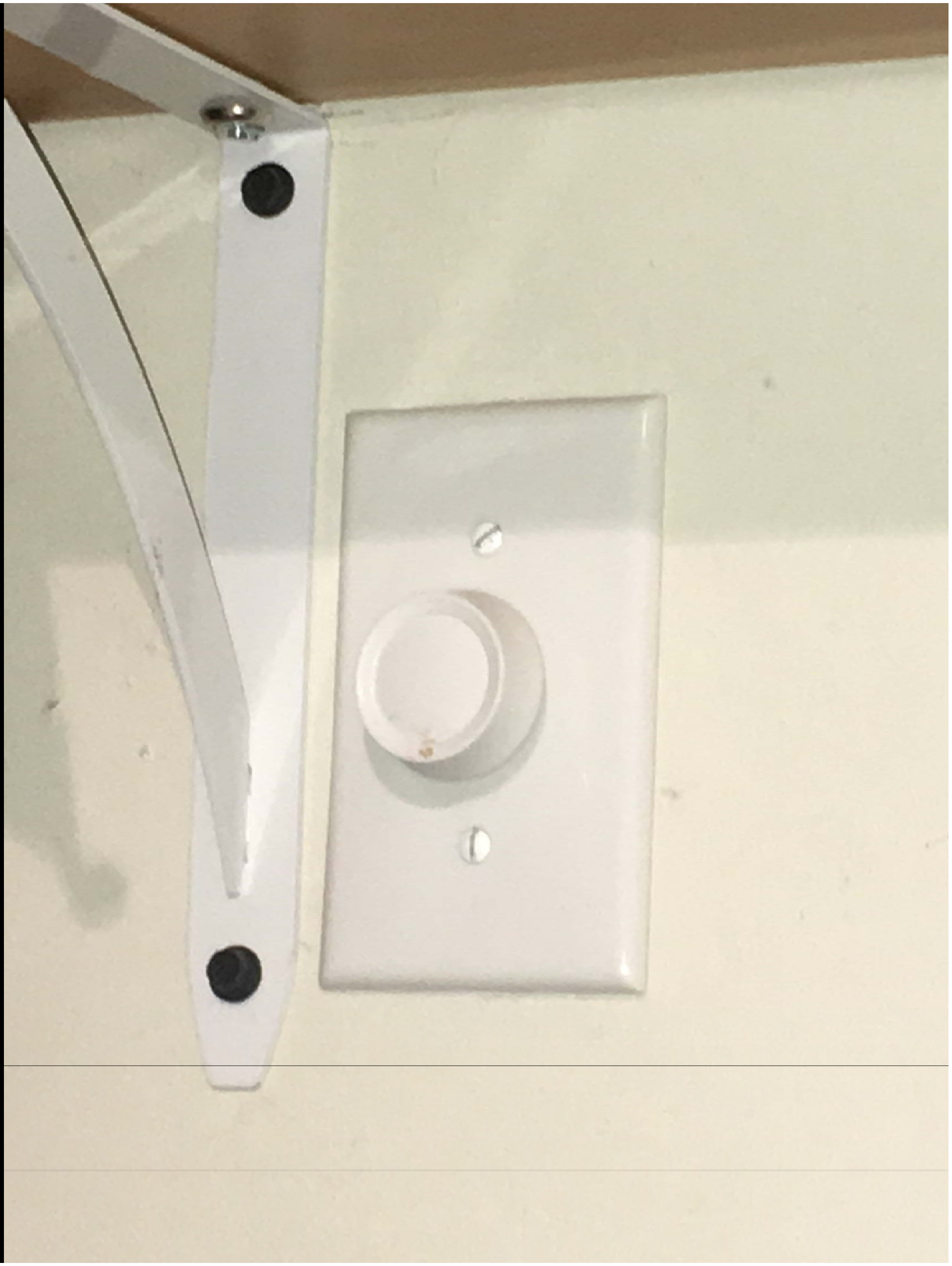
Bottom Lines

1. Pneumatic controls are often complemented by electro-mechanical relay logic
2. Pneumatic controls use pneumatic relays to perform logic operations
3. The fundamental principles behind both types of logic are identical





An Analog Signal



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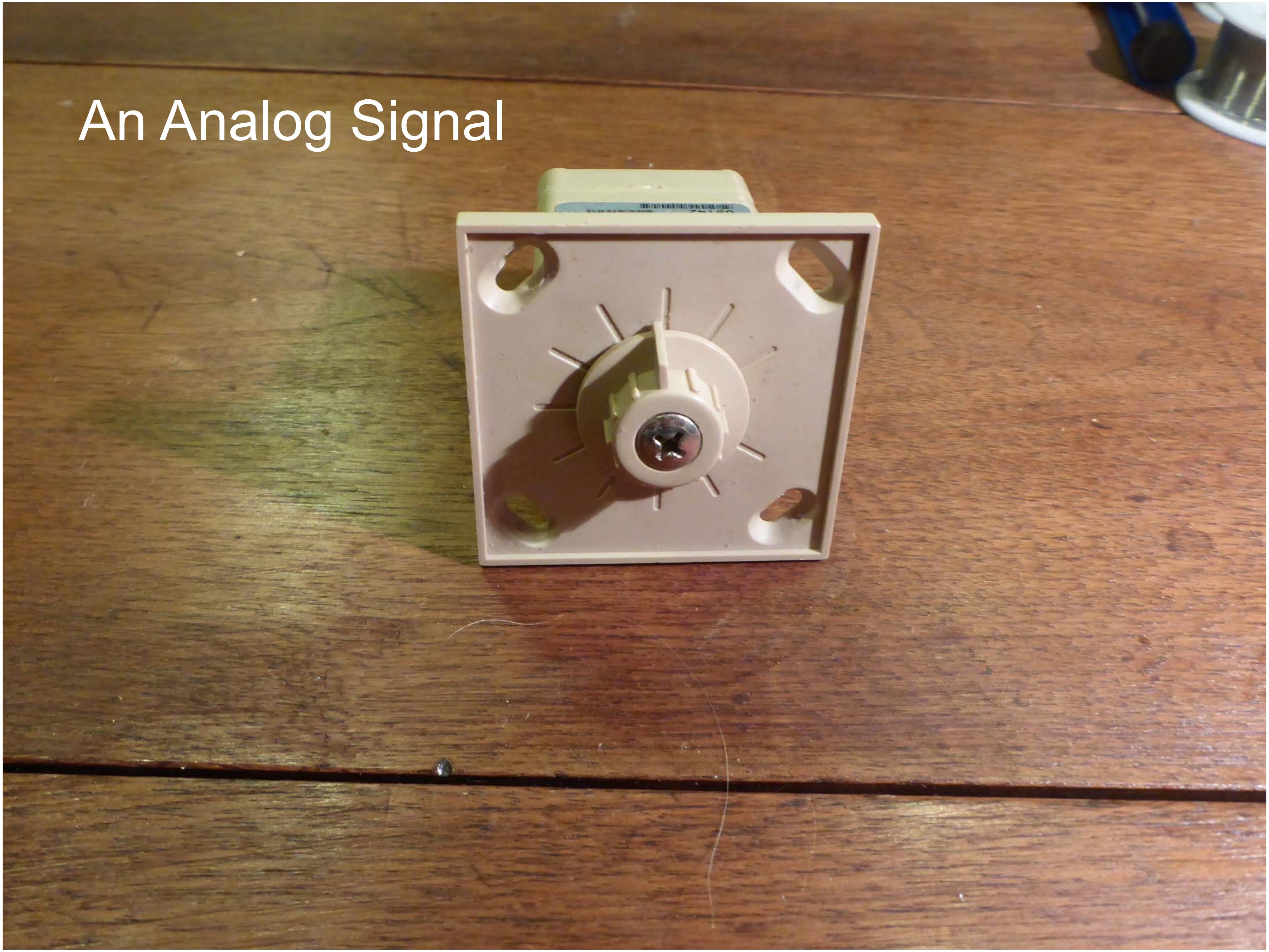

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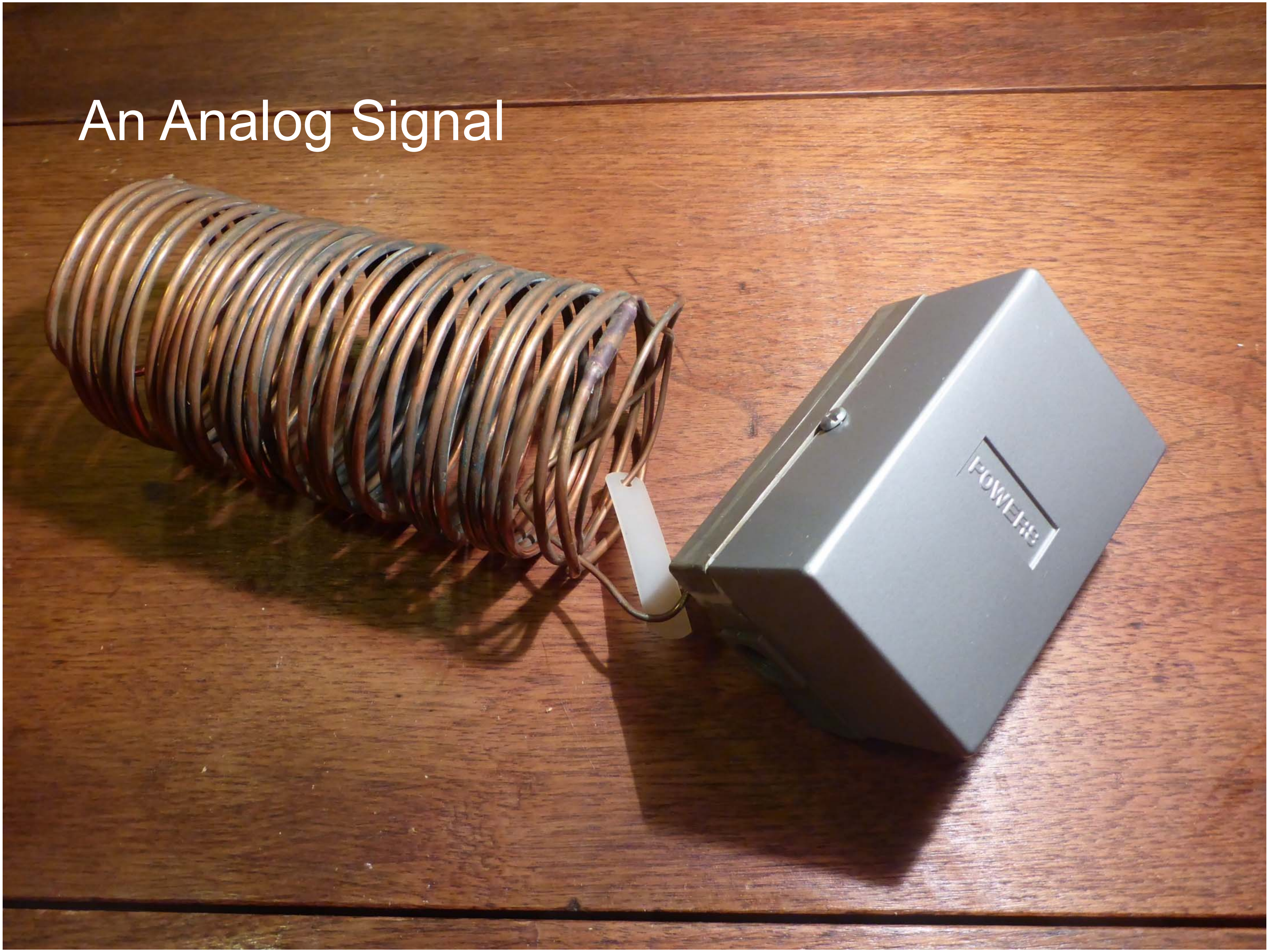

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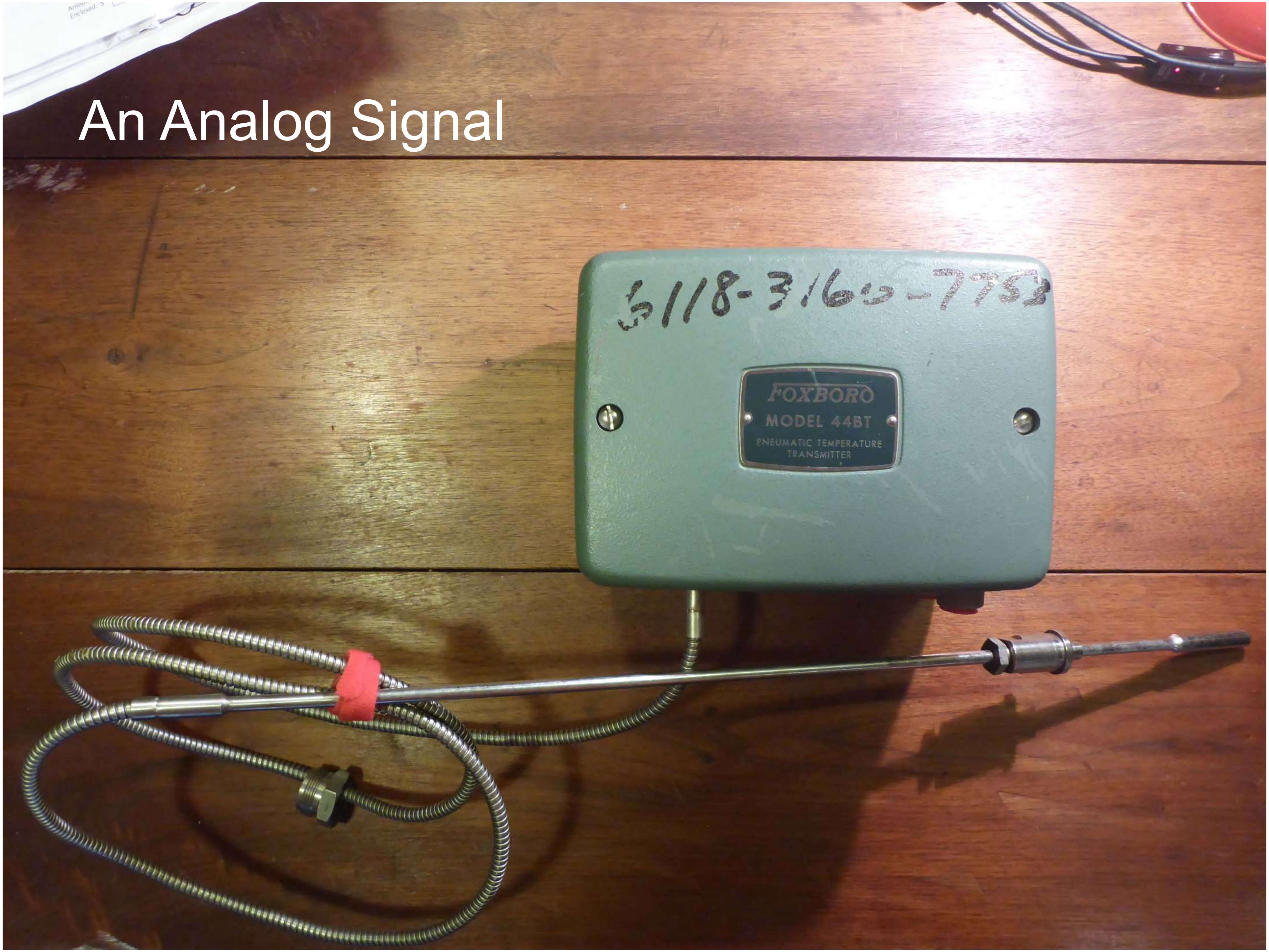

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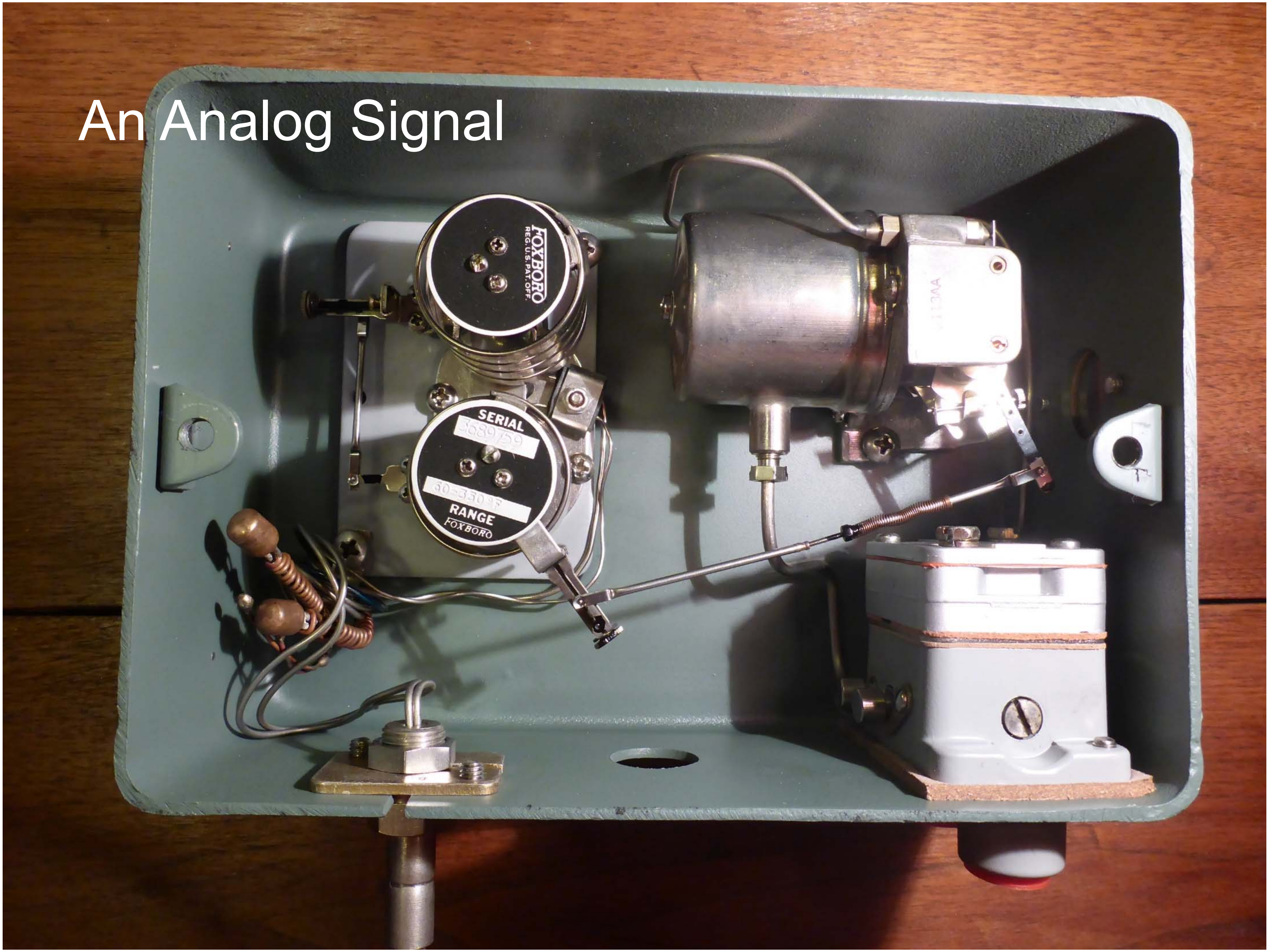

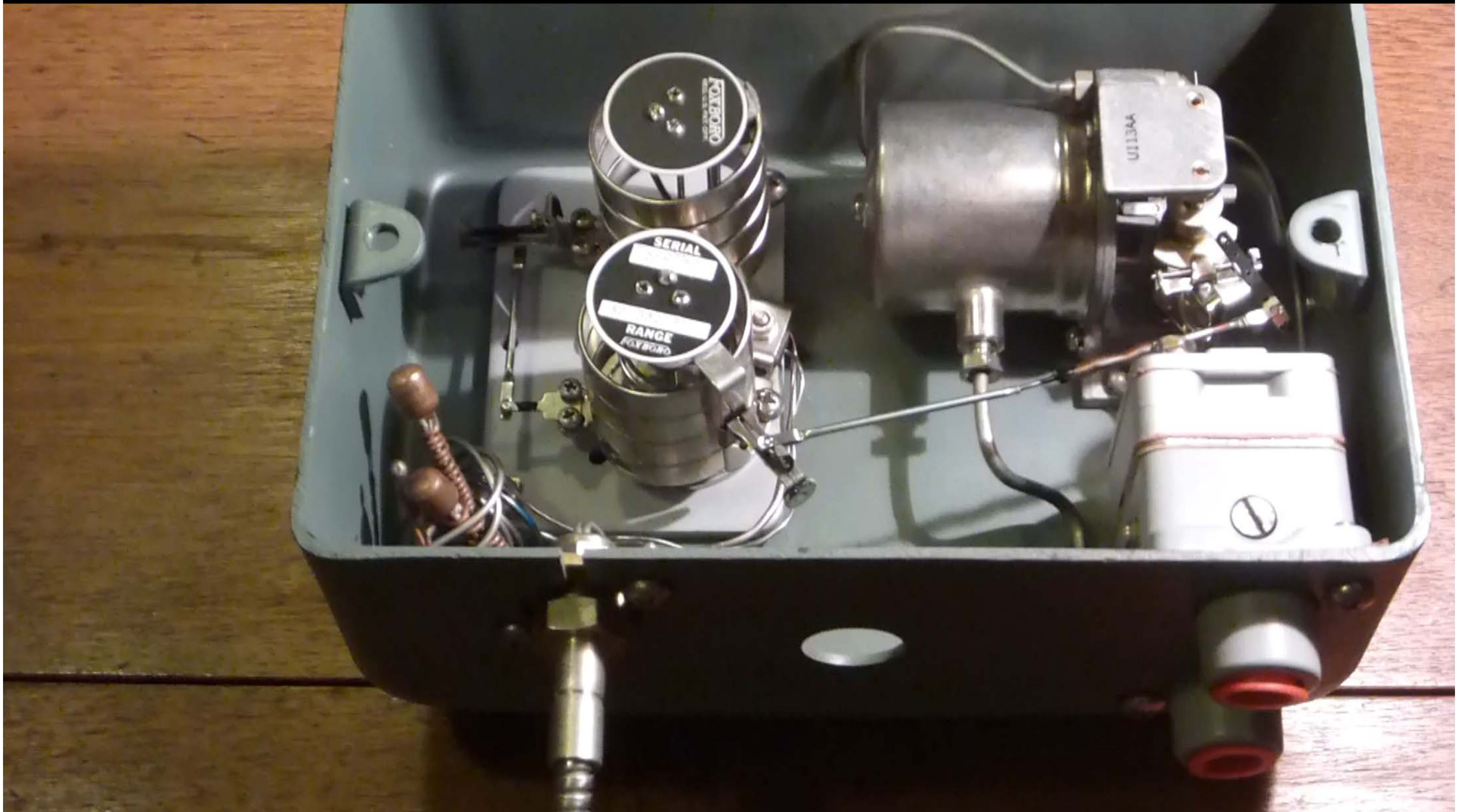
FOXBORO
SERIAL
RANGE
FOXBORO
U113AA

Control System Building Blocks

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

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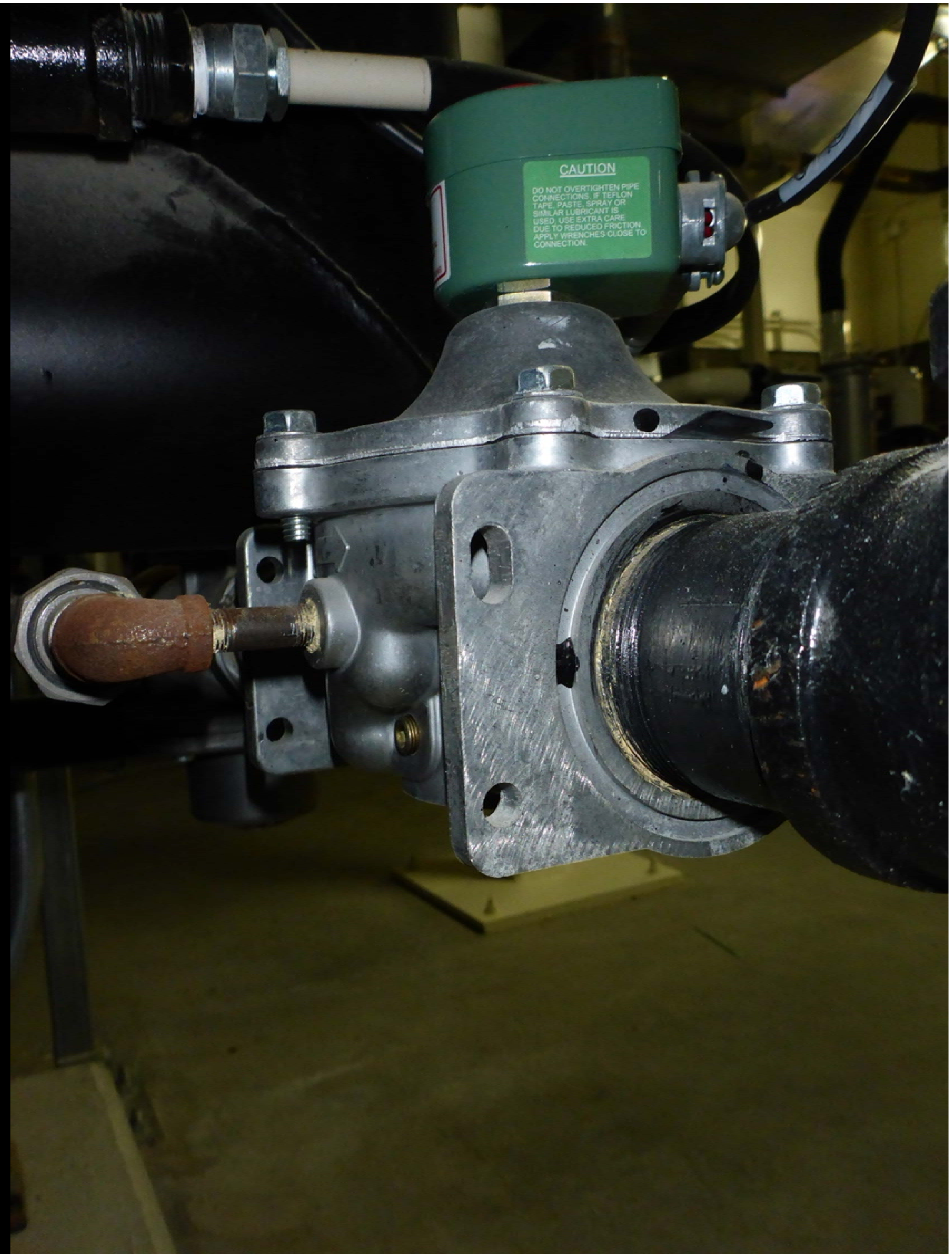
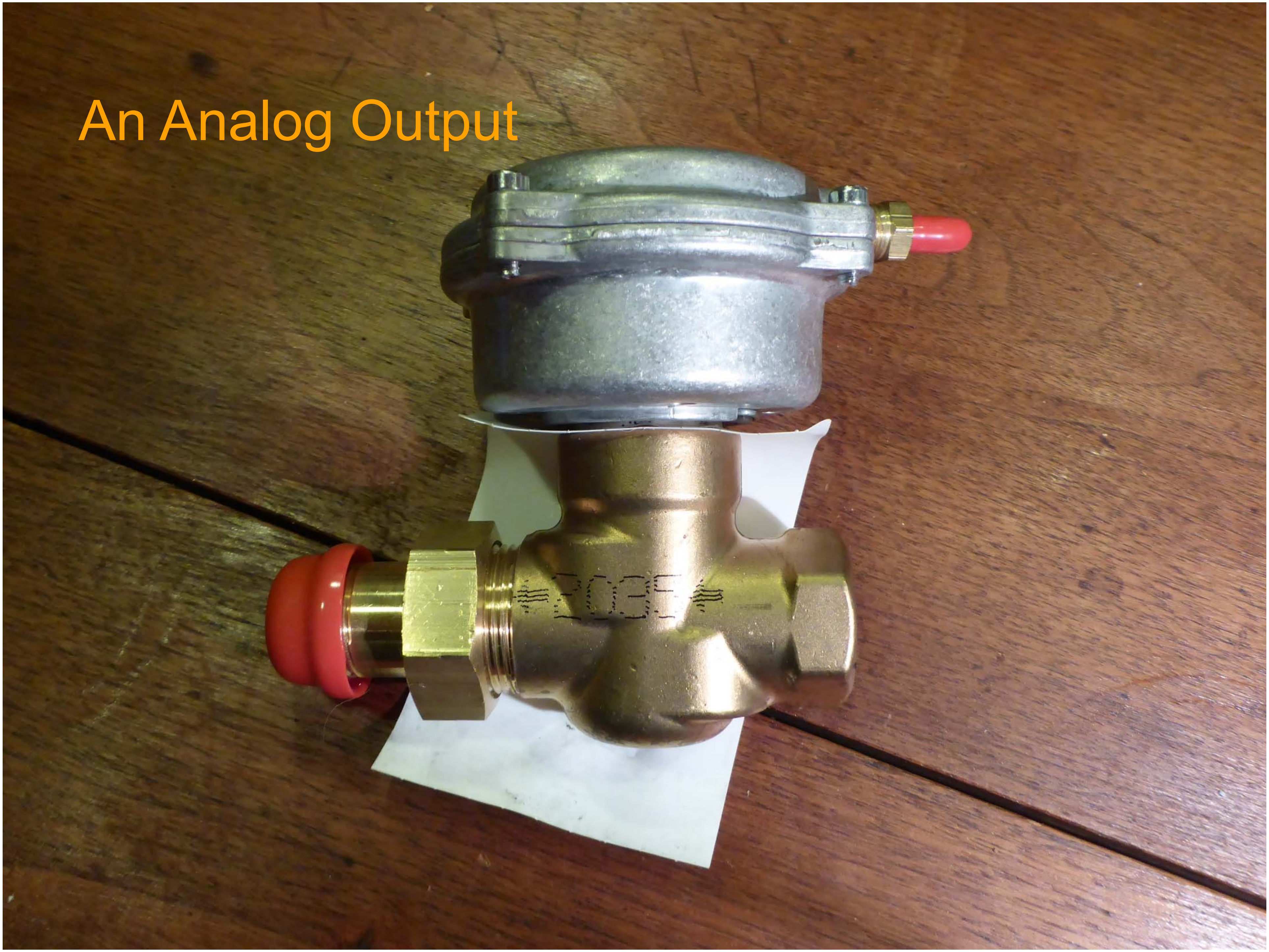
A Digital Output



An Analog Output



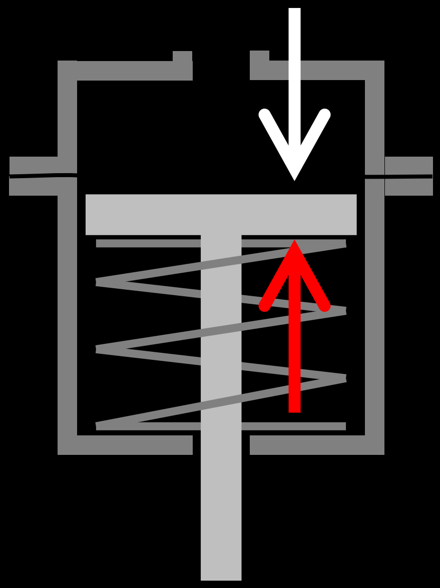
An Analog Output

Proportional Actuators

Pneumatic Sequencing

- 3-15 psi = standard signal
- Spring ranges allow sequencing
  - HW Coil – 3-5 psi = Full flow to no flow
  - Economizer – 7 – 10 psi = MOA to Maximum OA
  - CHW Coil – 12-15 psi – No flow to full flow
  - Can be used as a two position actuator

The Forces Acting on a Valve Actuator as Described in the Literature



Control Signal

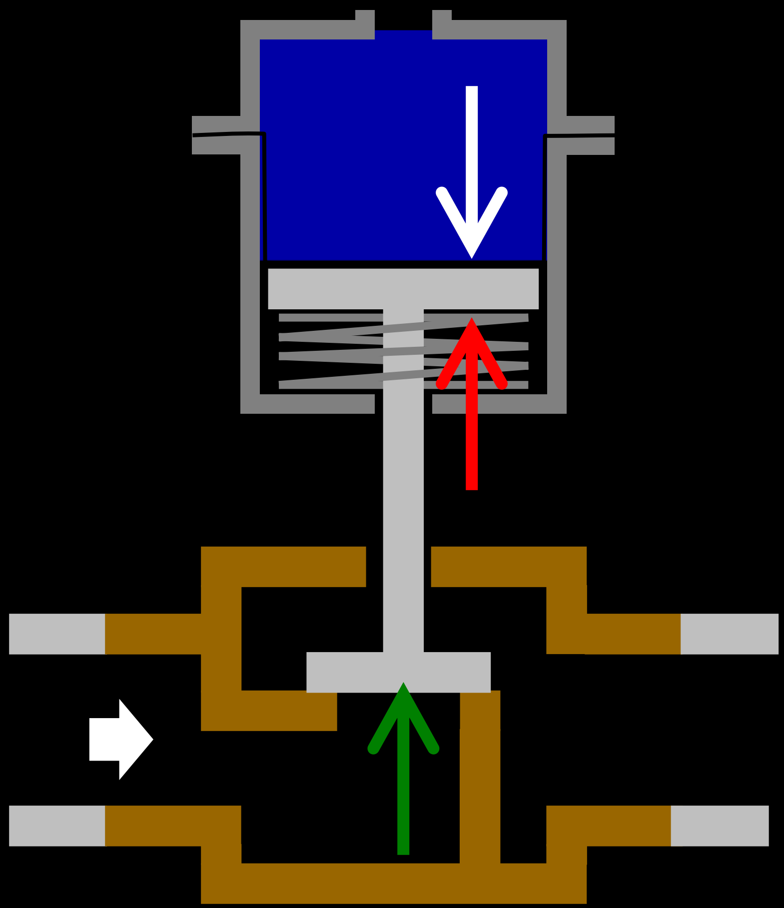
Force = Pressure x Area

Spring

Force = Spring Rate x Deflection

Facility Dynamics Engineering

The Forces Acting on a Valve Actuator in the Field



Control Signal

Force = Pressure x Area

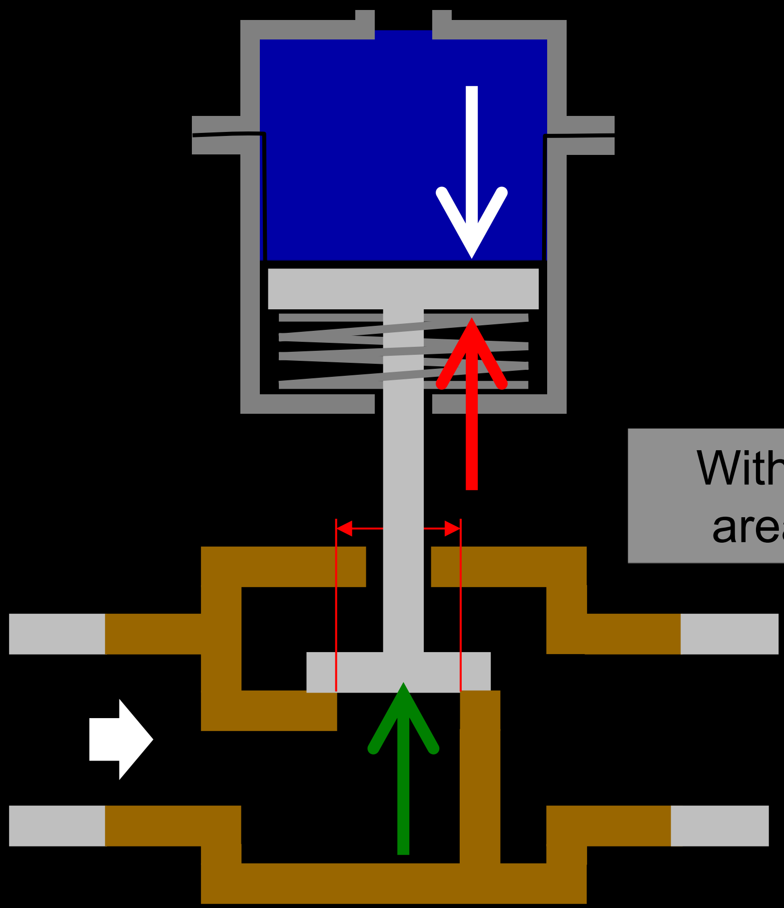
Spring

Force = Spring Rate x Deflection

Valve Plug Differential Pressure

Force = Effective Area x ΔP

The Forces Acting on a Valve Actuator in the Field

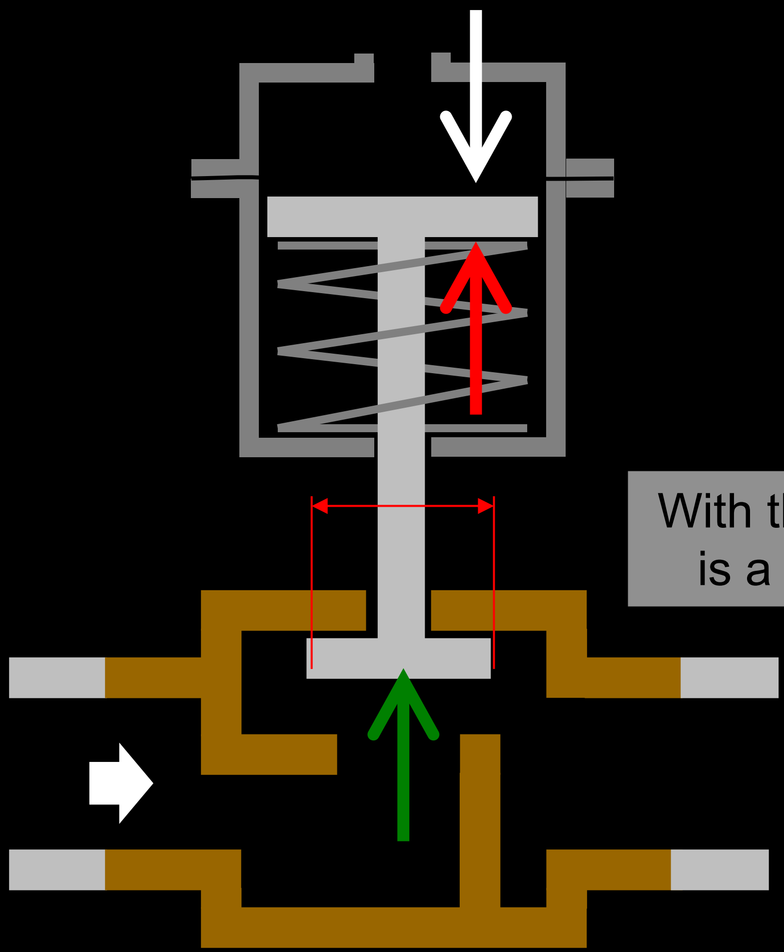


Plug force will vary as the result of a number of operating variables

- Effective area can change

With the valve closed, the effective area is a function of this diameter

The Forces Acting on a Valve Actuator in the Field



Plug force will vary as the result of a number of operating variables

- Effective area can change

With the valve open, the effective area is a function of a different diameter

Facility Dynamics Engineering

Positioners

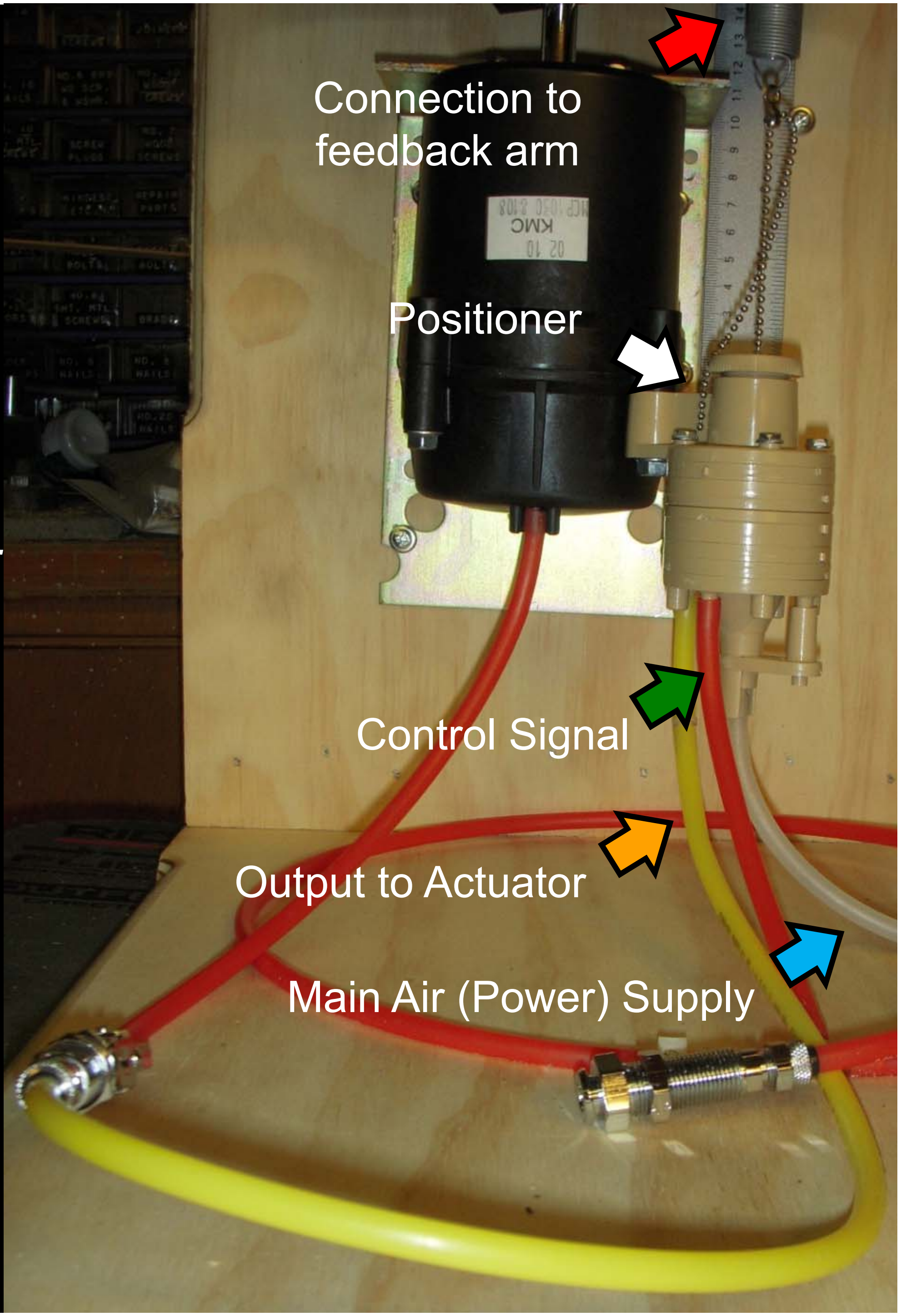
Pneumatic and Electric

- Positive positioning relays … *a.k.a "Positive positioners" a.k.a. "Positioning relay" a.k.a. "Positioners" …*

  monitor actuator motion …

  … and compare it to the desired actuator position ….

  … and "do what ever it takes" to get the actuator to move an amount that corresponds to the input change
- An independent energy source provides the power to do this

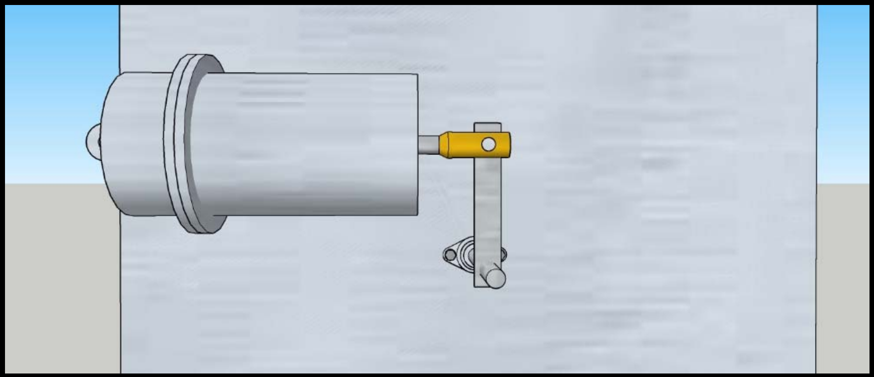


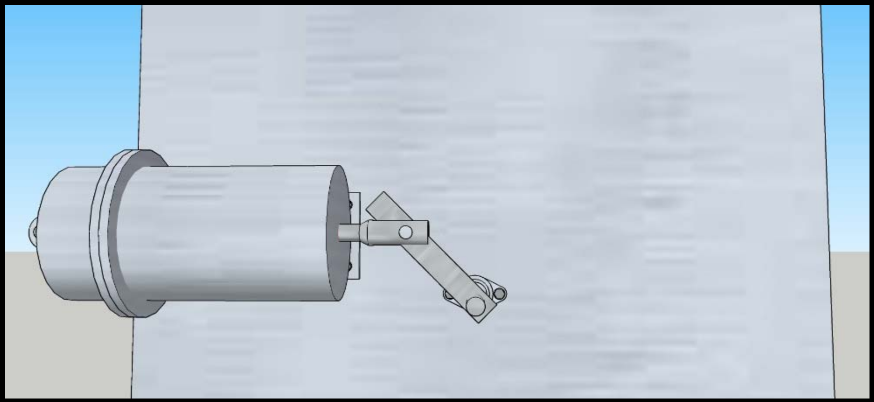
Dampers Can See Similar Variation in Power Required vs. Stroke

- Aerodynamic loads can vary with stroke
- Jamb seal loads can increase as the blades become aligned with the frame
- Blade seals require a very specific torque applied to the damper shaft to compress them and achieve rated leakage

Dampers Can See Similar Variation in Power Required vs. Stroke

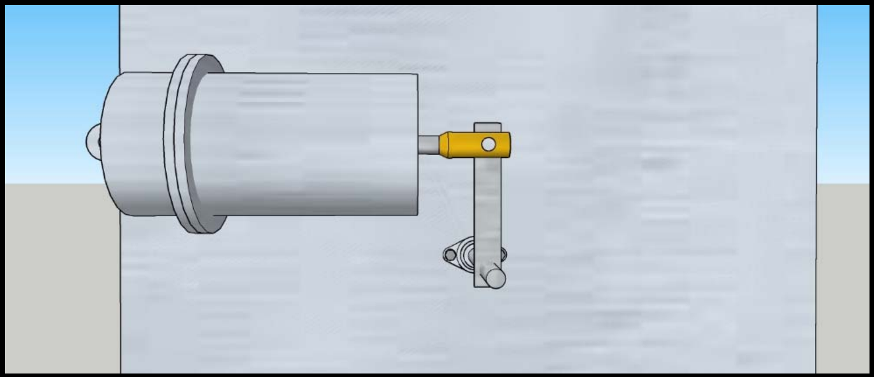
- Aerodynamic loads can vary with stroke
- Jamb seal loads can increase as the blades become aligned with the frame
- Blade seals require a very specific torque applied to the damper shaft to compress them and achieve rated leakage
- The arrangement of the crank arm and linkage will have a significant impact



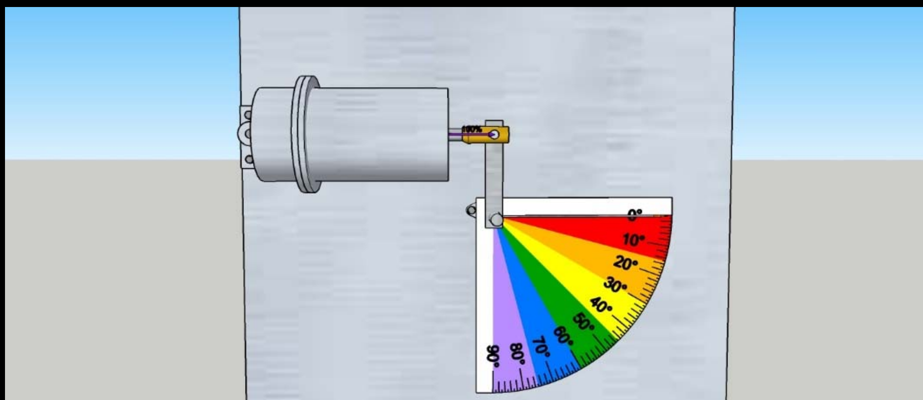


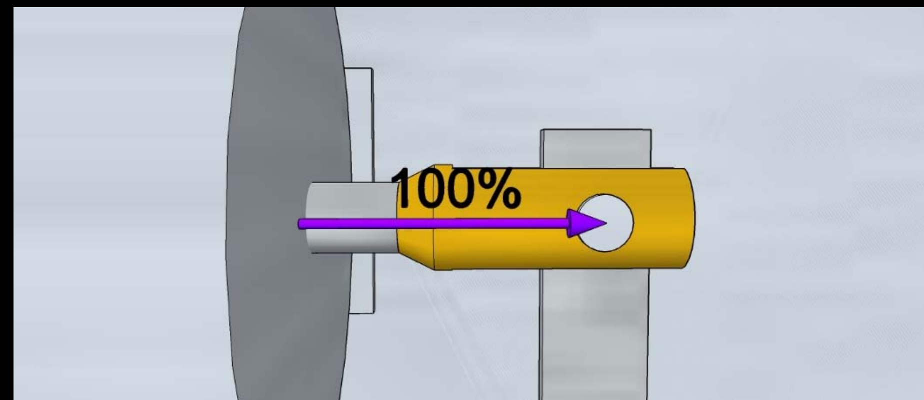
Let's Do a Break-out

- Watch the video Pneumatic Actuator Motion v1.mp4 in the Linkage Lab folder
- Note blade rotation, shaft extension and force available to produce torque
- For the 7 positions shown, document
  - Shaft extension
  - Blade rotation
  - Percent of actuator force available to produce torque
- Plot the results



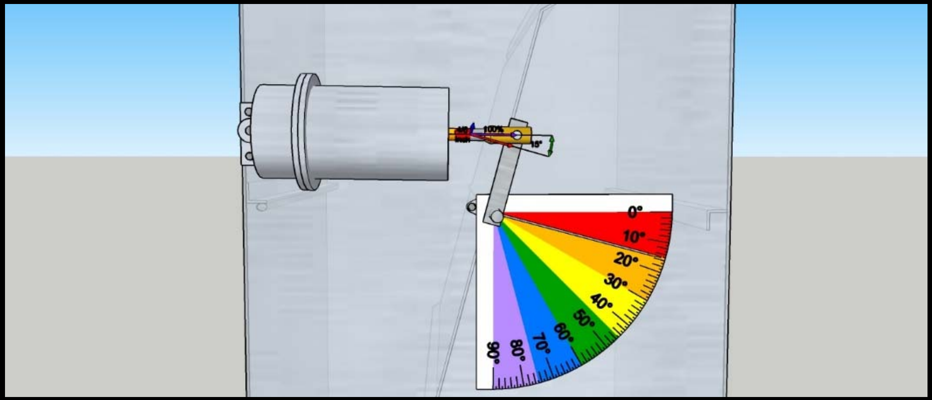
The First Point

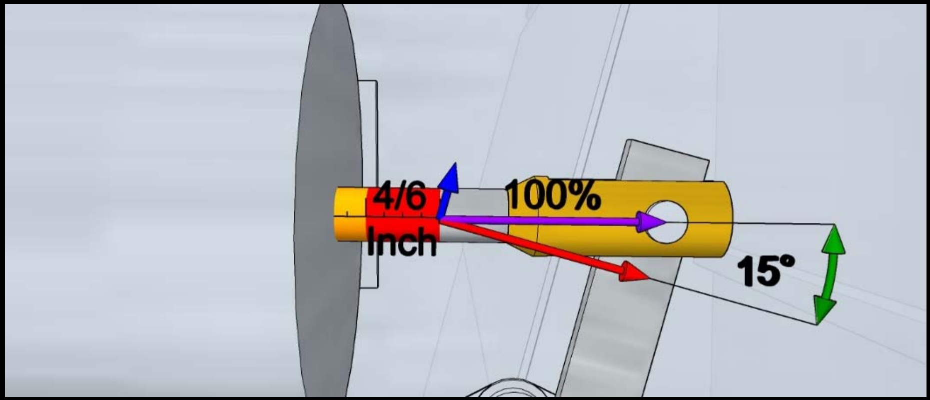




Crank Rotation, °	Shaft Extension, in.	Shaft Extension, 6ths of an inch	Angle between Shaft and Crank Centerline, °	Angle between Shaft and Crank Centerline, Radians	% of Full Stroke Damper Blade Rotation	% of Full Stroke Shaft Extension	% of Actuator Force Available to Produce Torque	Straight Line, 6ths of an inch
0	0	0.00	90	1.5708	0.00%	0.00%	100%	0.00

The First Point





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15	59/64	5.53	15	0.2618	16.67%	23.05%	97%	0.67

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Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

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Control Process	Logic and mechanisms that tries to bring the controlled variable into agreement with the set point

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Digital Logic

Digital Logic

Boolean Algebra; The Fundamental Principle Behind Computer Logic

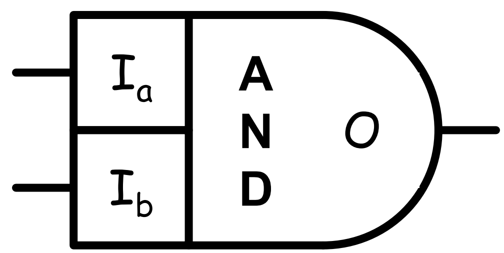
- Boolean algebra is the algebra of two values
  - 0 and 1
  - True and False
  - On and Off
- Computers are machines that "think" using two values
- Boolean algebra can represent how computers think
- "Truth tables" represent the result of Boolean operations

AND truth table and logic symbol

I_a	I_b	$O = I_a . I_b$
F	F	F
F	T	F
T	F	F
T	T	T

Possible Input States

Result



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T	F	T
T	T	T

Possible Input States

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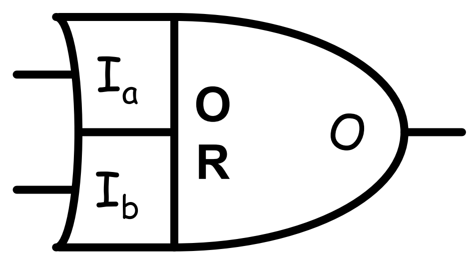

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T	F	T
T	T	T

Possible Input States

Result

For more information on Boolean Logic see Chapter 2 of The Art of Assembly Language; http://homepage.mac.com/randyhyde/webster.cs.ucr.edu/www.artofasm.com/DOS/pdf/ch02.pdf

Relay Logic = A Form of Boolean Algebra

Open Contact = False; Closed Contact = True

Relay Logic **AND**

Both contacts have to be closed to get current from A to B

AND truth table

I_a	I_b	$O=I_a.I_b$
F	F	F
F	T	F
T	F	F
T	T	T

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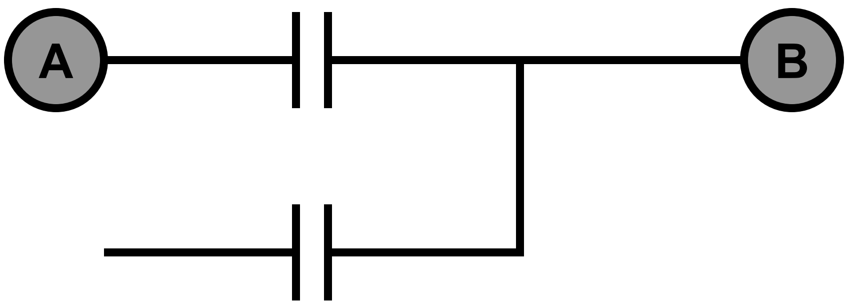
Relay Logic **OR**



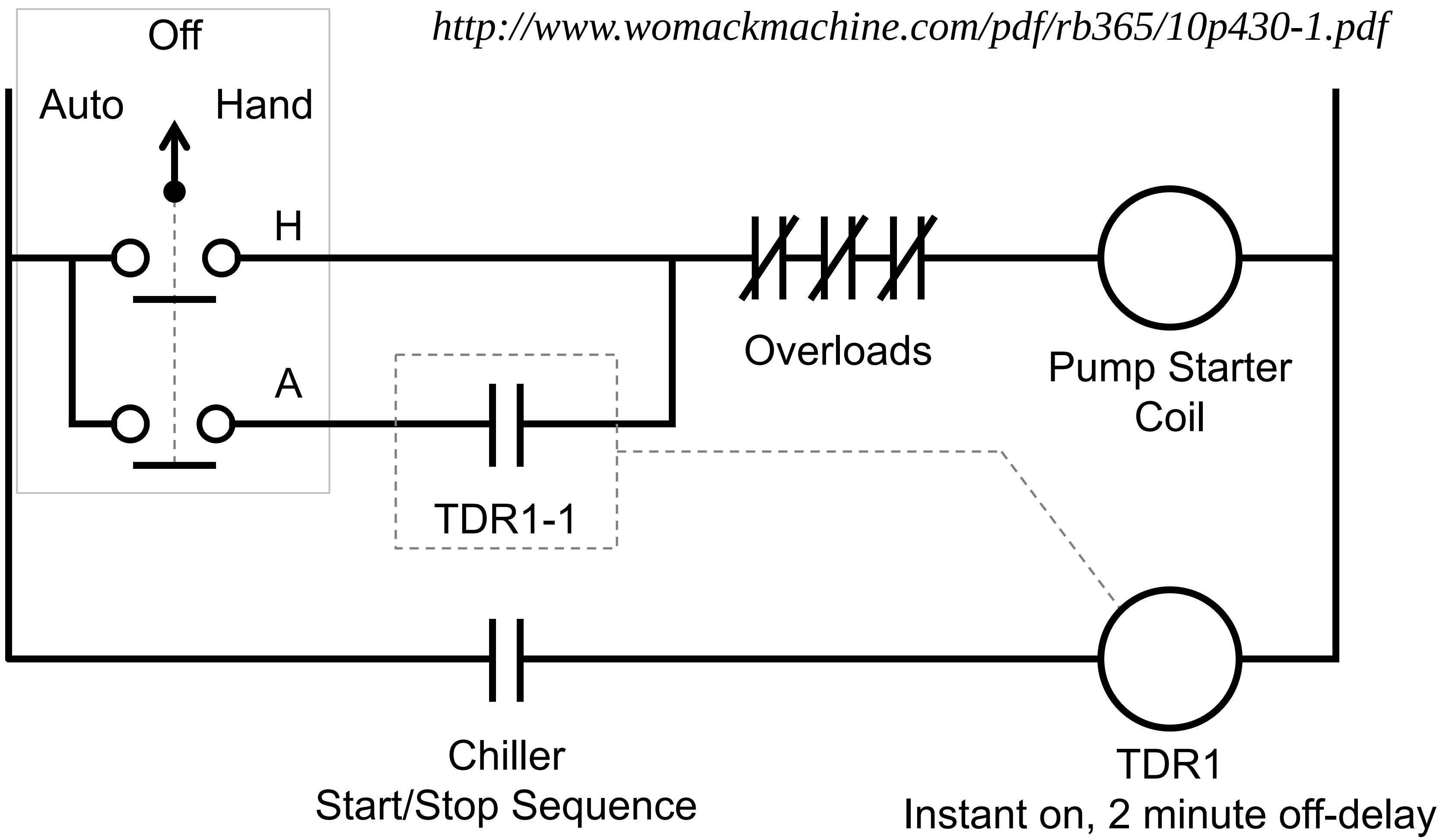
Either or both contacts being closed will get current from A to B

OR truth table

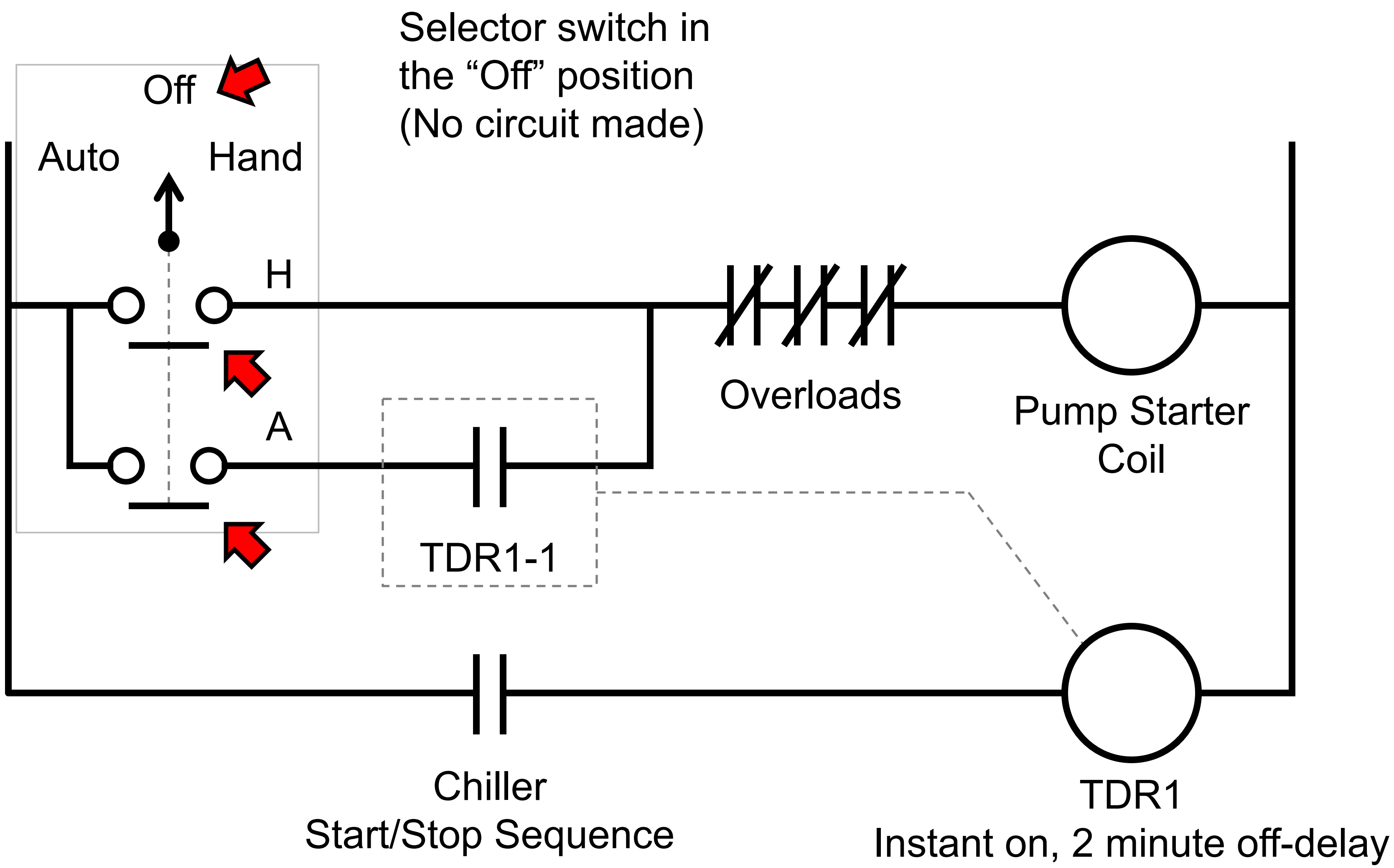
I_a	I_b	$O=I_a+I_b$
F	F	F
F	T	T
T	F	T
T	T	T

Controlling an Evaporator Pump with Relay Logic

JIC (Joint Industry Council) ladder diagram symbol list available from Womack Machine Supply Co. website at http://www.womackmachine.com/pdf/rb365/10p430-1.pdf



Controlling an Evaporator Pump with Relay Logic



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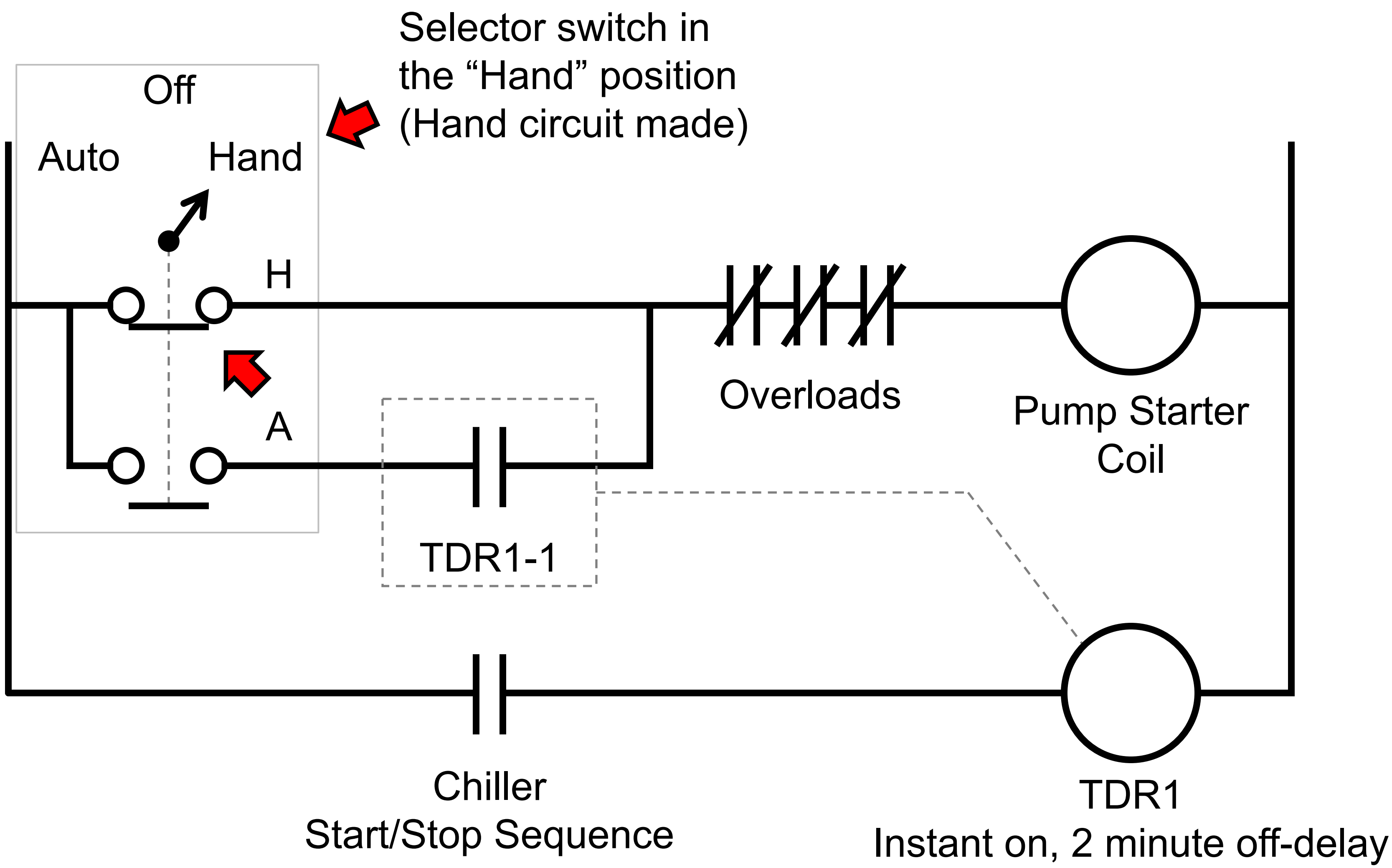

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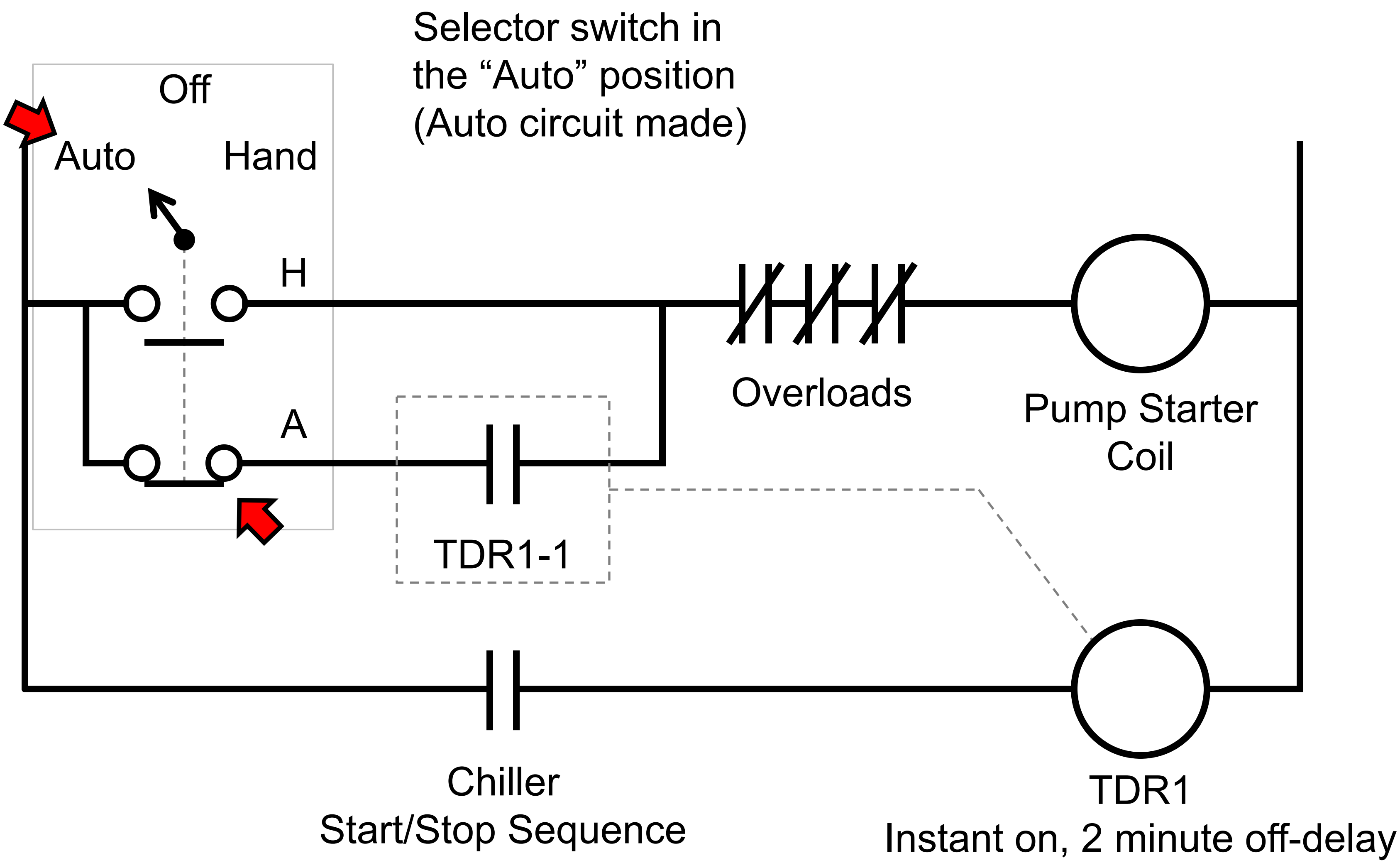

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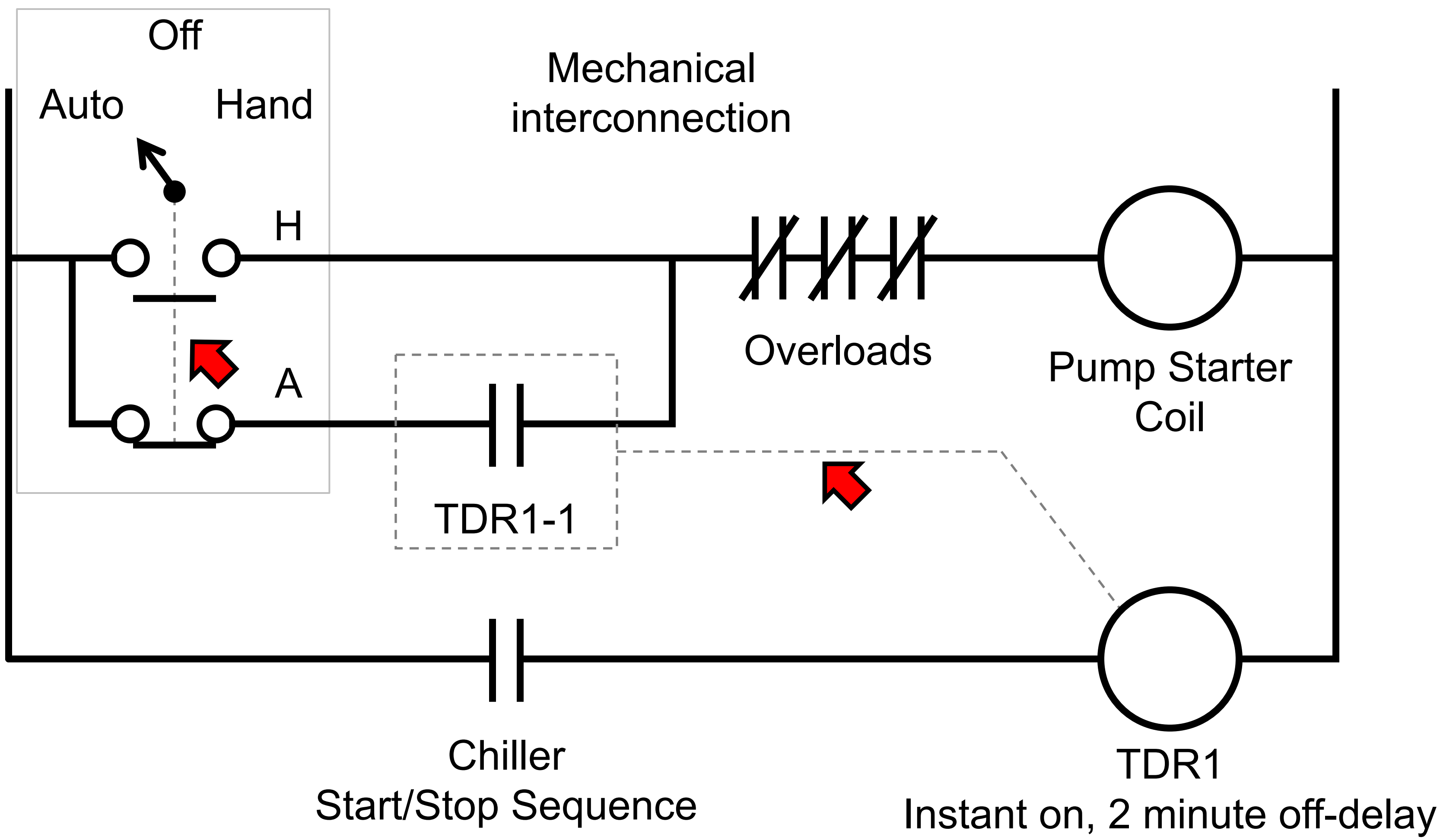

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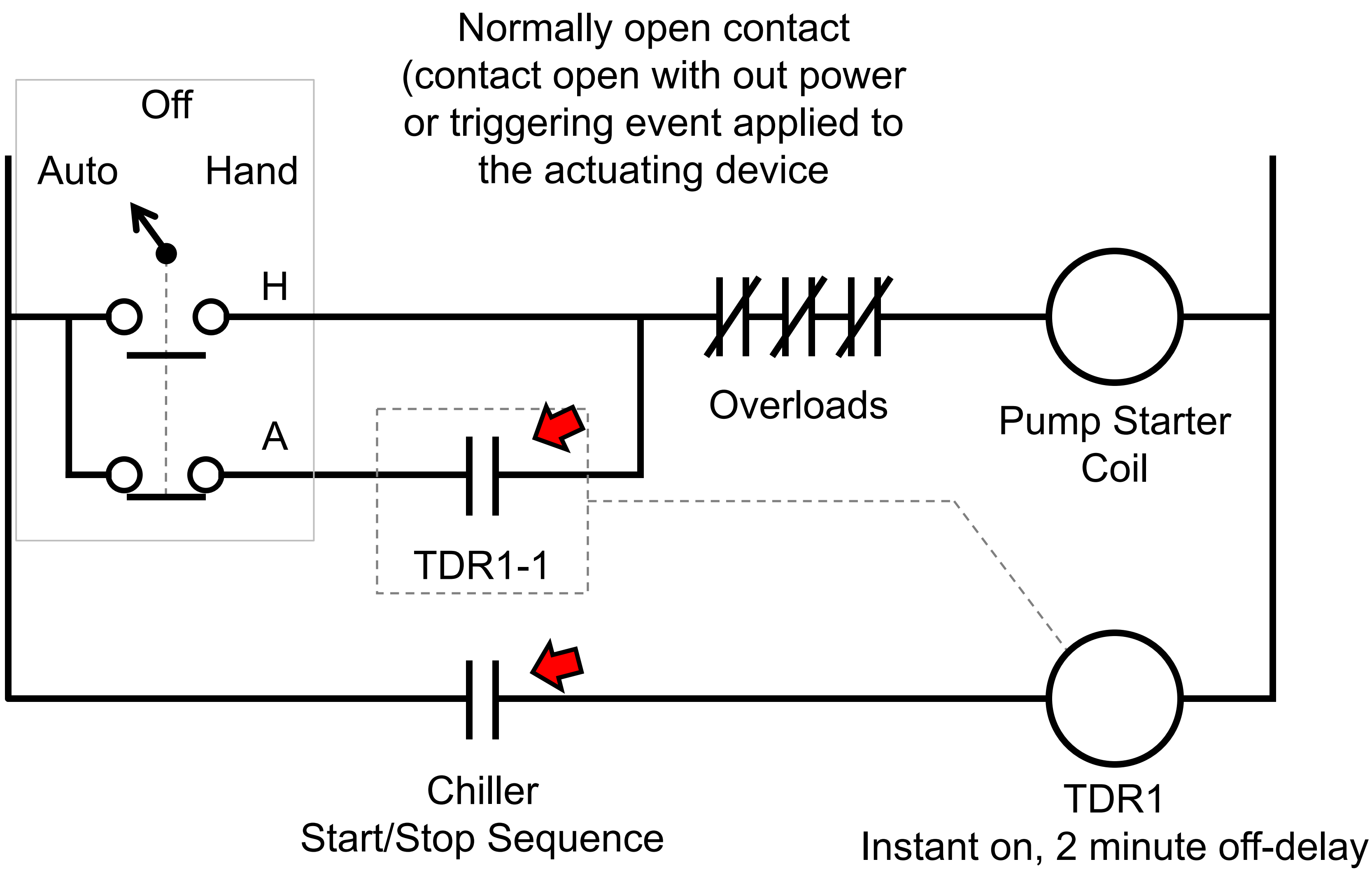

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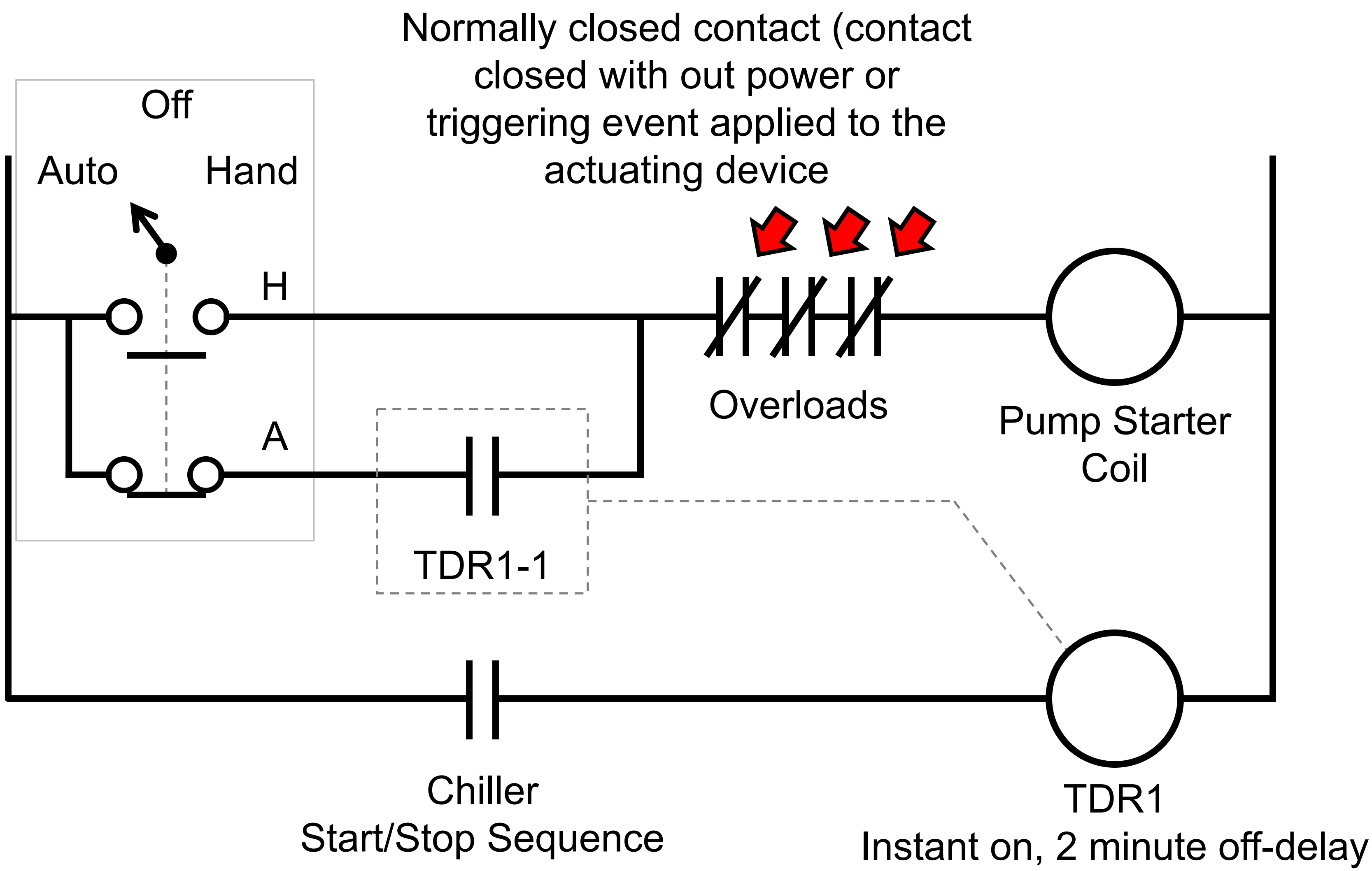

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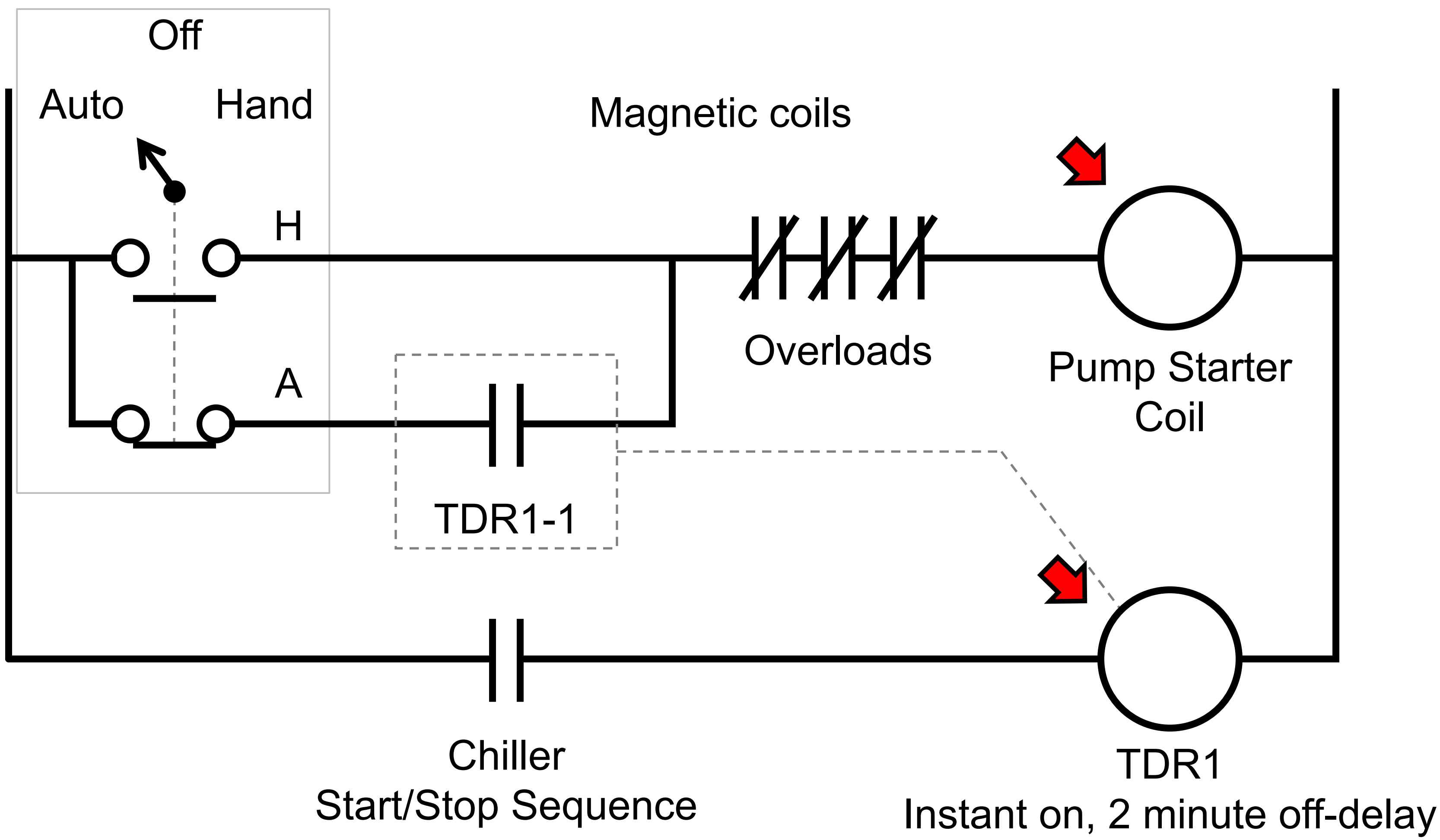
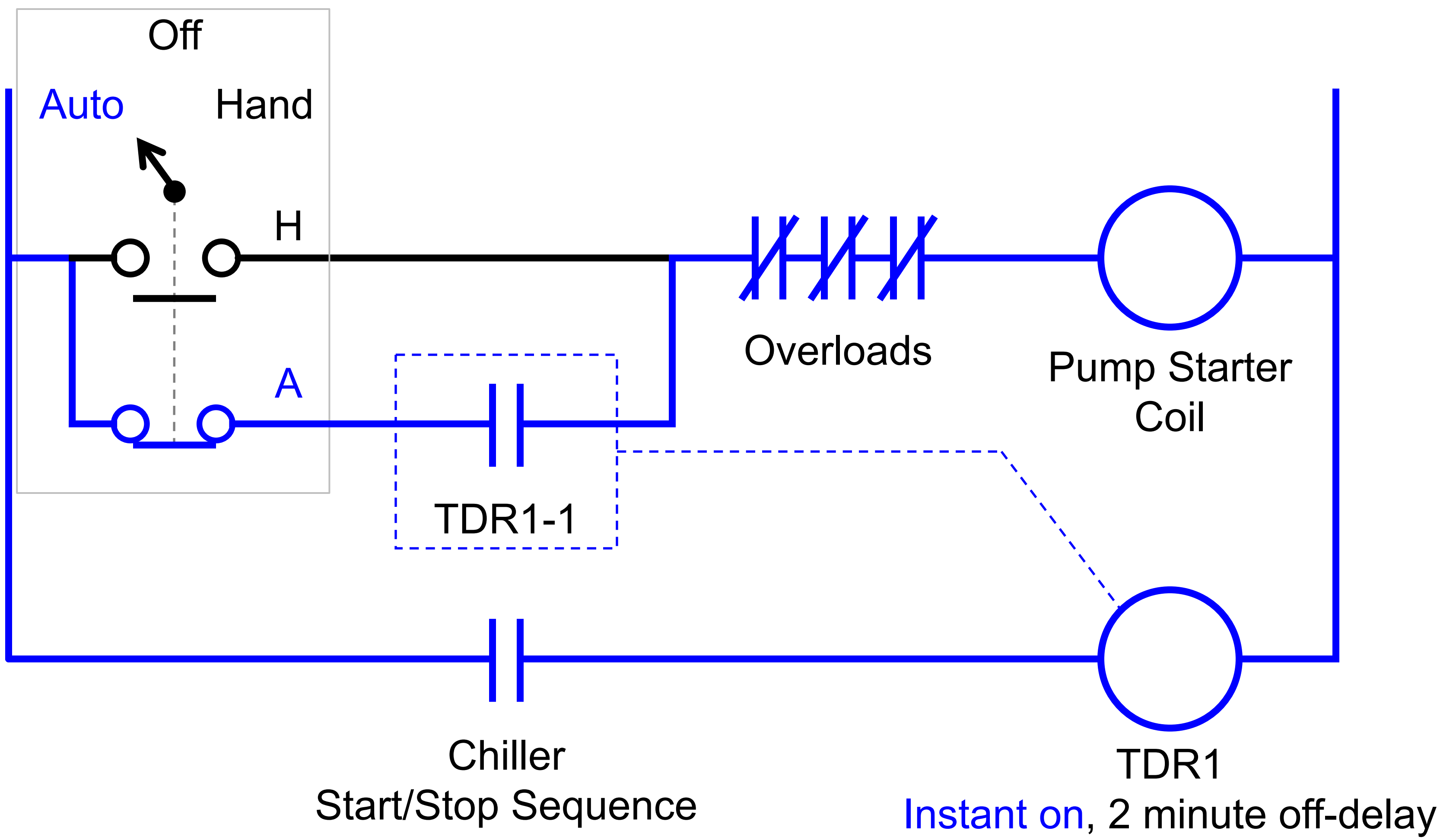


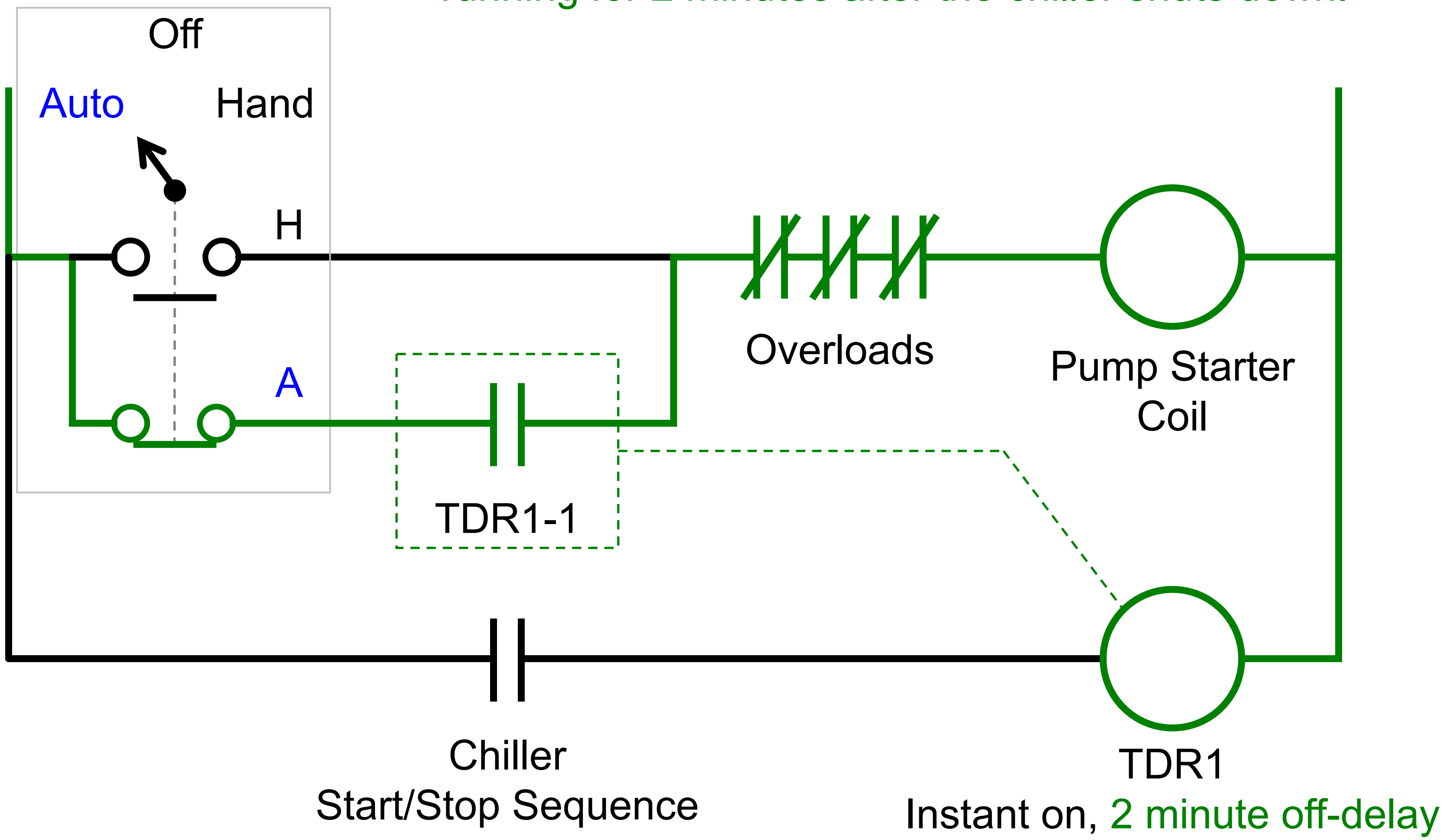
Controlling an Evaporator Pump with Relay Logic

Design Intent: In “Auto”, start the pump when required by the chiller start sequence.



Controlling an Evaporator Pump with Relay Logic

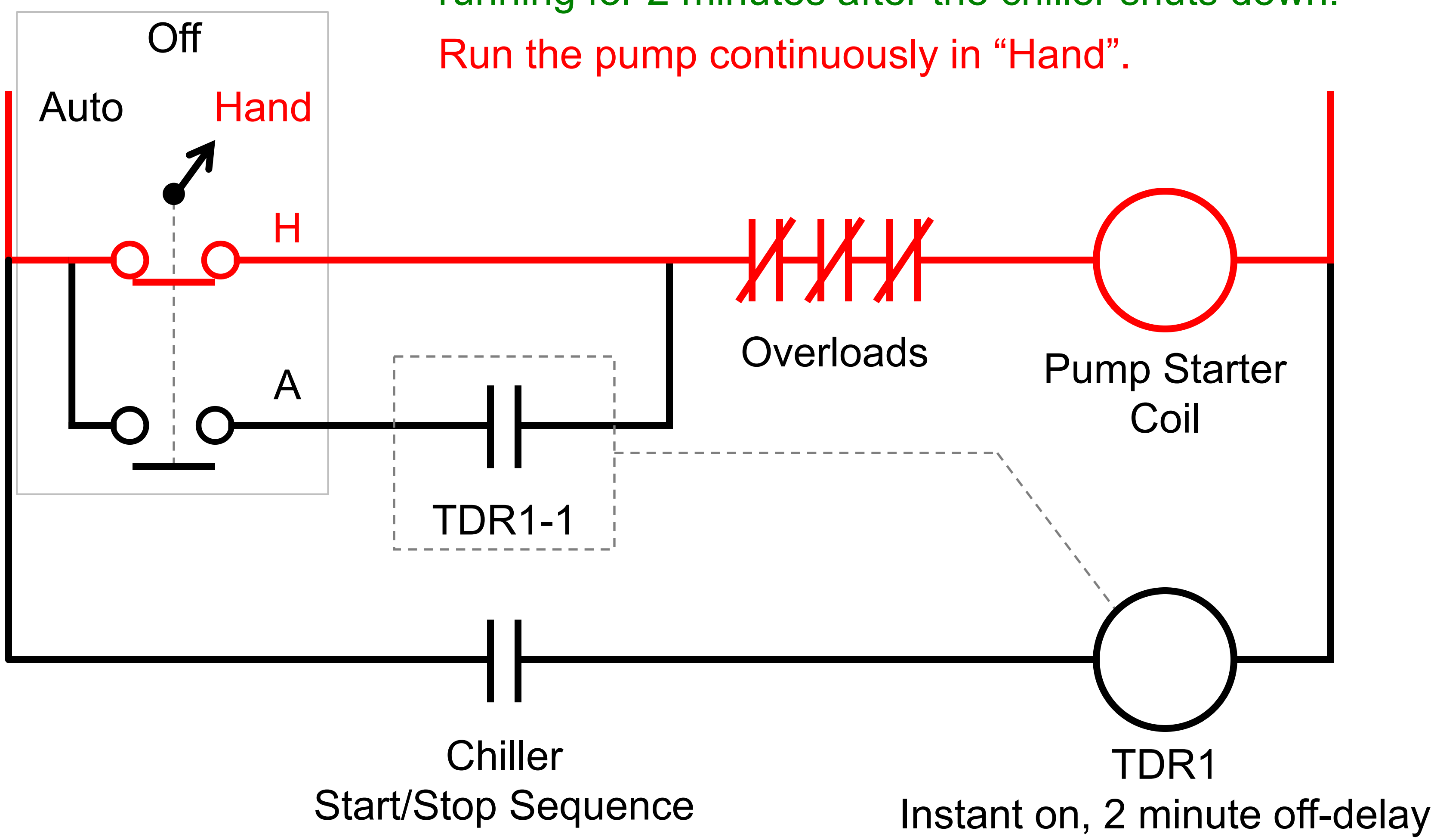
Design Intent: In "Auto", start the pump when required by the chiller start sequence. Keep it running for 2 minutes after the chiller shuts down.



Controlling an Evaporator Pump with Relay Logic

Design Intent: In “Auto”, start the pump when required by the chiller start sequence. Keep it running for 2 minutes after the chiller shuts down.

Run the pump continuously in “Hand”.

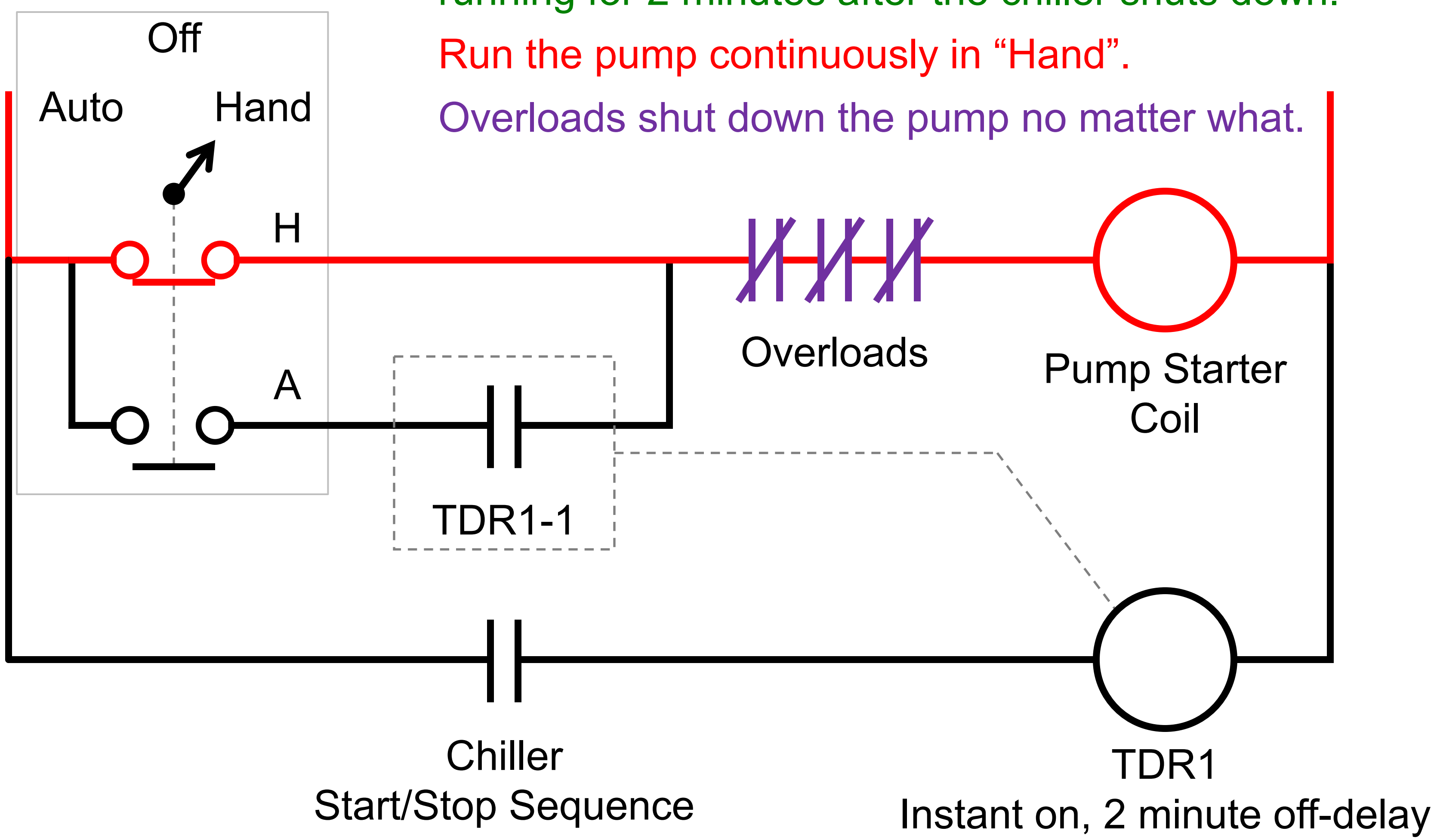


Controlling an Evaporator Pump with Relay Logic

Design Intent: In "Auto", start the pump when required by the chiller start sequence. Keep it running for 2 minutes after the chiller shuts down.

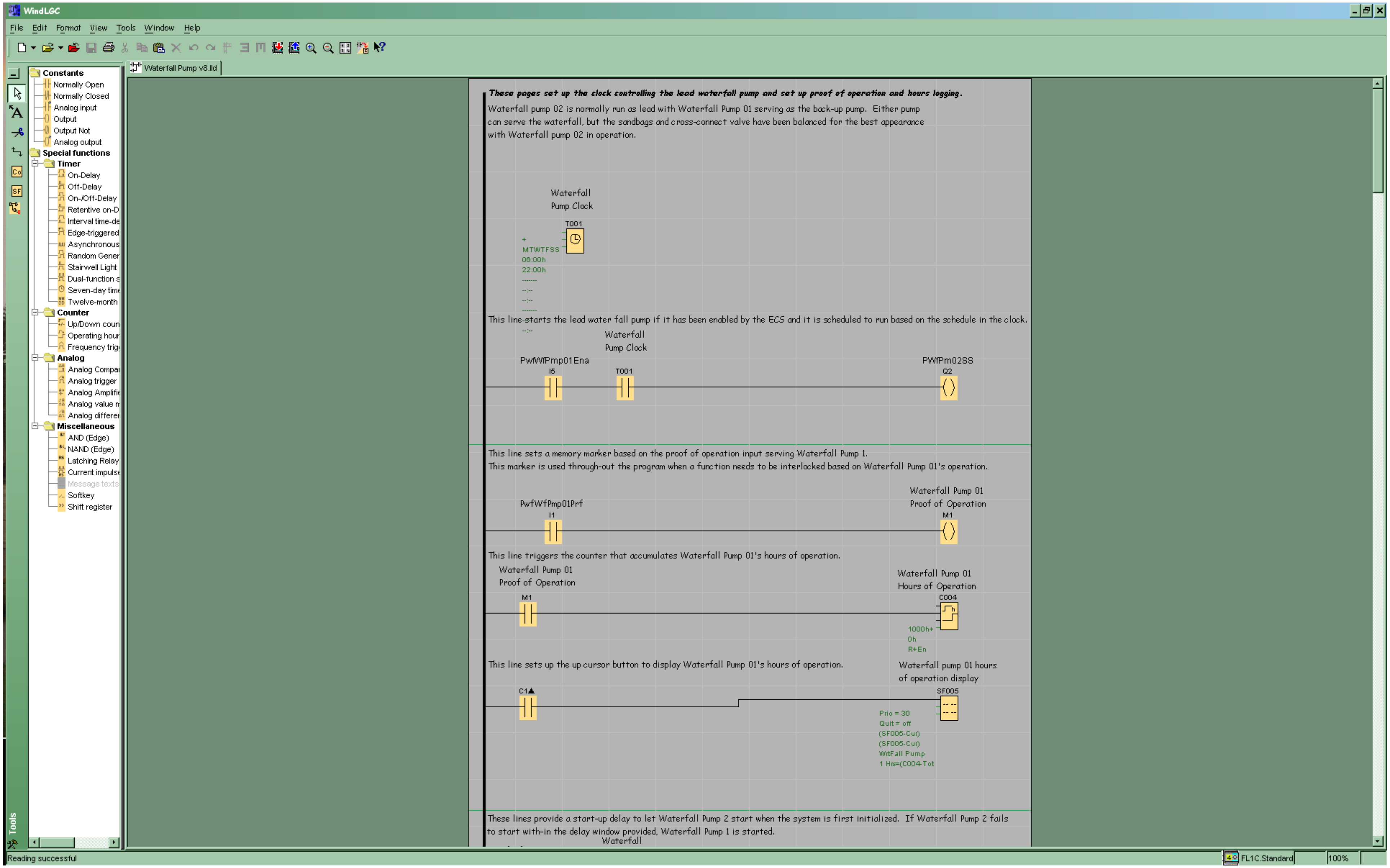
Run the pump continuously in "Hand".

Overloads shut down the pump no matter what.

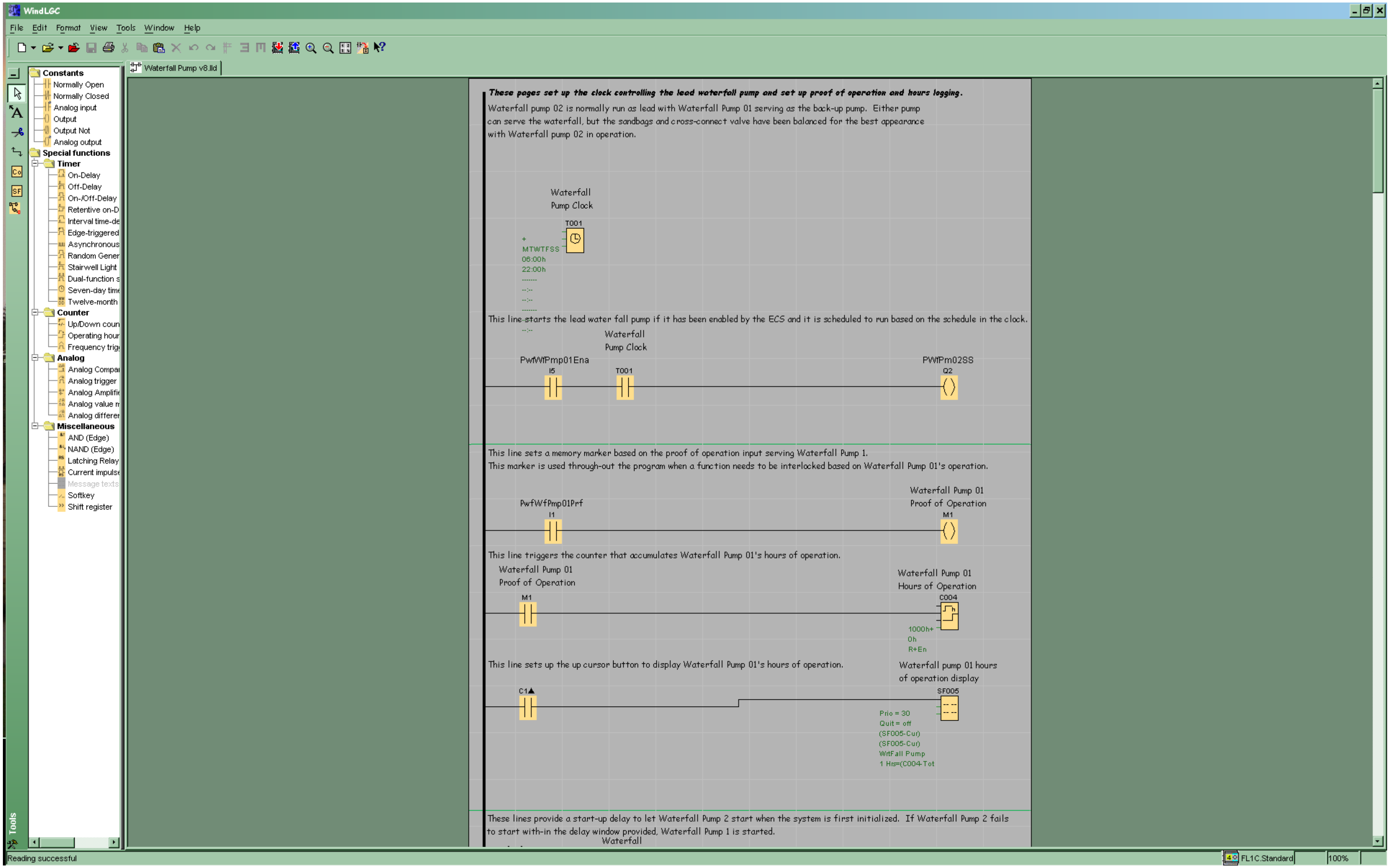


Programmable Logic Controllers (PLCs) Use Ladder Diagram Symbols to Write Programs

IDEC SmartRelay Program Controlling a Water Feature

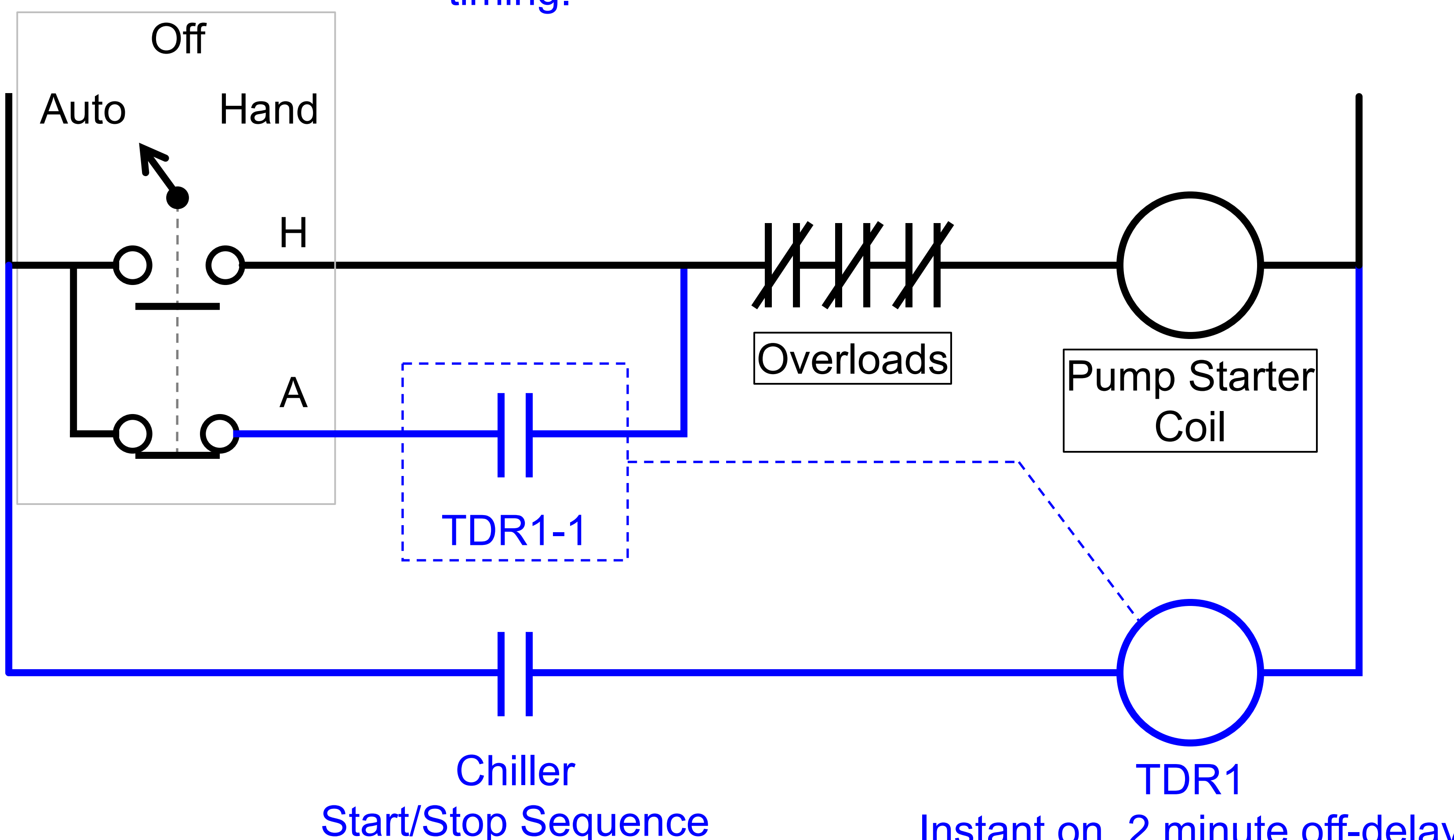


IDEC SmartRelay Program Controlling a Water Feature



Controlling an Evaporator Pump with Relay Logic

In current technology DDC systems, computer logic has taken over much of the automation and timing.



Controlling an Evaporator Pump with Relay Logic

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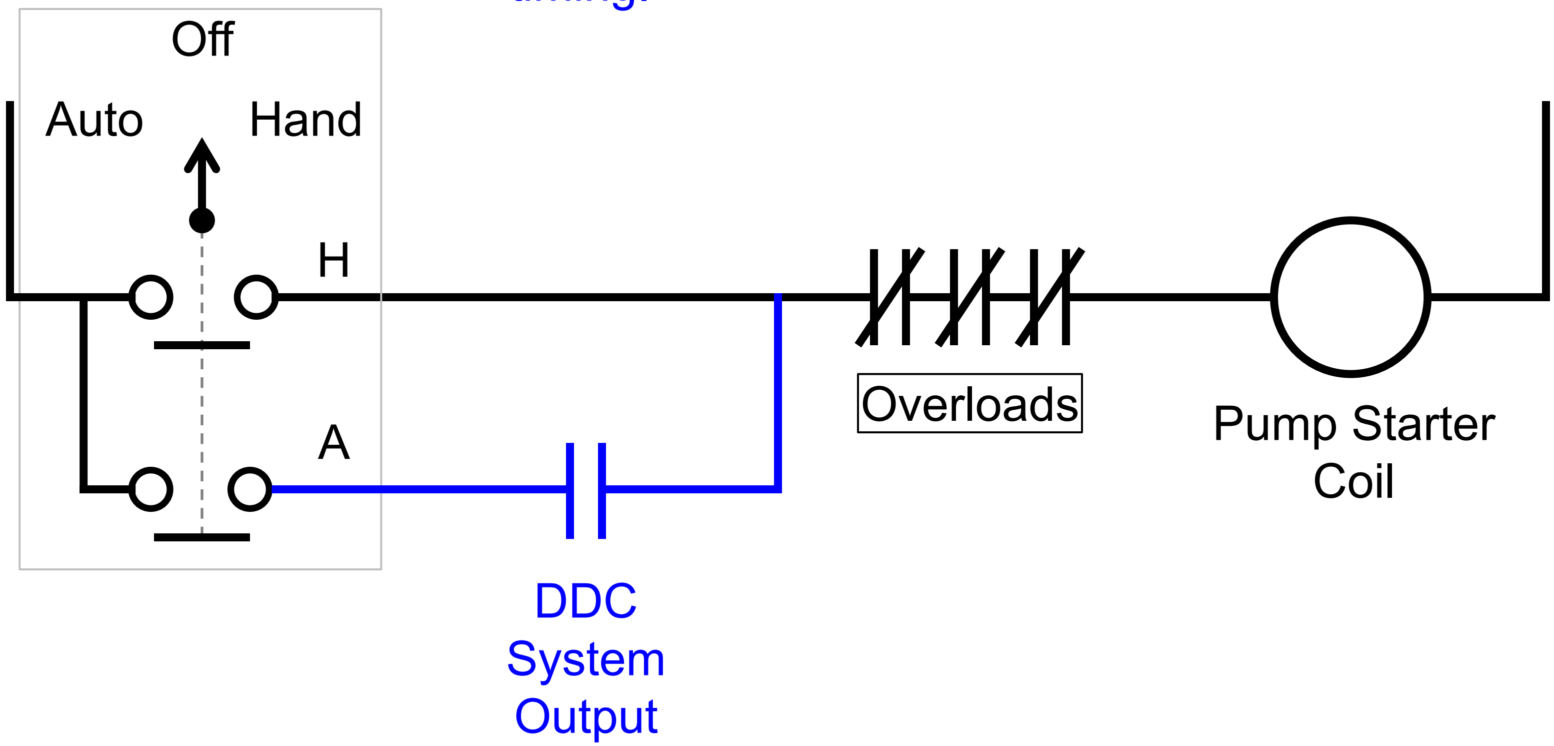
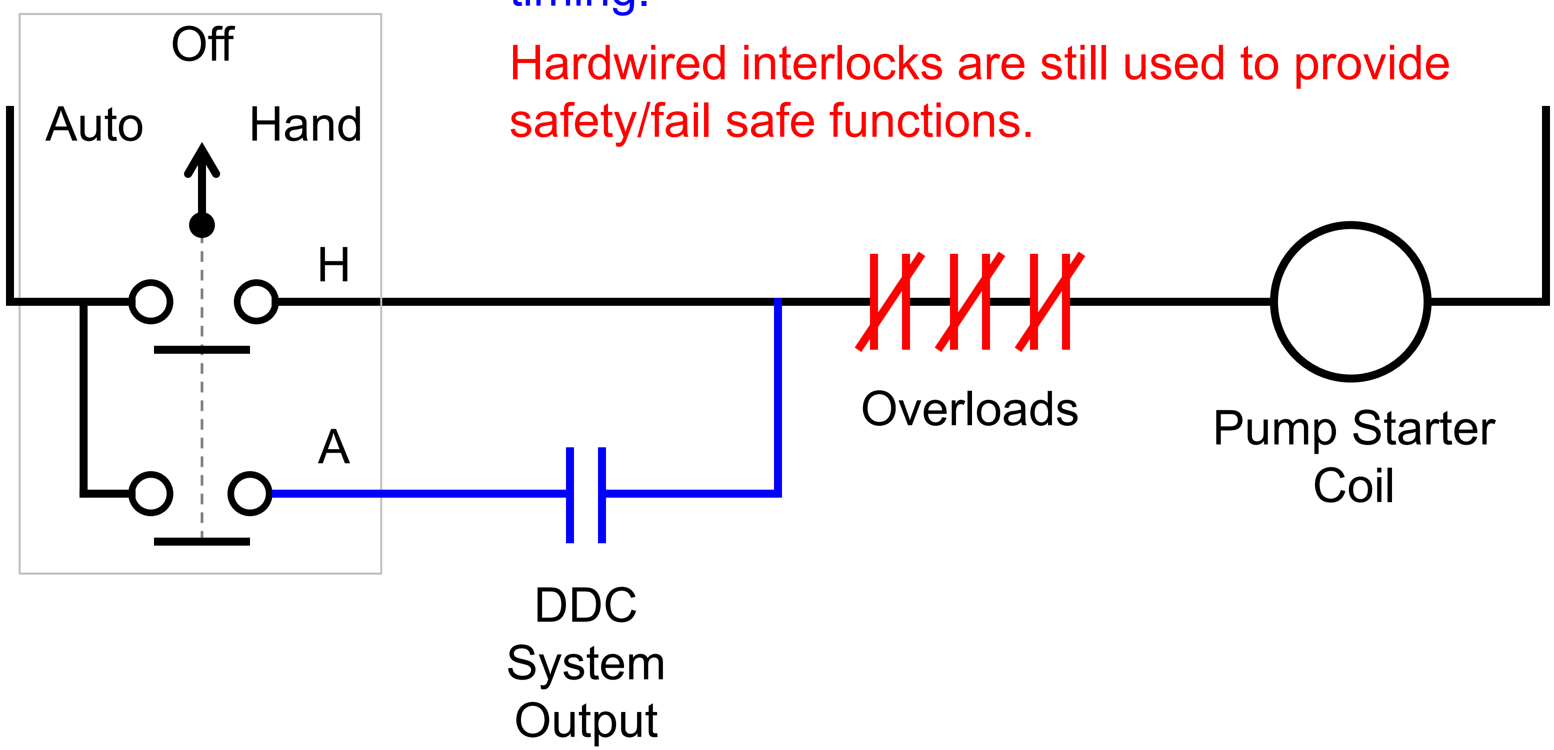
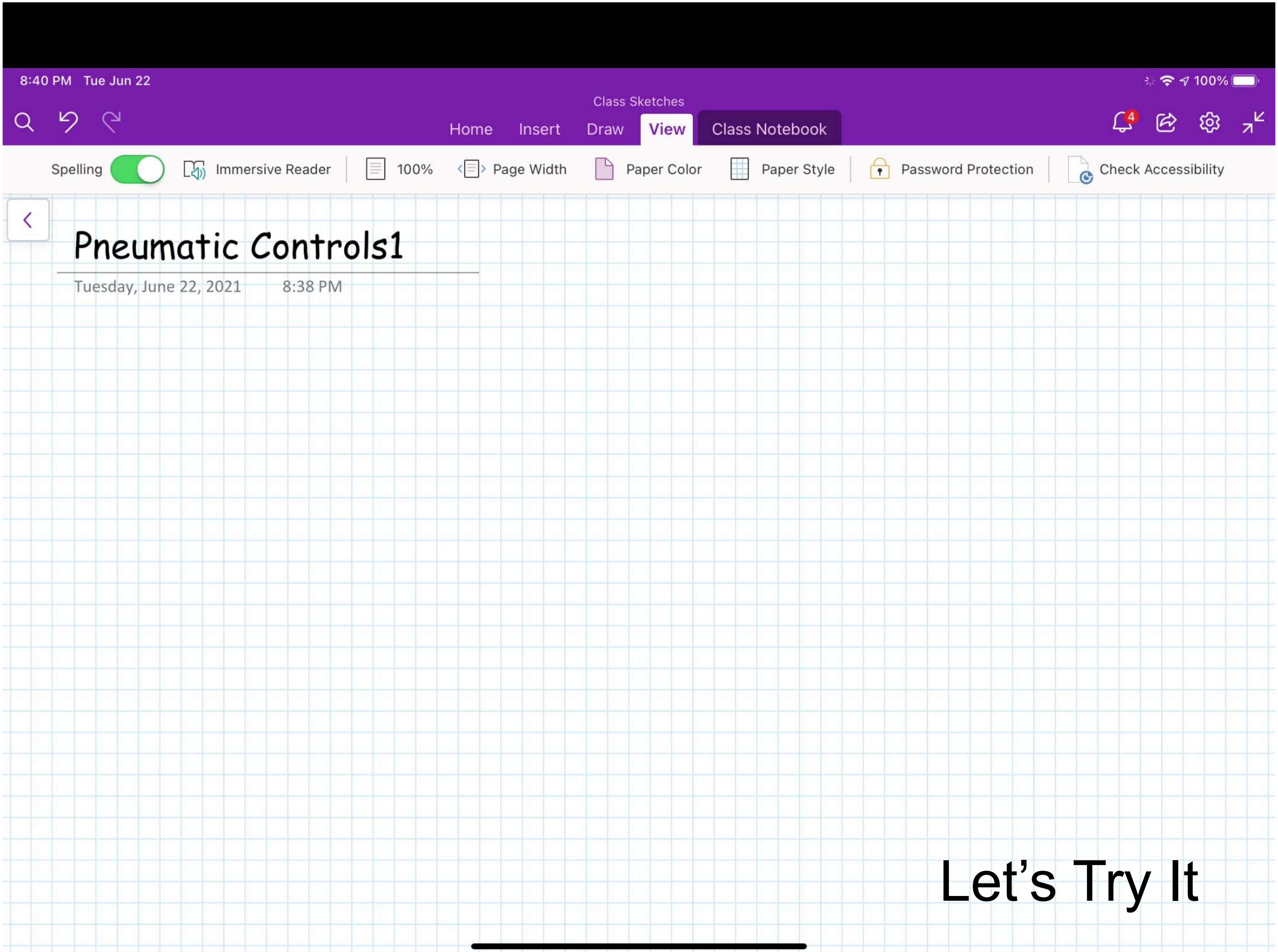


Controlling an Evaporator Pump with Relay Logic

In current technology DDC systems, computer logic has taken over much of the automation and timing.

Hardwired interlocks are still used to provide safety/fail safe functions.




8:40 PM Tue Jun 22
100%
Class Sketches
Home
Insert
Draw
View
Class Notebook
4
Spelling
Immersive Reader
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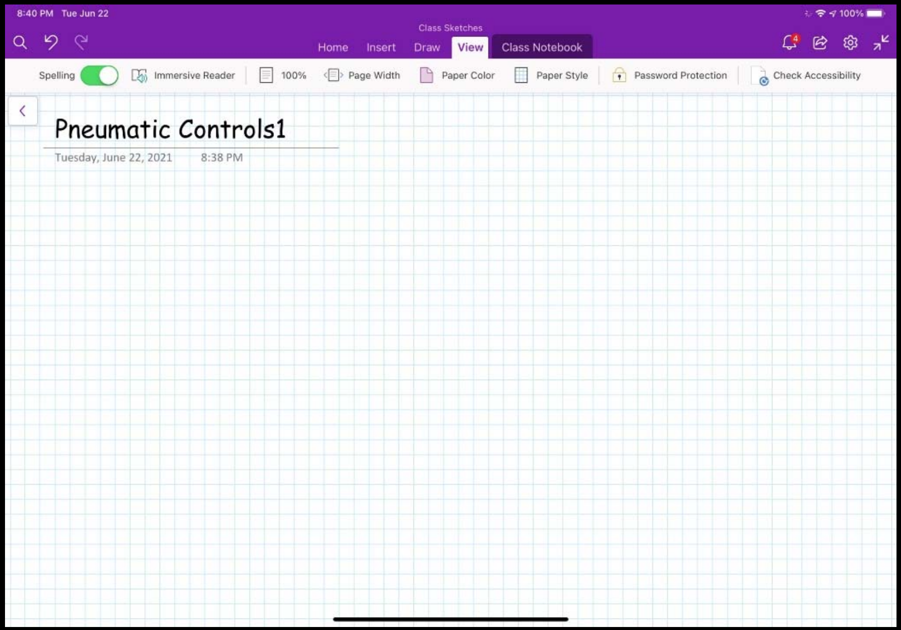
Page Width
Paper Color
Paper Style
Password Protection
Check Accessibility
Pneumatic Controls1
Tuesday, June 22, 2021
8:38 PM

Let's Try It

Let’s Try It in a Break-out Session

Consider a typical AHU

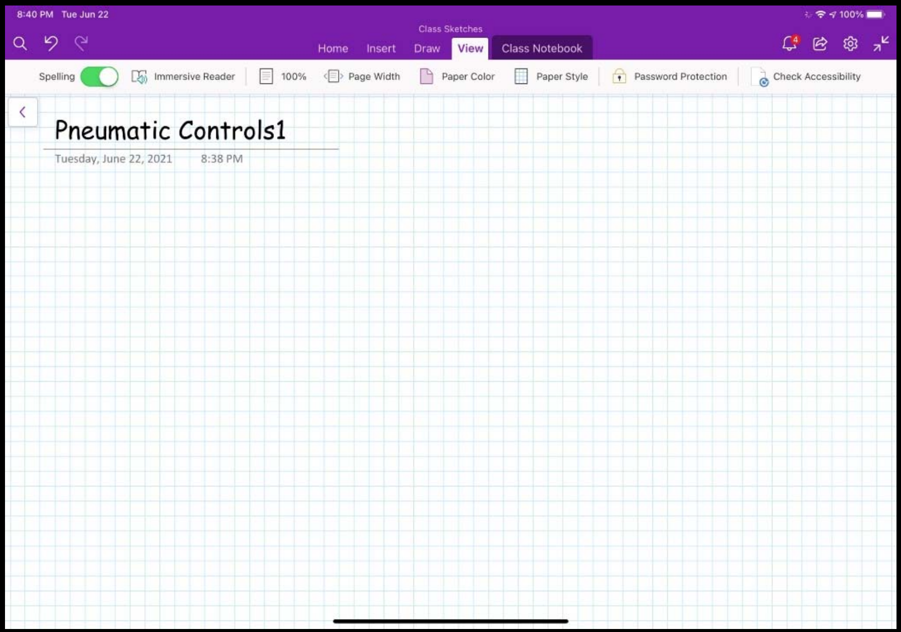
- Economizer equipped
- Variable air volume
- Chilled water cooling
- Hot water warm-up and reheat
- Serving a commercial office building



Let’s Try It in a Break-out Session

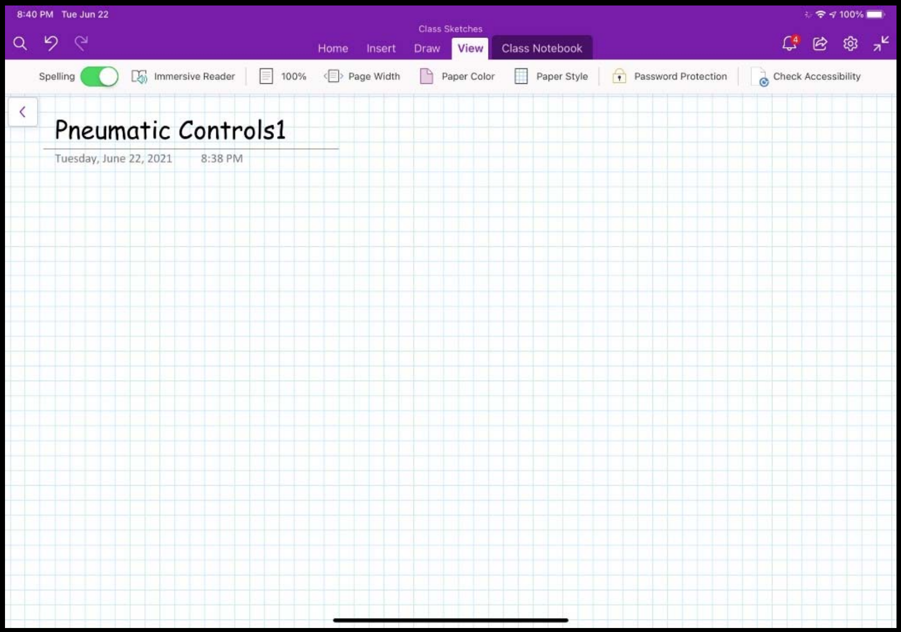
What would the interlock circuit logic need to address?

- Schedule?
- Override?
- Safeties?
- Set-back/Set-up?



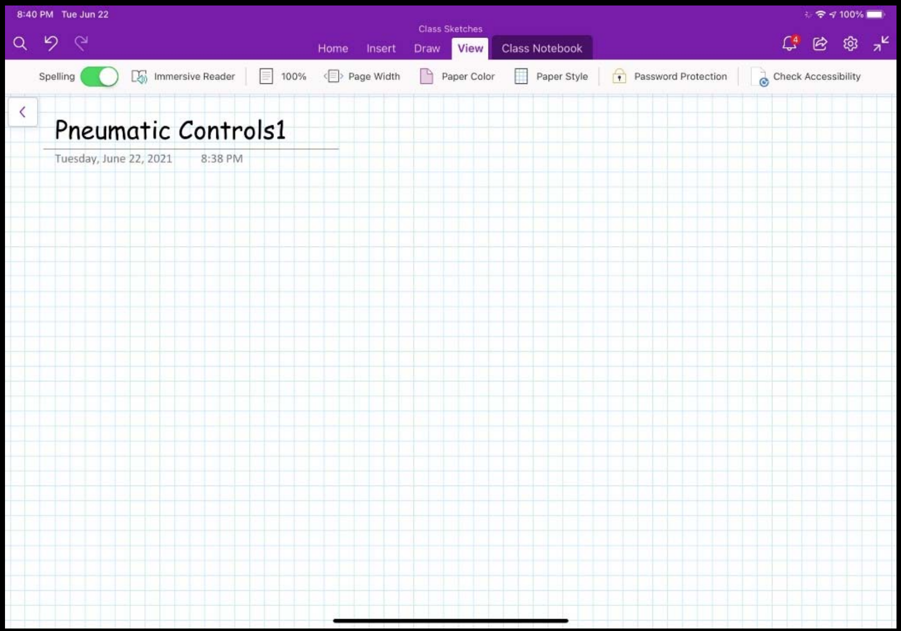
Let’s Try It in a Break-out Session

- What functions would be “OR”?
- What functions would be “AND”?
- What functions would be in the “AUTO” leg of the circuit?
- What functions would be common to “HAND” and “AUTO”



Let’s Try It in a Break-out Session

1. Write a bullet point narrative and be prepared to share your thoughts when we com back together
2. I will work with you to sketch the interlock circuit interactively based on your ideas



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Class Sketches

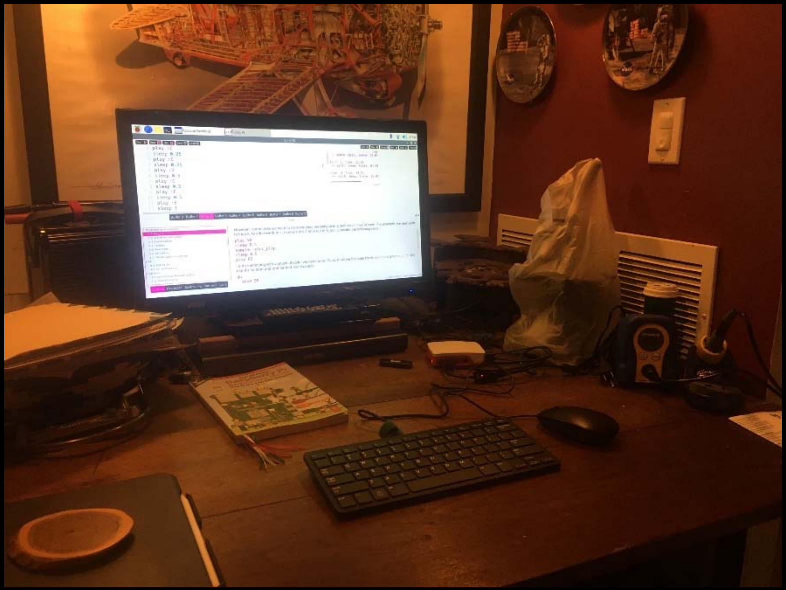
Home Insert Draw View Class Notebook

Spelling Immersive Reader 100% Page Width Paper Color Paper Style Password Protection Check Accessibility

Pneumatic Controls1

Tuesday, June 22, 2021 8:38 PM

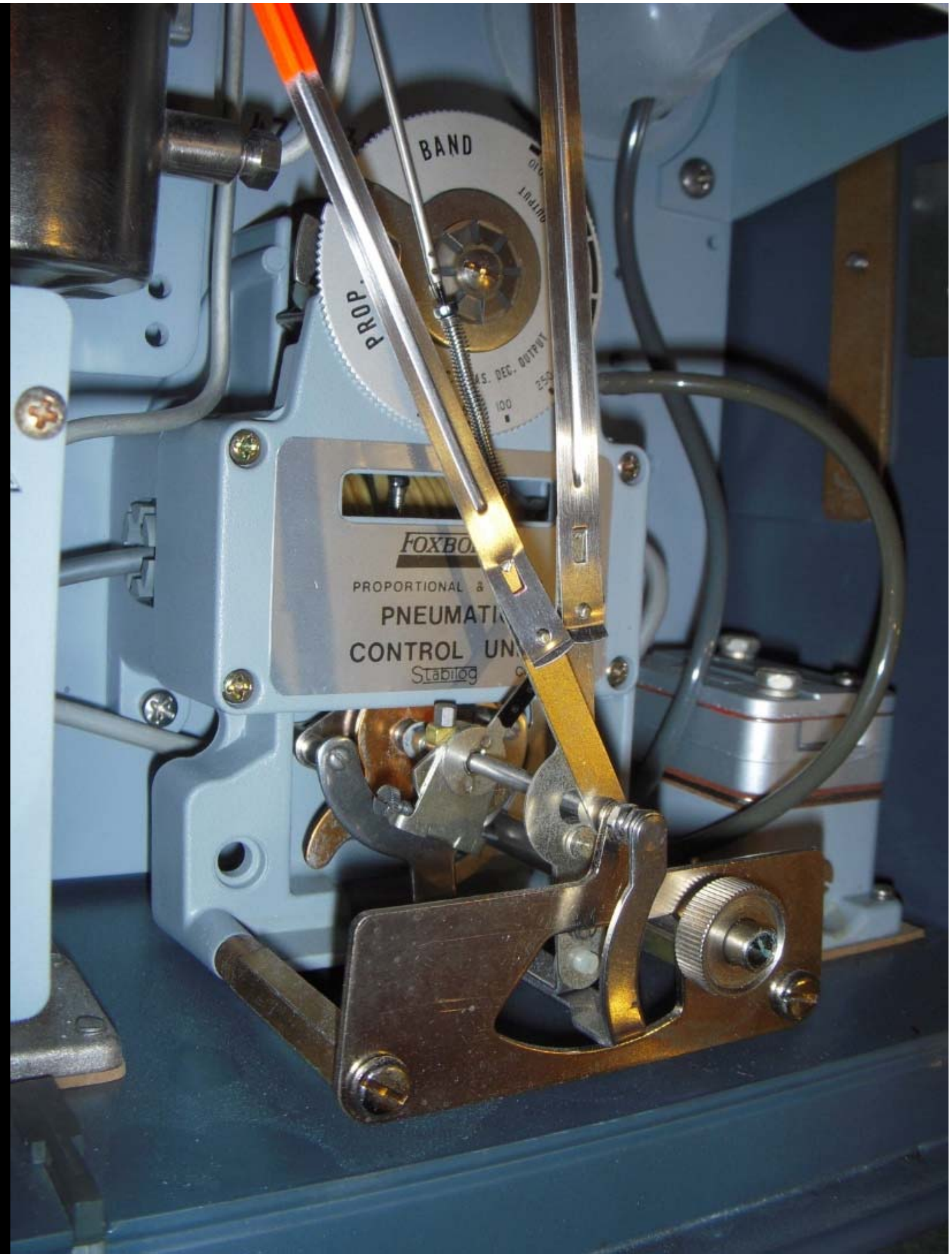
Digital Logic



Learn by doing

- https://av8rdas.wordpress.com/2011/12/04/learning-about-relay-logic-build-your-very-own-jeopardy-game/
- https://av8rdas.wordpress.com/2011/12/19/making-a-jeopardy-game-board-in-powerpoint-to-supplement-your-light-and-buzzer-system-and-learning-a-bit-about-powerpoint-templates/
- https://www.raspberrypi.org/

Analog Logic



A Long, Long, Time Ago, in a Galaxy Far, Far, Away, Logic Was a Physical Thing

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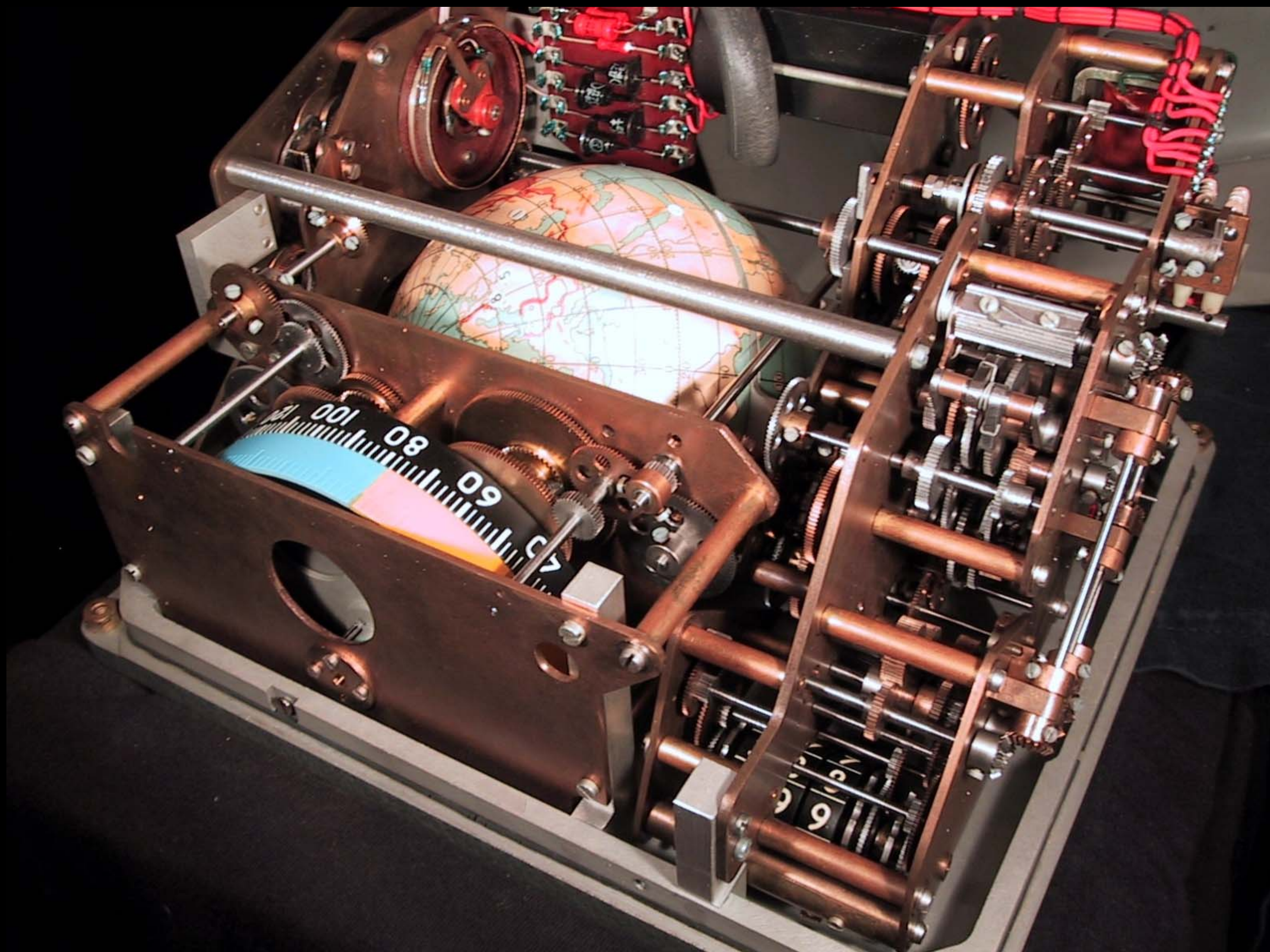

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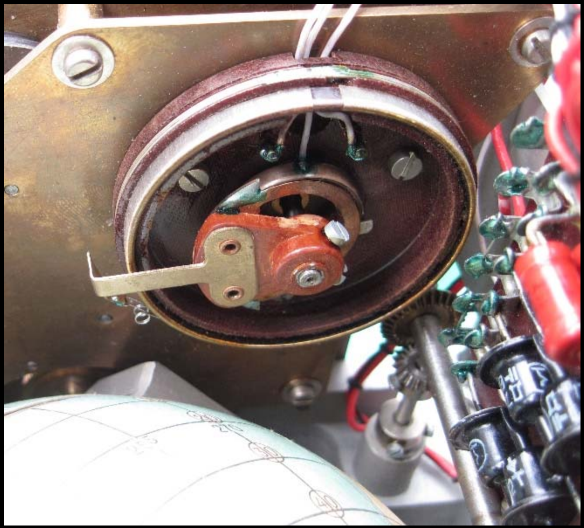

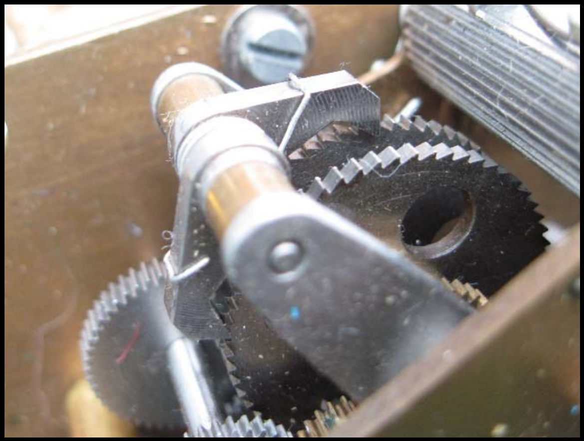

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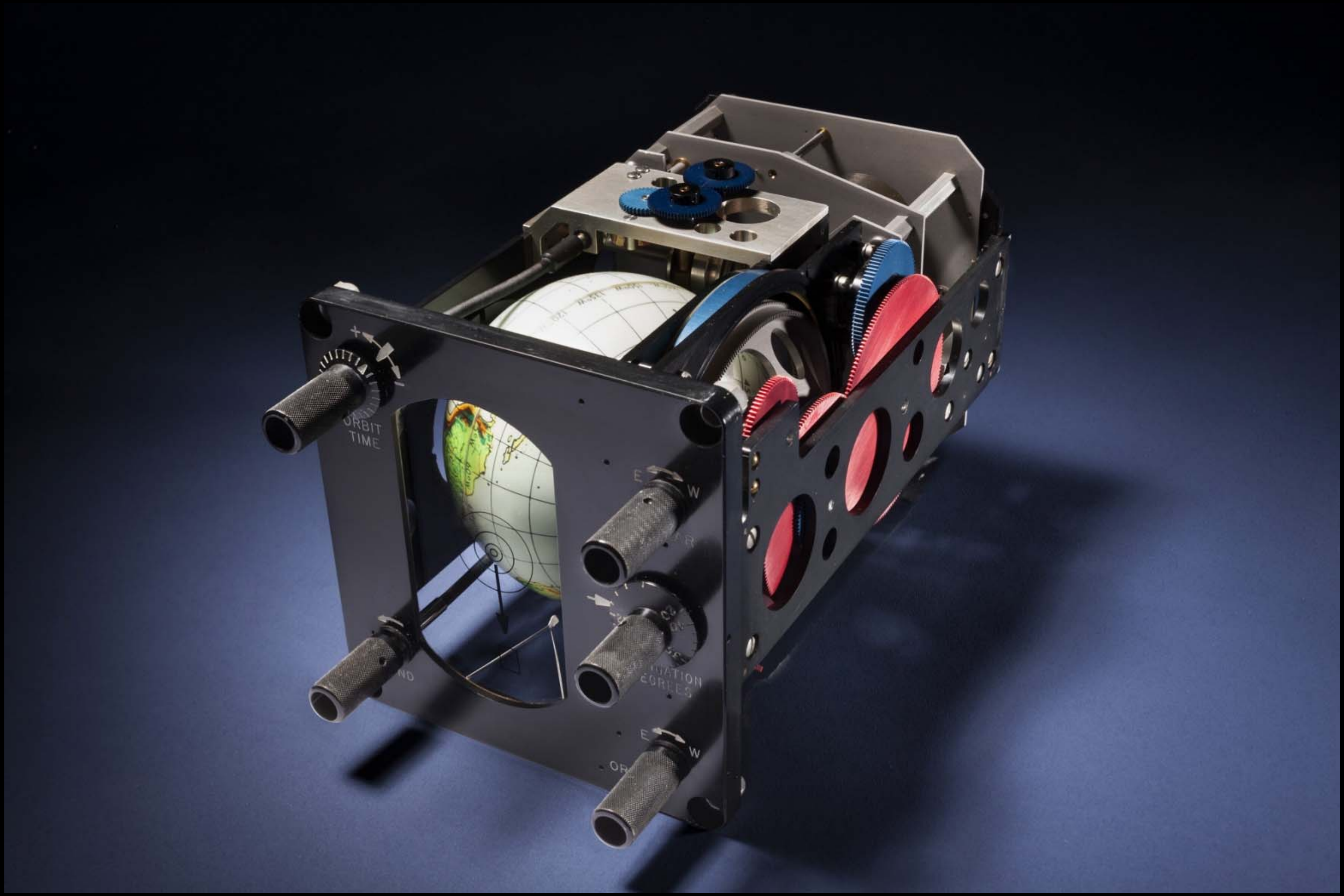
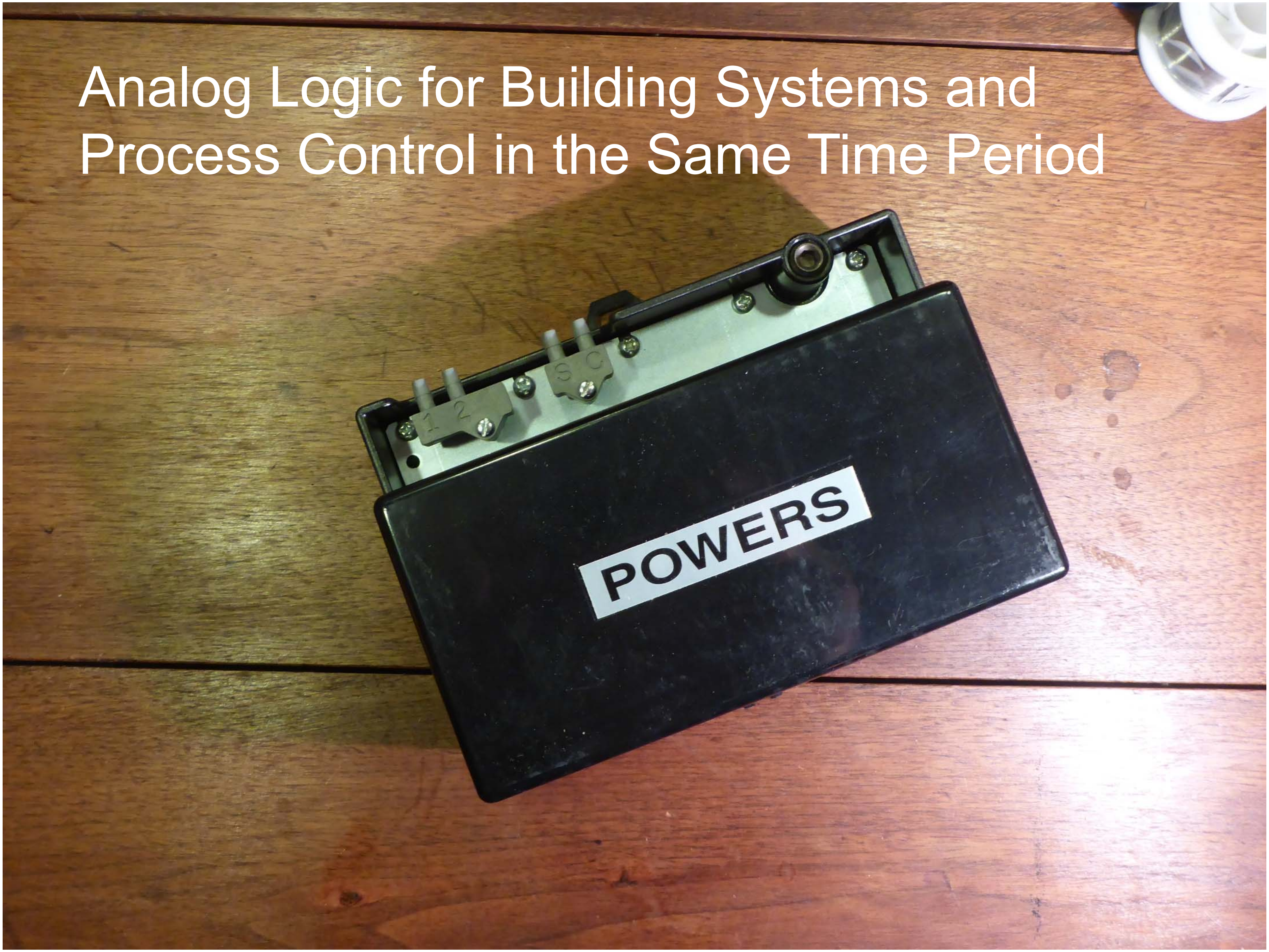
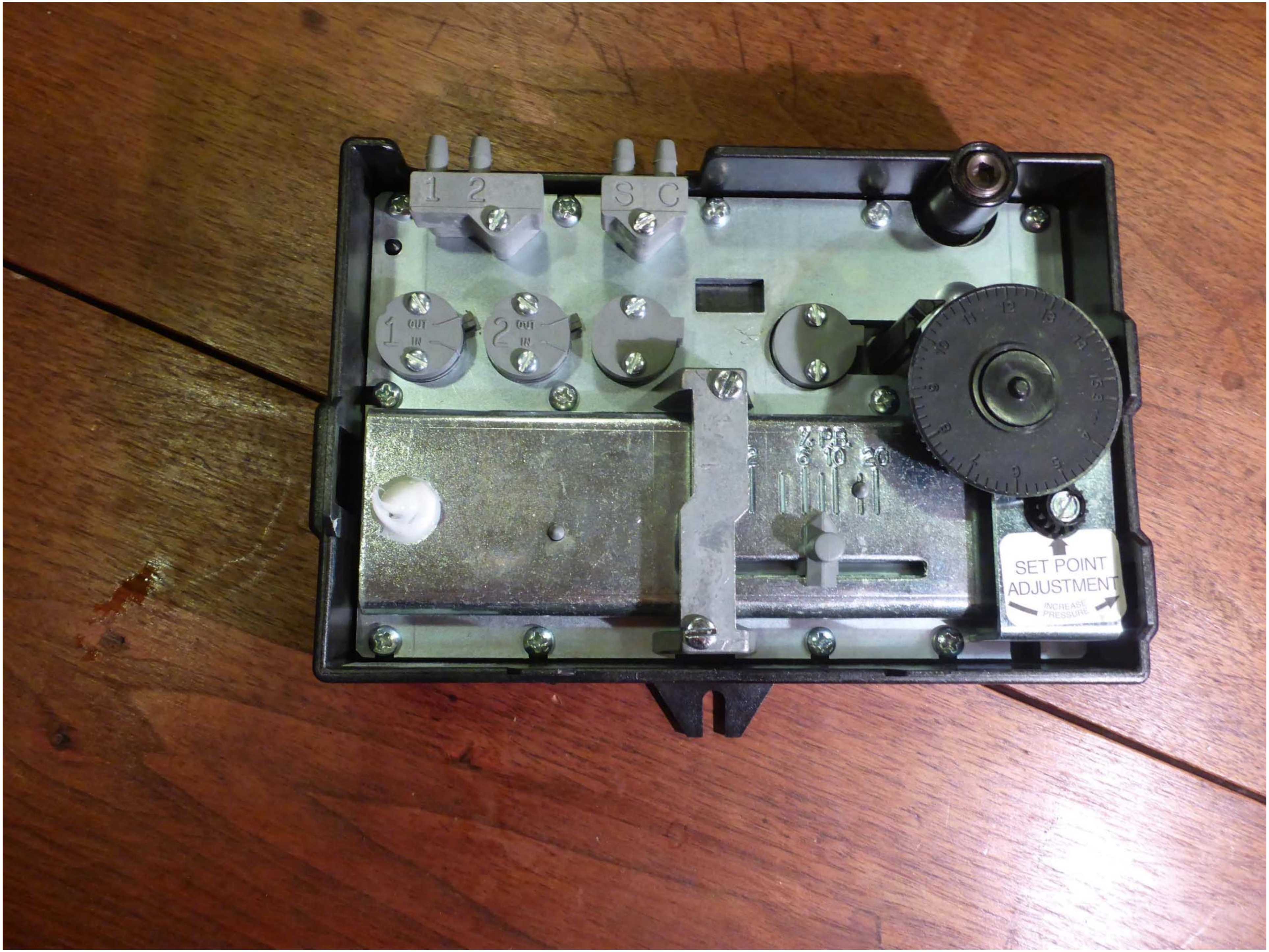


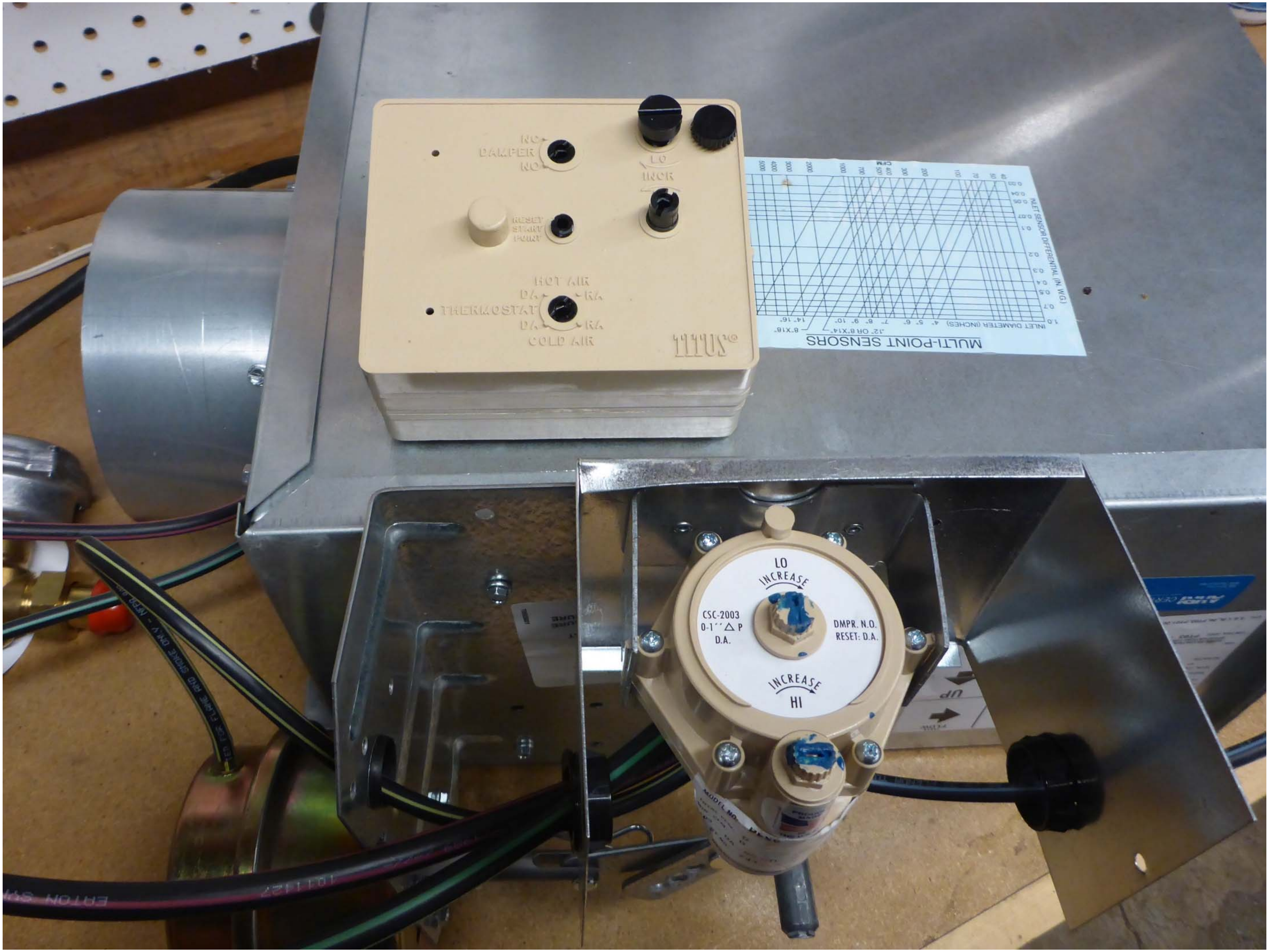

Analog Logic for Building Systems and
Process Control in the Same Time Period
POWERS
1 2
S C



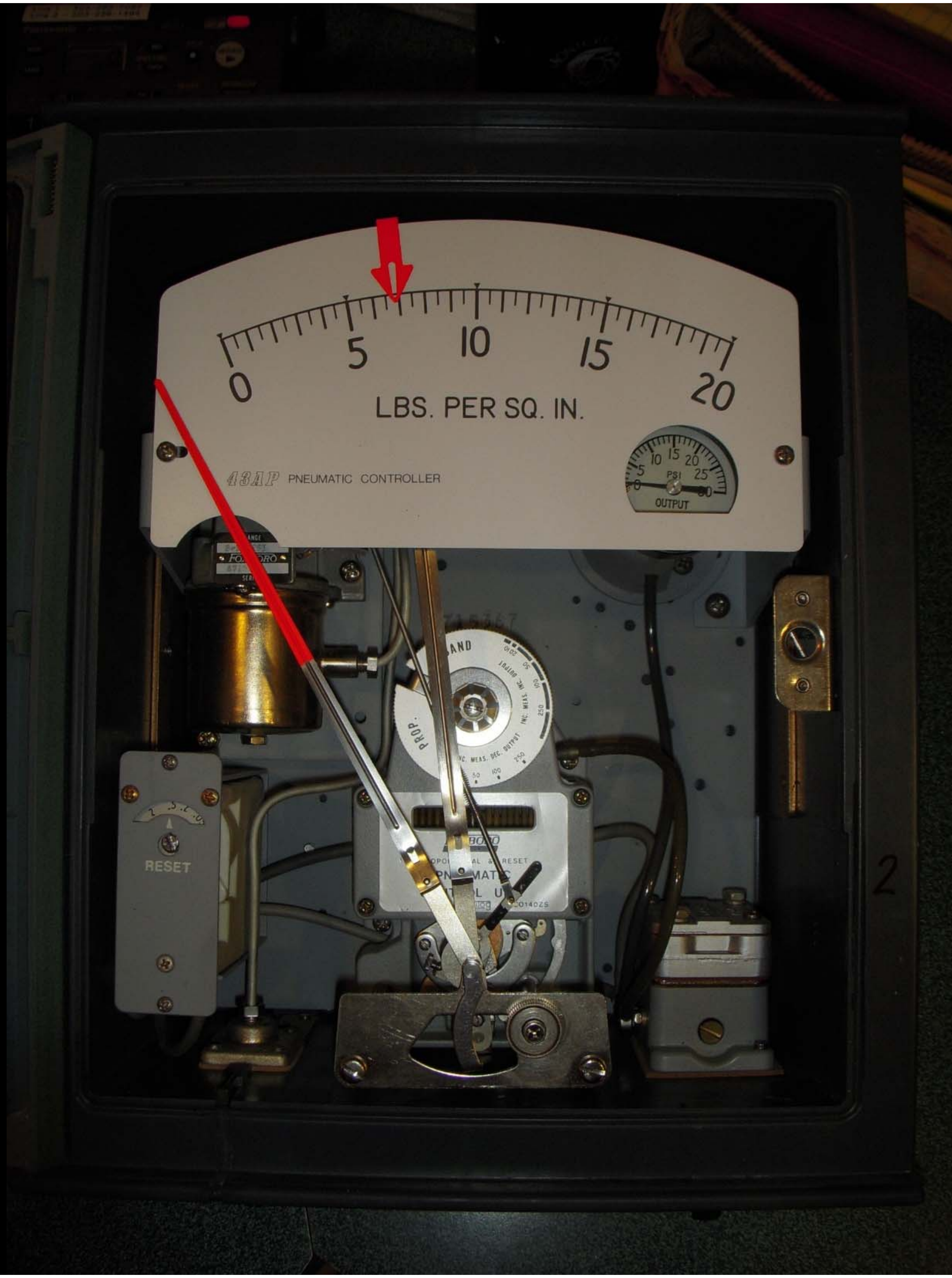
1 2
S C
1 OUT IN
2 OUT IN
% P.B.
5 10 20
SET POINT
ADJUSTMENT
INCREASE
PRESSURE


36X46
POWERS


50
60
80
80

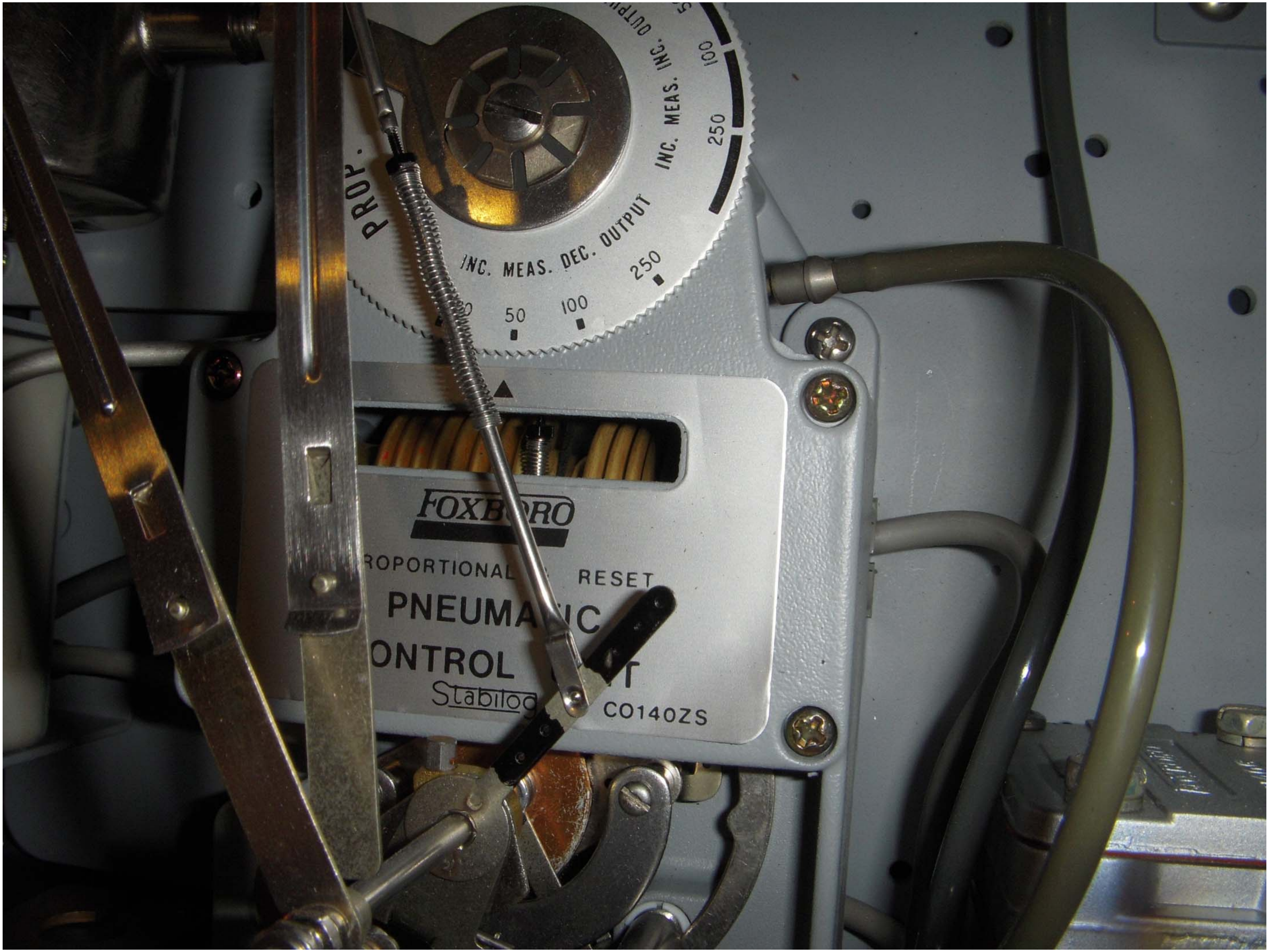

DAMPER
RESET
START
POINT
HOT AIR
THERMOSTAT
COLD AIR
LO
INCR
TITUS
MULTI-POINT SENSORS
LO
INCREASE
CSC-2003
0-1'' △ P
D.A.
DMPR. N.O.
RESET: D.A.
INCREASE
HI

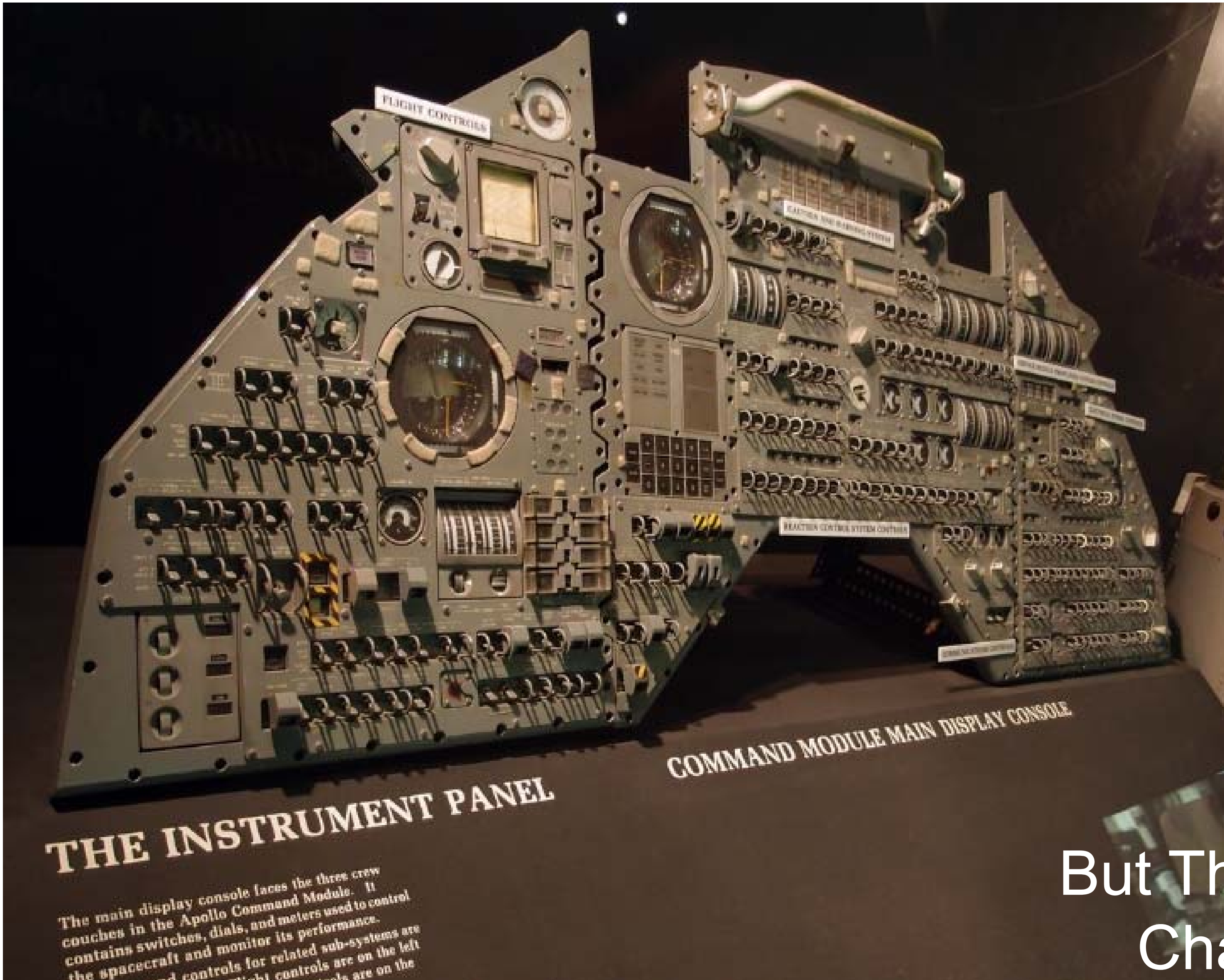

S-2
0
5
10
15
20
LBS. PER SQ. IN.
43AP PNEUMATIC CONTROLLER
PSI
FOXBORO


0 5 10 15 20
LBS. PER SQ. IN.
43AP PNEUMATIC CONTROLLER
PSI
OUTPUT
RESET


RESET
5.2

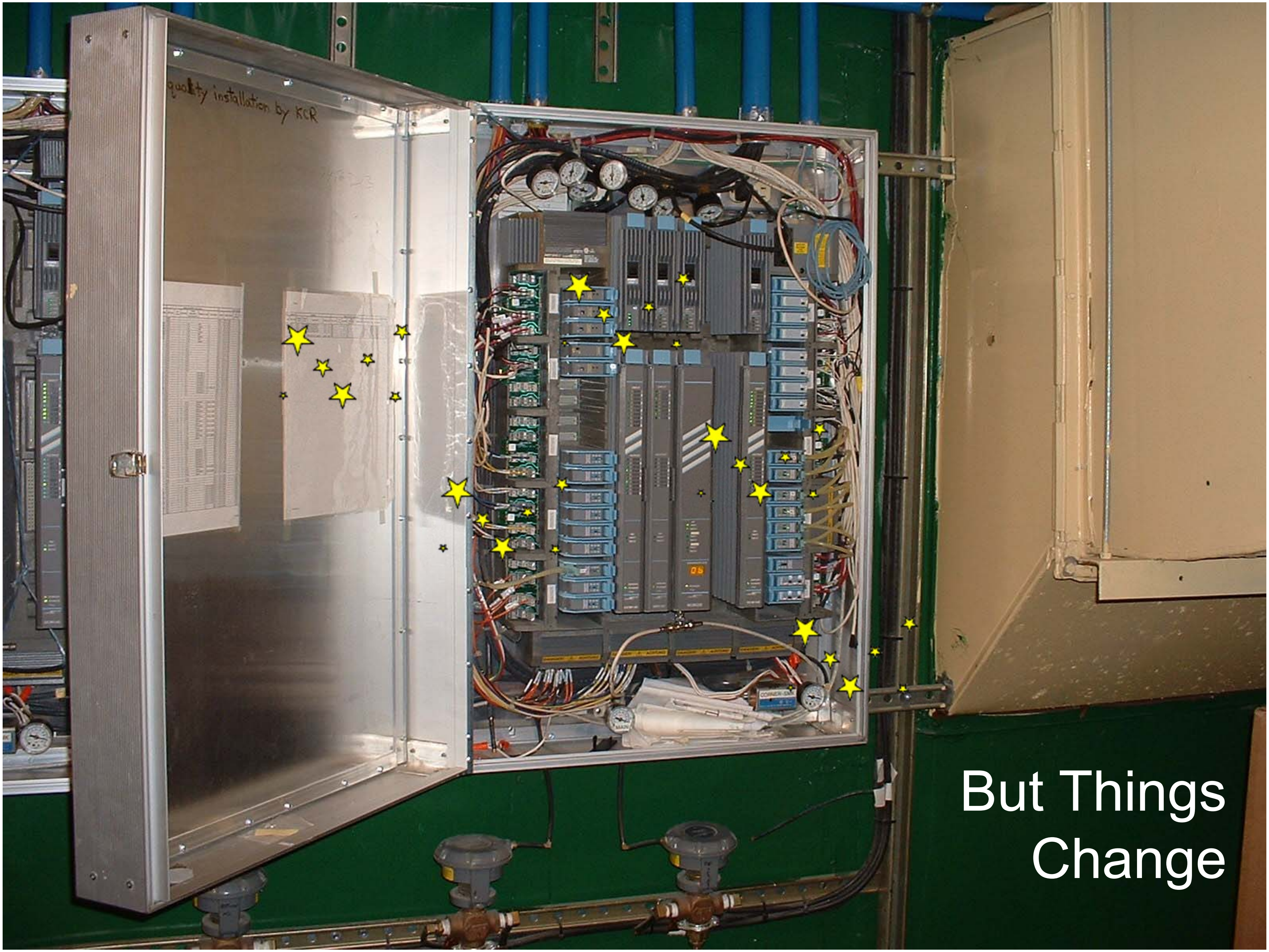

0
5
15
LBS. PER SQ. IN.
43AP PNEUMATIC CONTROLLER
RANGE
FOXBORO
SERIAL
PROP.
AND


PROP.
INC. MEAS. DEC. OUTPUT
INC. MEAS. INC.
50
100
250
FOXBORO
ROPORTIONAL RESET
PNEUMA IC
ONTROL T
Stabilog
C0140ZS

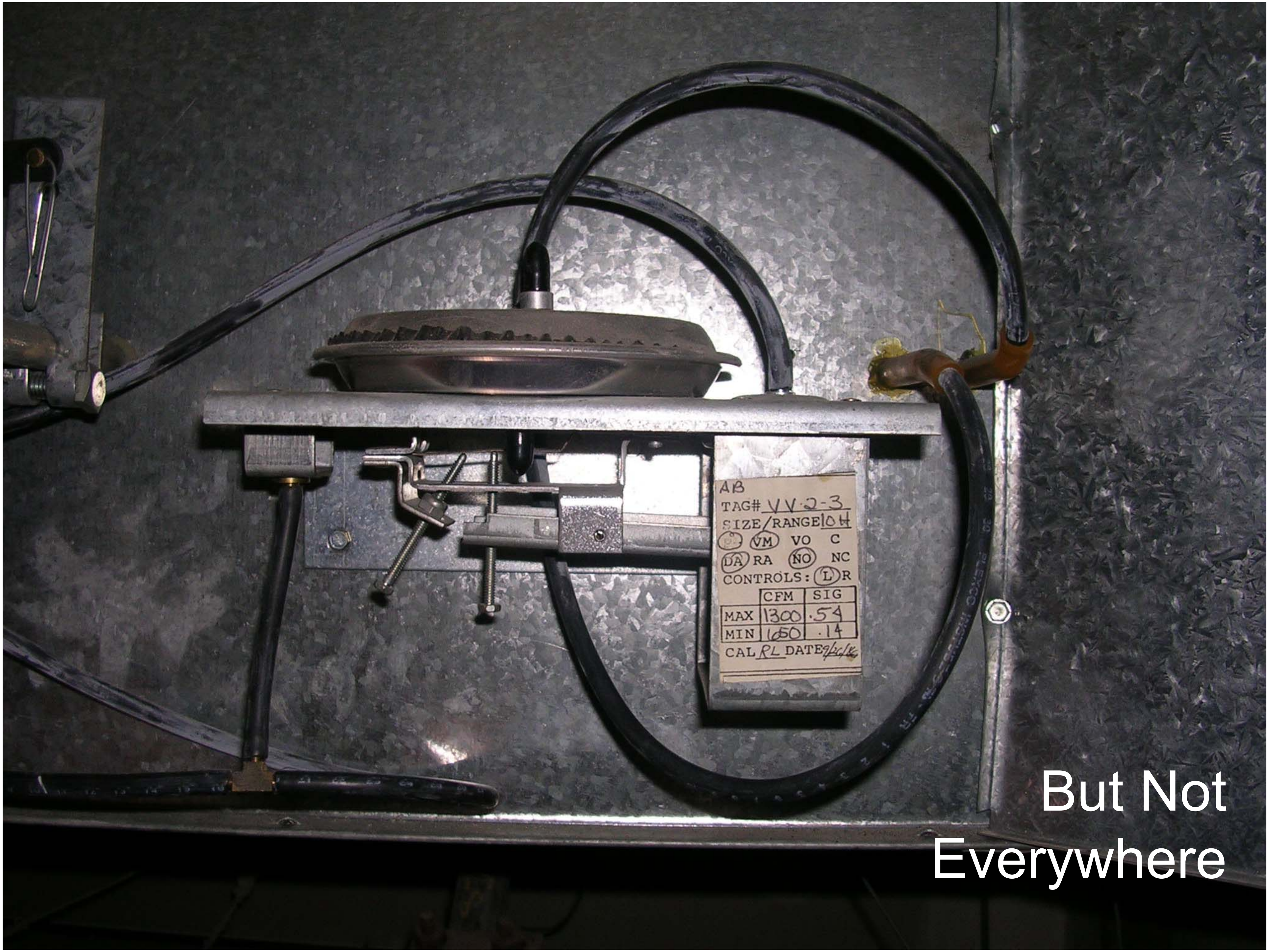


But Things Change

But Things Change



But Things Change


AB
TAG# VV-2-3
SIZE/RANGE 10 H
VM VO C
DA RA NO NC
CONTROLS: L R
CFM SIG
MAX 1300 .54
MIN 650 .14
CAL RL DATE
But Not
Everywhere

The Relationship Between Velocity and Velocity Pressure

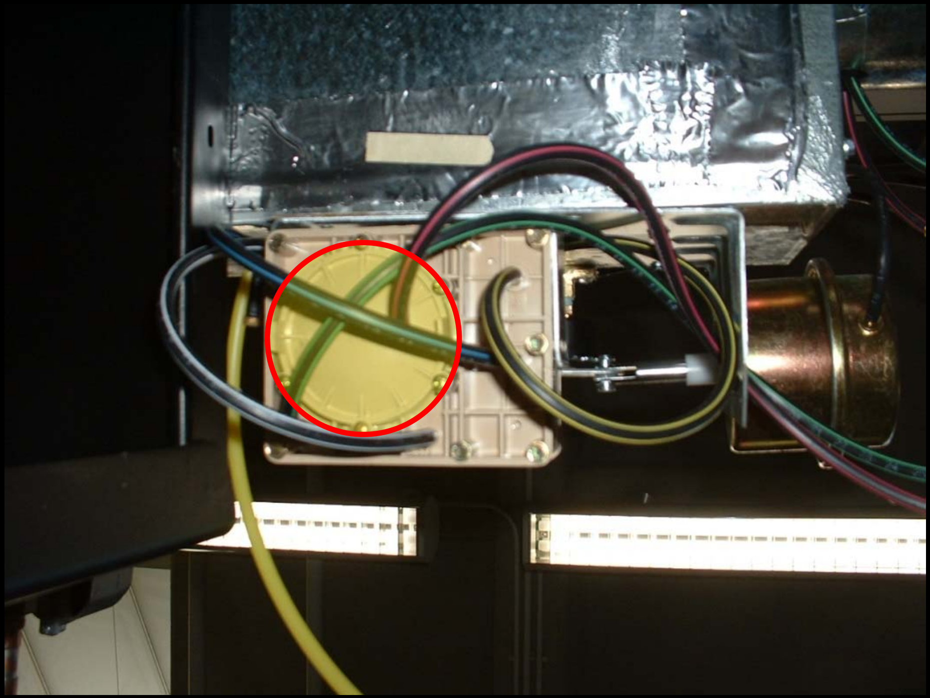
12 inch VAV Box

- Maximum flow
  - 2,000 cfm
  - VP = .2494 in.w.c.
- Minimum flow
  - 325 cfm
  - VP = .0066 in.w.c.

The Relationship Between Velocity and Velocity Pressure

12 inch VAV Box

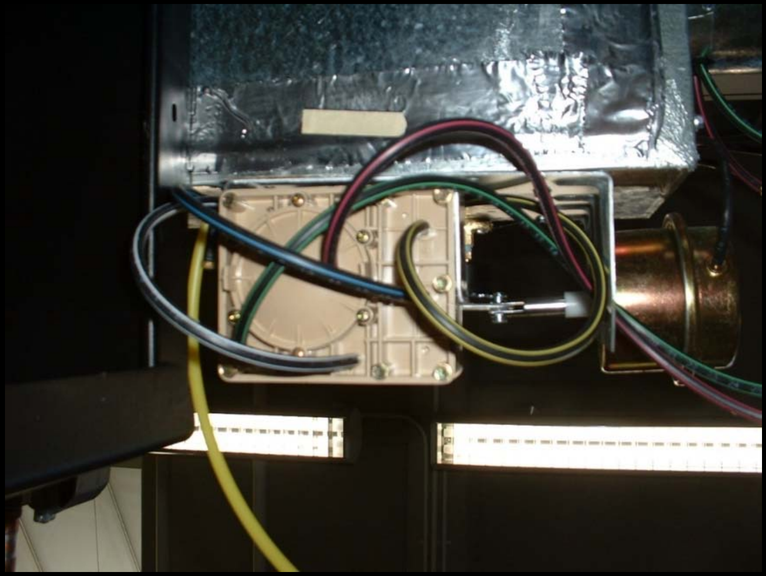
- Maximum flow
  - 2,000 cfm
  - VP = 0.2494 in.w.c.
  - Force = 0.0465 lb
  - Force = 0.74 oz
- Minimum flow
  - 325 cfm
  - VP = 0.0066 in.w.c.
  - Force = 0.0017 lb
  - Force = 0.03 oz



Frame of reference; a letter in an envelop weighs about 1 oz.

Pneumatic Terminal Failure Modes

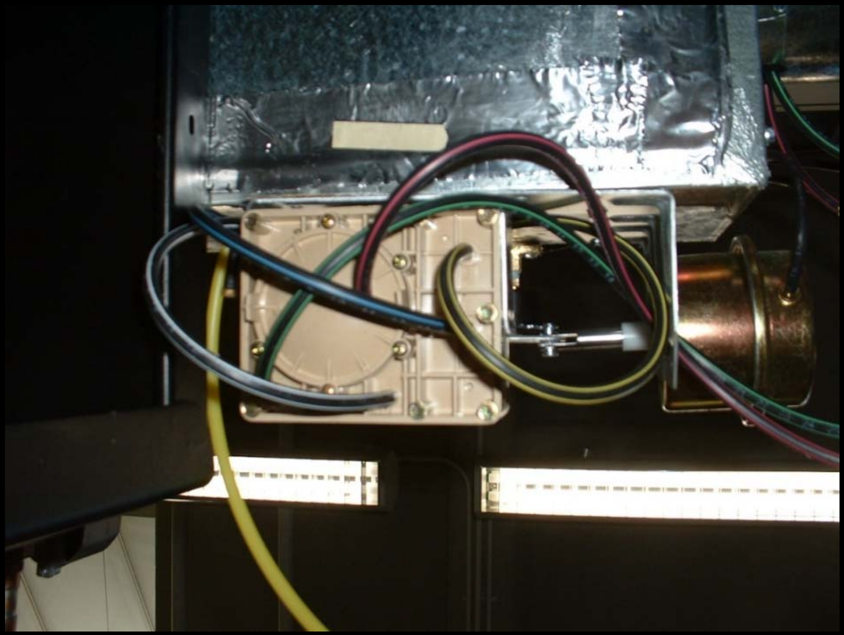
- Flow set points drift up
- Recent experience
  - Sample 10 of 45 pneumatic zones
  - Three years since last service effort



- Many of the controllers worked
- Many thermostats were out of calibration
- 0 (zero) zones were regulating at the required flow
- Many zones were wide open
- Some reheat valves were leaking through

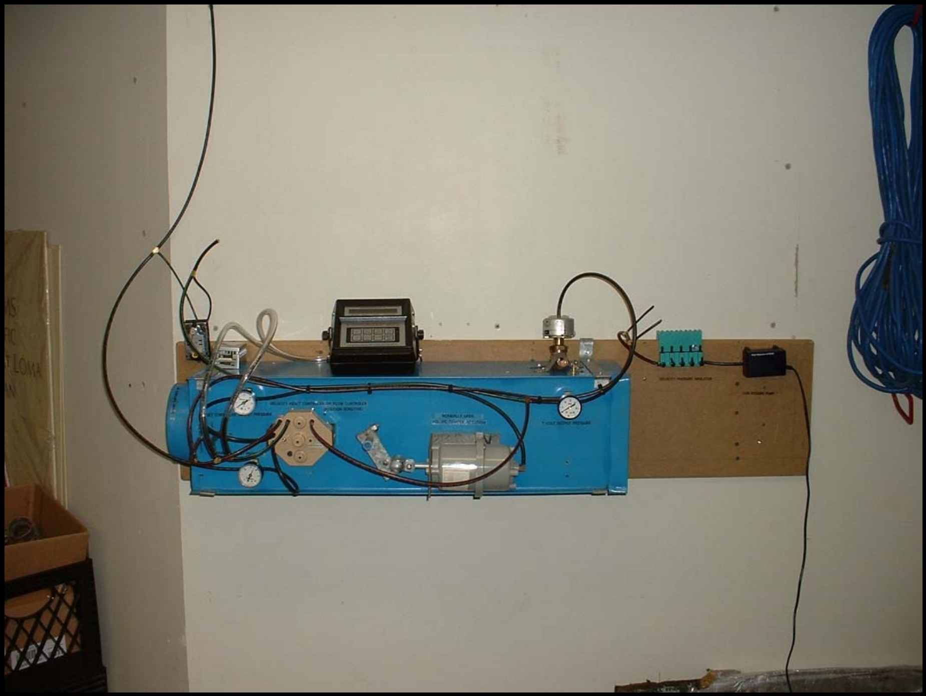
Pneumatic Terminal Bottom Lines

- Pneumatic terminals are common in existing buildings
- Pneumatic terminals are still being installed in “match existing” tenant improvement projects



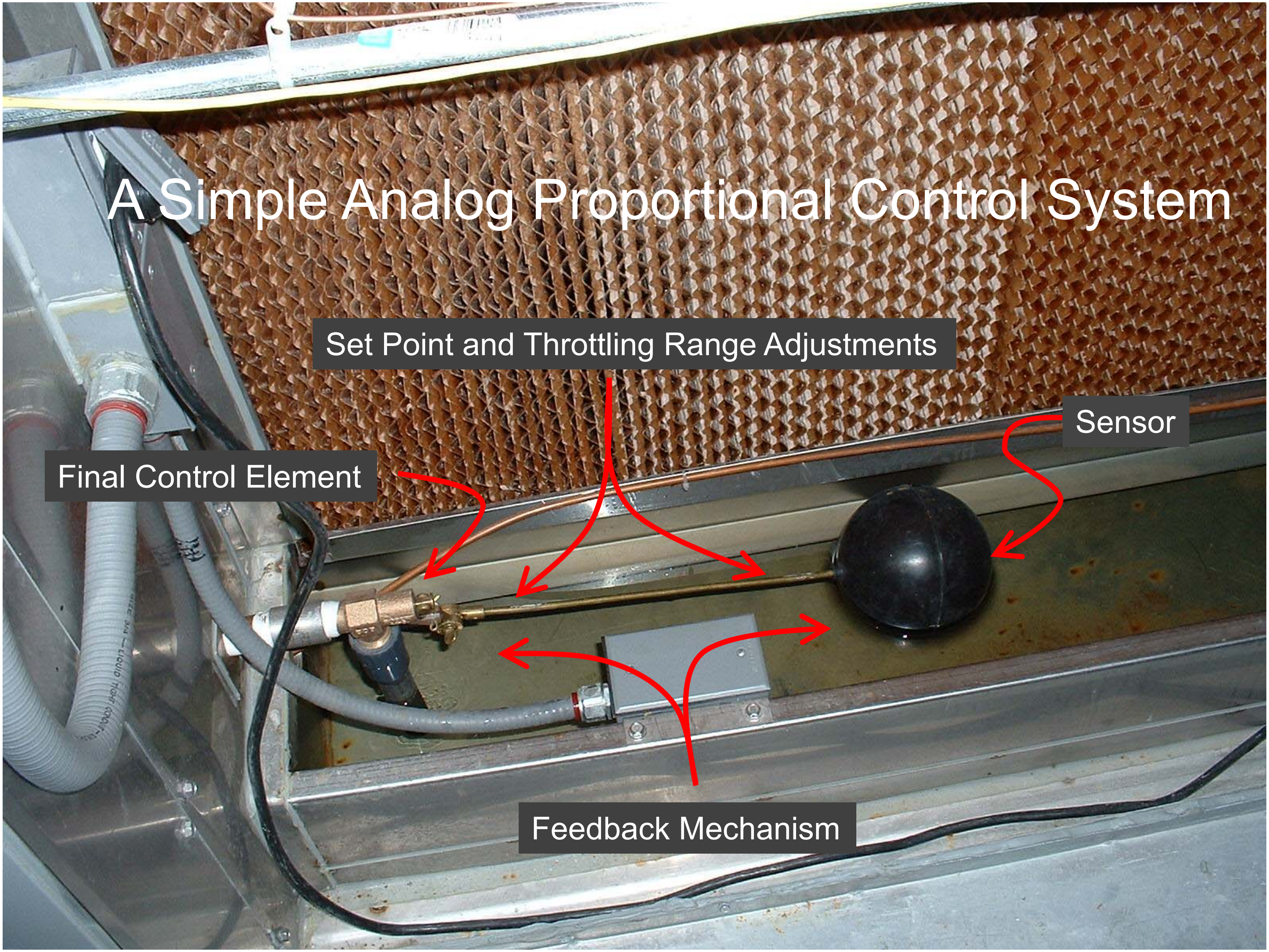
Pneumatic Terminal Bottom Lines

- Pneumatic terminals are common in existing buildings
- Pneumatic terminals are still being installed in “match existing” tenant improvement projects
- Pneumatic terminals represent an opportunity for mechanically minded folks to make a big impact on building performance and efficiency



Proportional Control

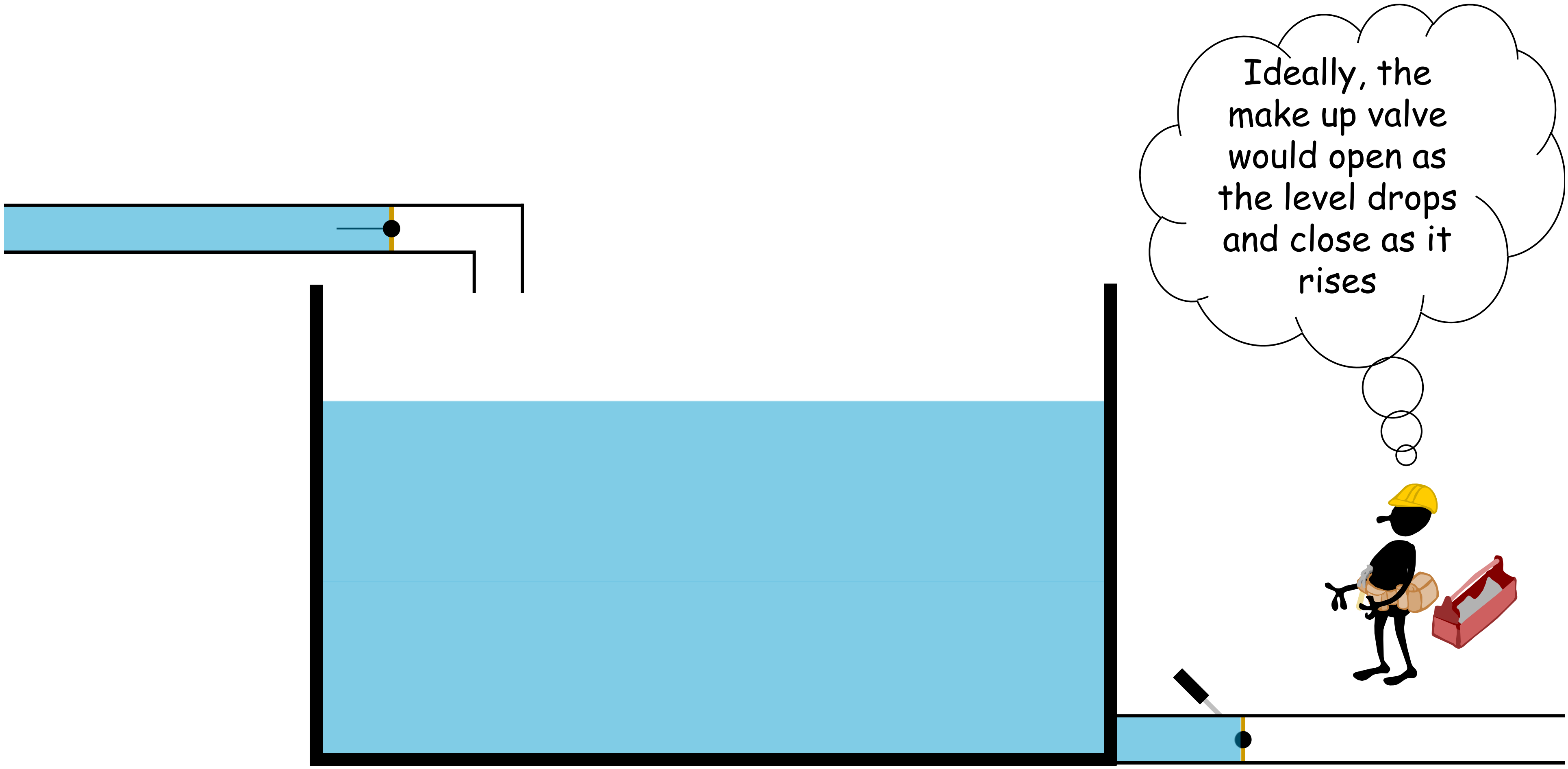
A Fundamental Pneumatic Control System Principle


A Simple Analog Proportional Control System
Set Point and Throttling Range Adjustments
Sensor
Final Control Element
Feedback Mechanism

A Simple Control System

The make up valve is the device to be controlled; a.k.a. the *Controlled Variable*

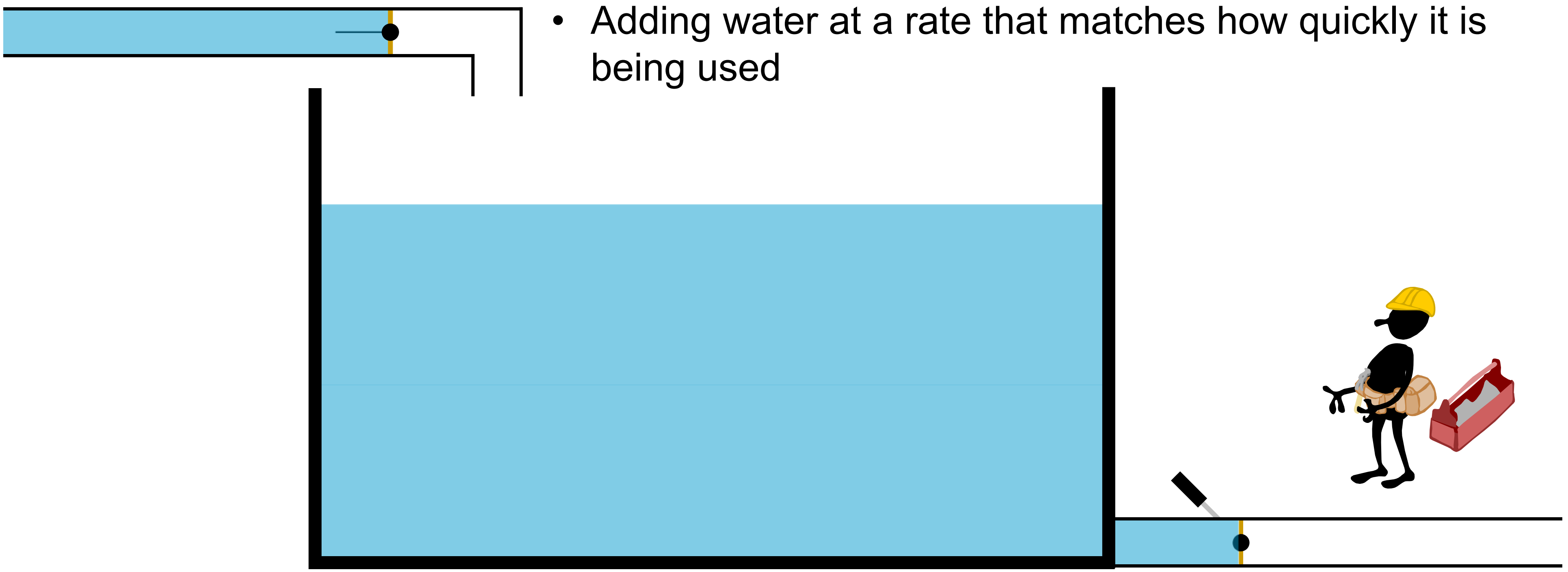
A Simple Control System



A Simple Control System

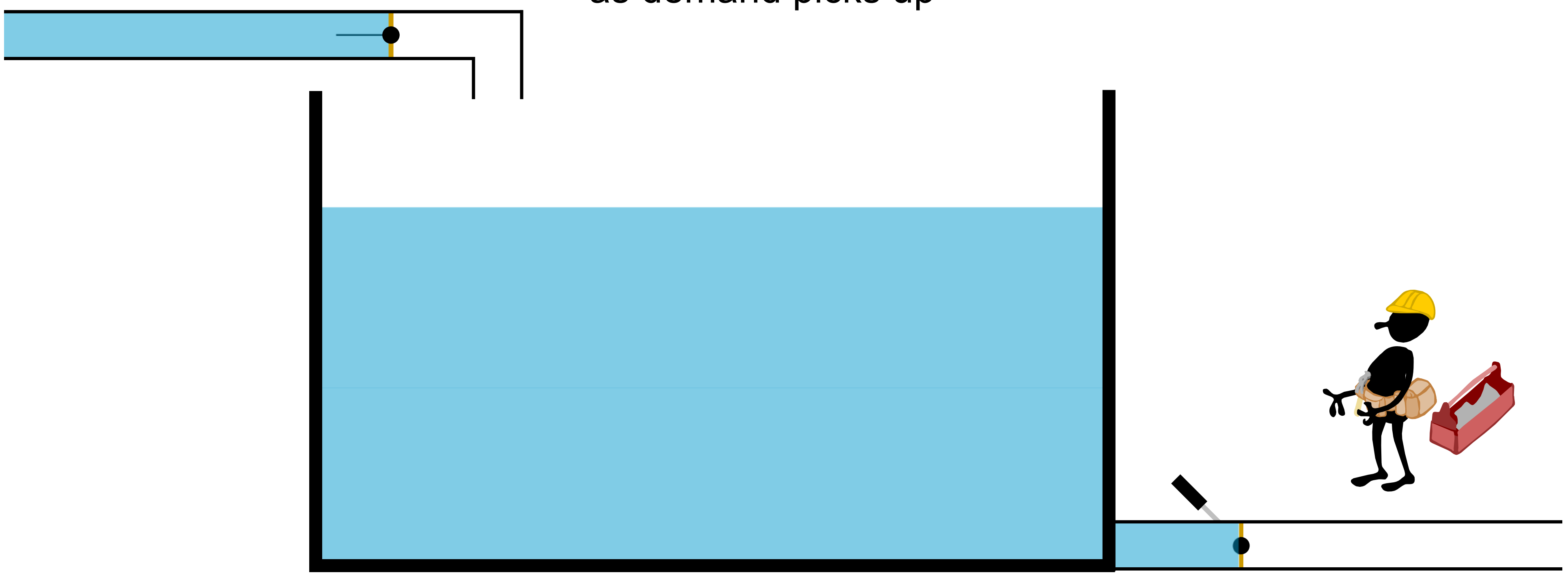
Because the tank acts as a flywheel in the system, it would be possible to serve the load by:

- Adding water when the level drops to a certain point
- Adding water at a rate that matches how quickly it is being used



A Simple Control System

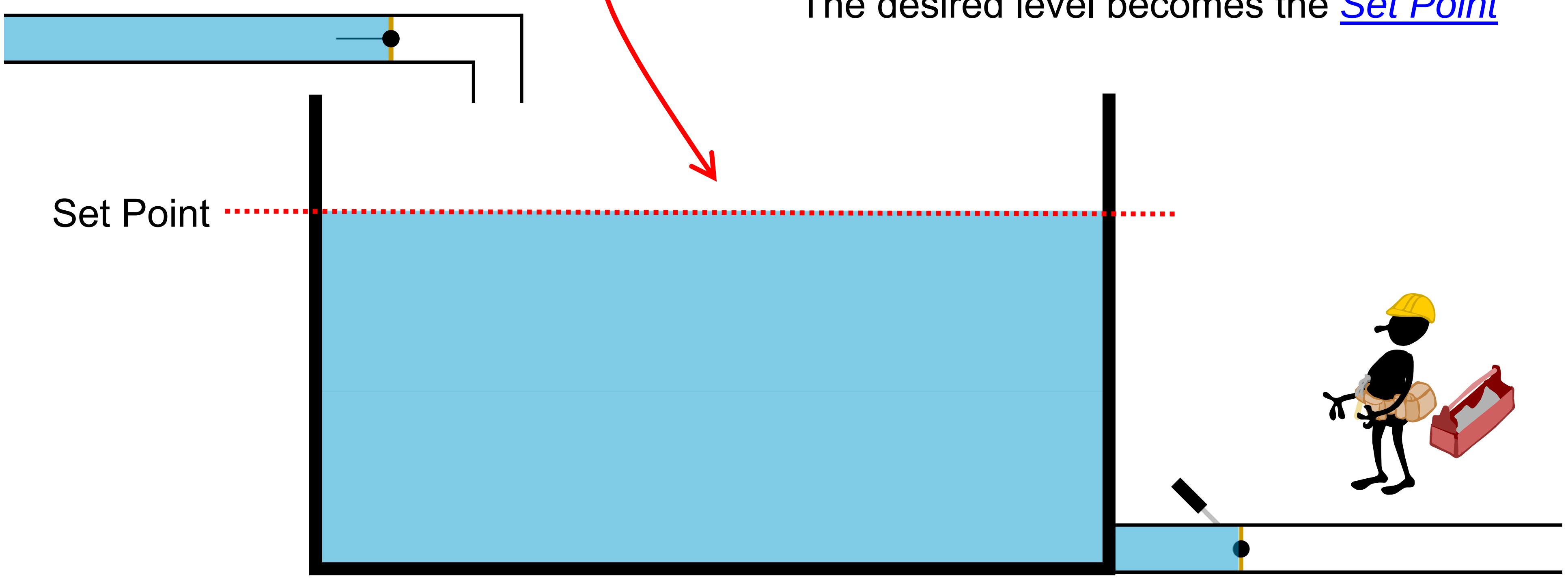
Monitoring the tank water level will allow us to gauge how much make up we need to add as demand picks up



A Simple Control System

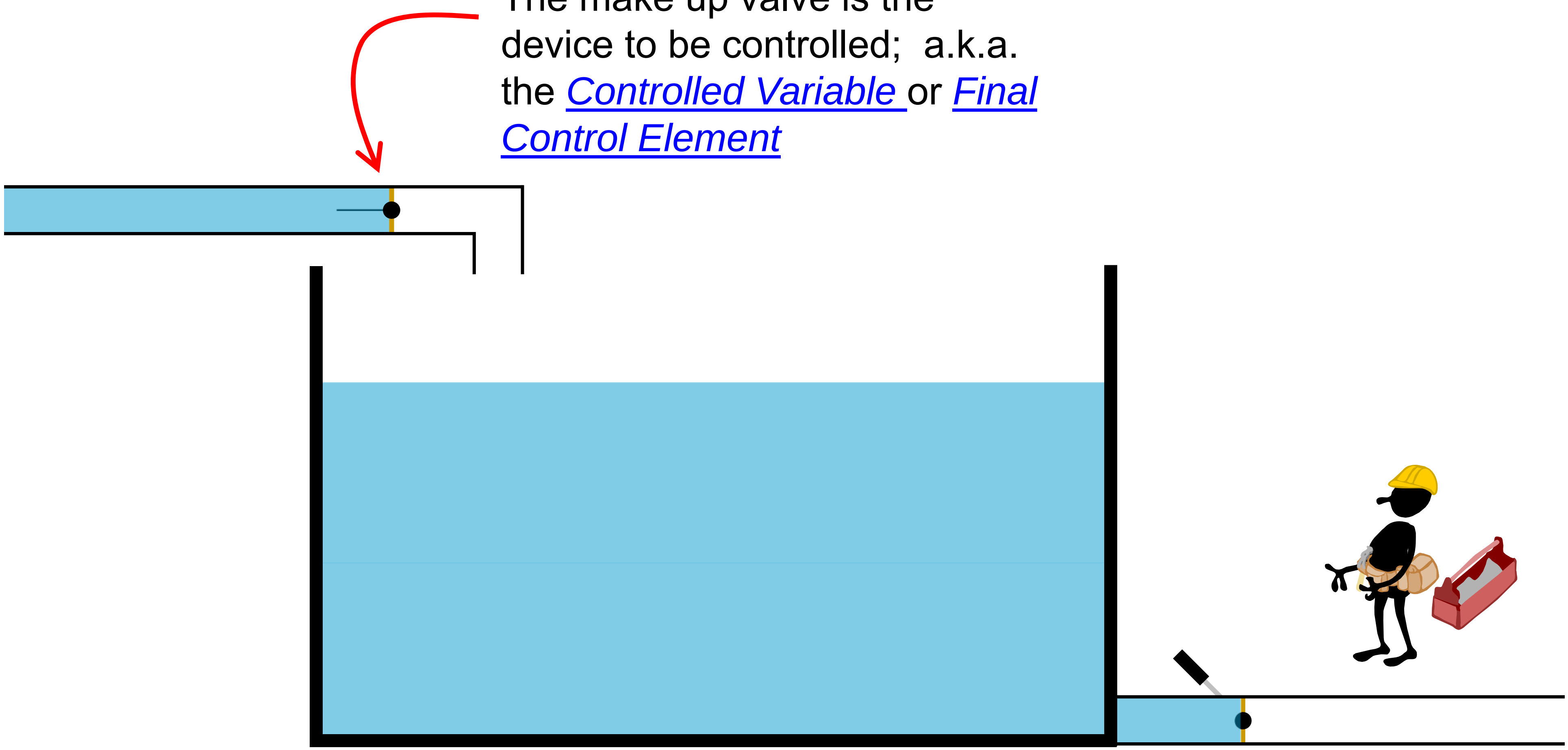
The tank water level is the *Process Variable*

The desired level becomes the *Set Point*



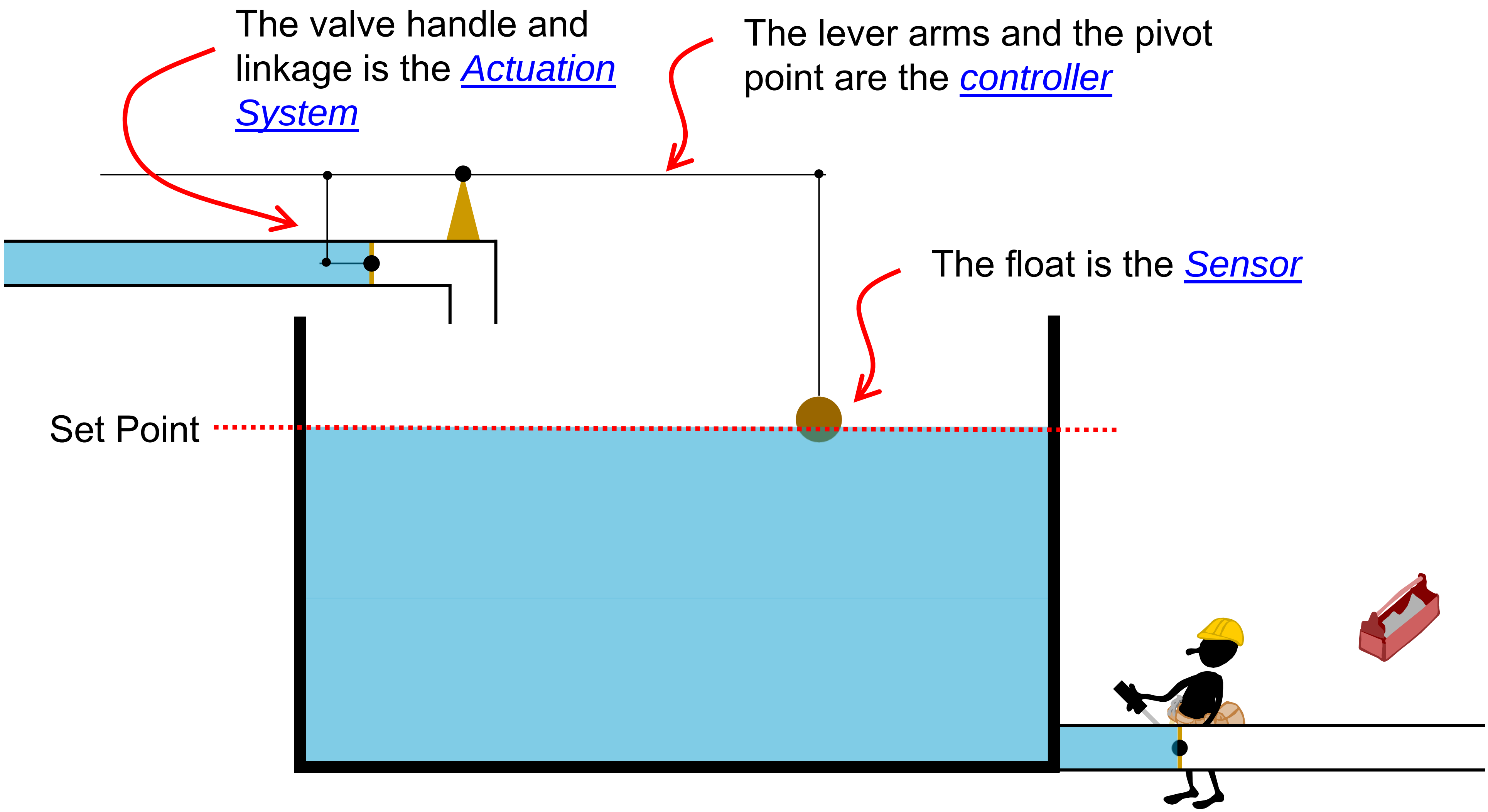
A Simple Control Requirement

The make up valve is the device to be controlled; a.k.a. the *Controlled Variable* or *Final Control Element*



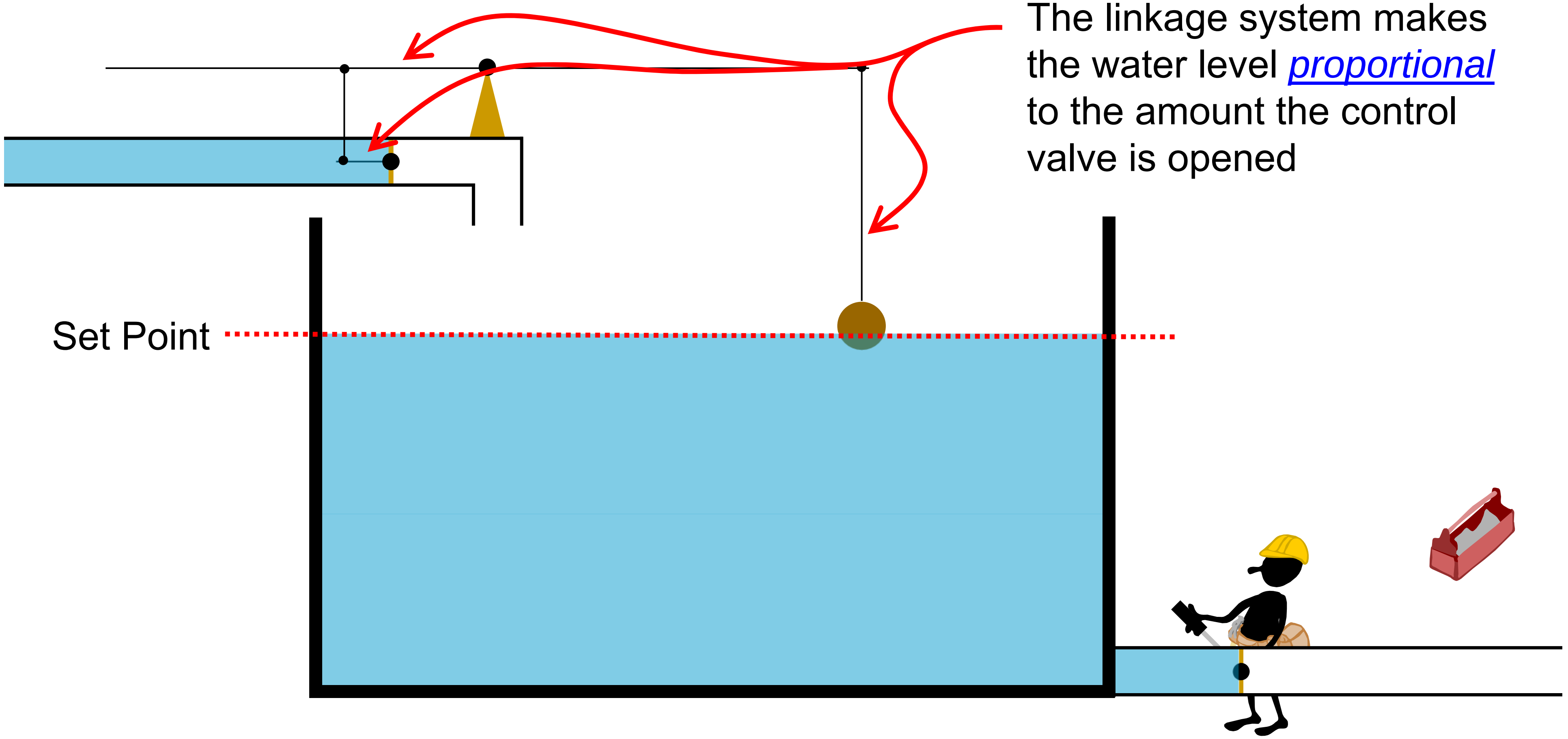
Set Points

A Simple Proportional Control System

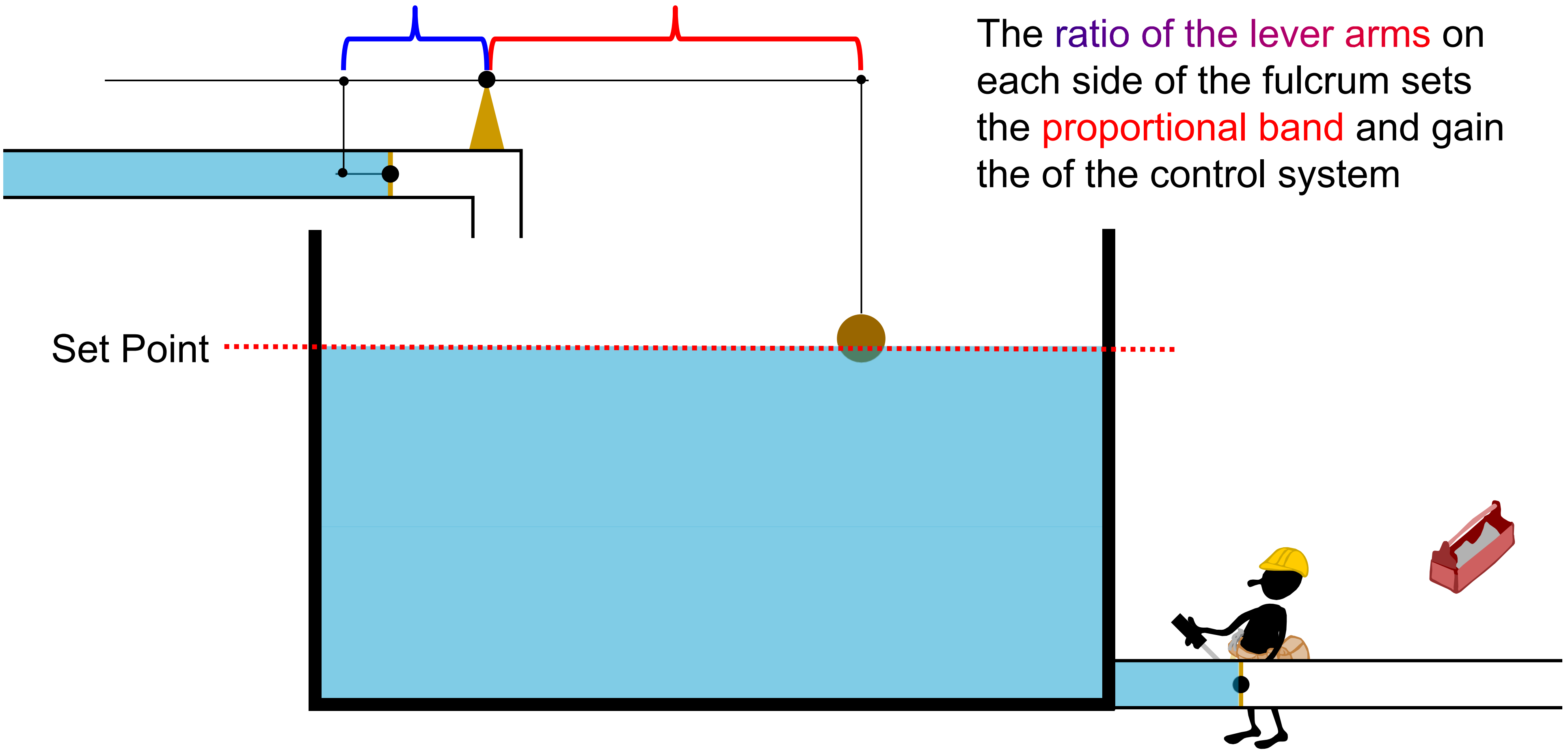


A Simple Proportional Control System

The linkage system makes the water level *proportional* to the amount the control valve is opened



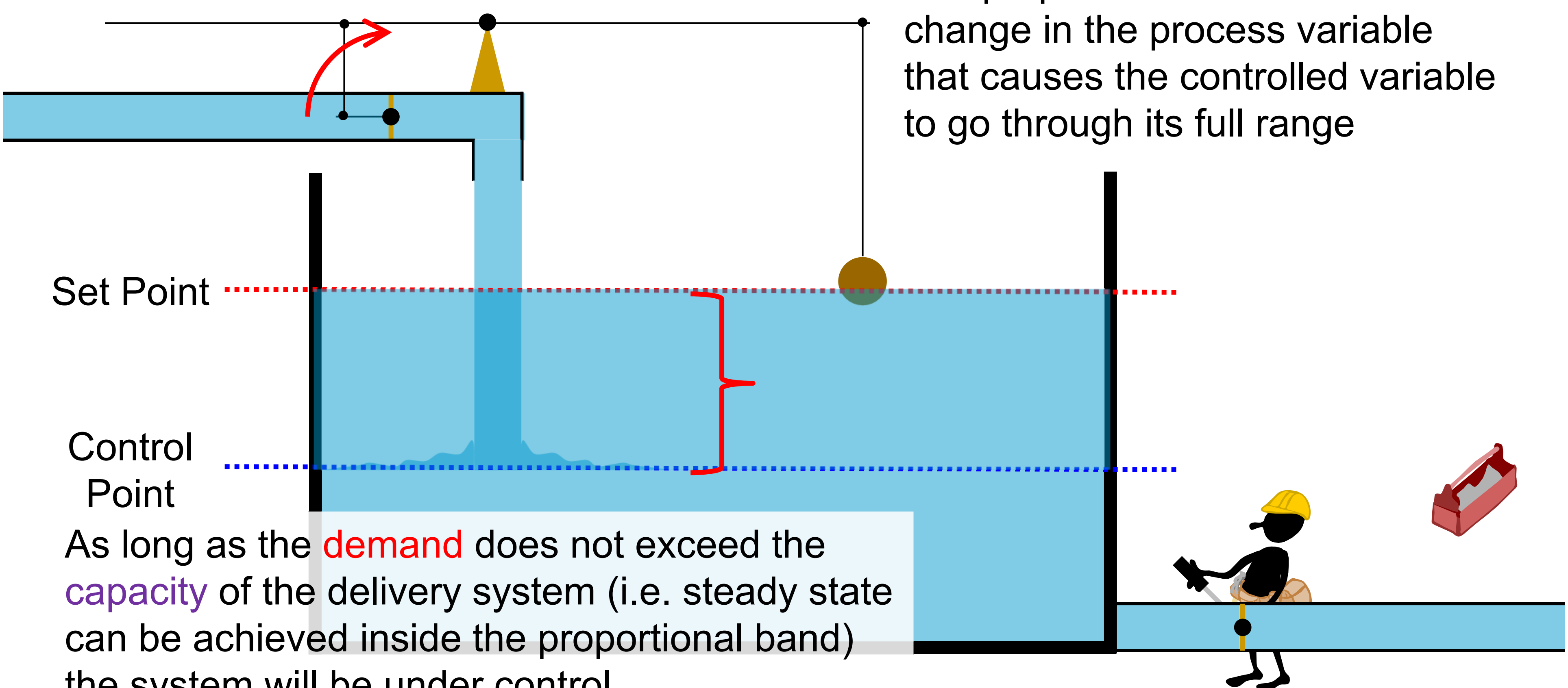
A Simple Proportional Control System



The ratio of the lever arms on each side of the fulcrum sets the proportional band and gain the of the control system

A Simple Proportional Control System

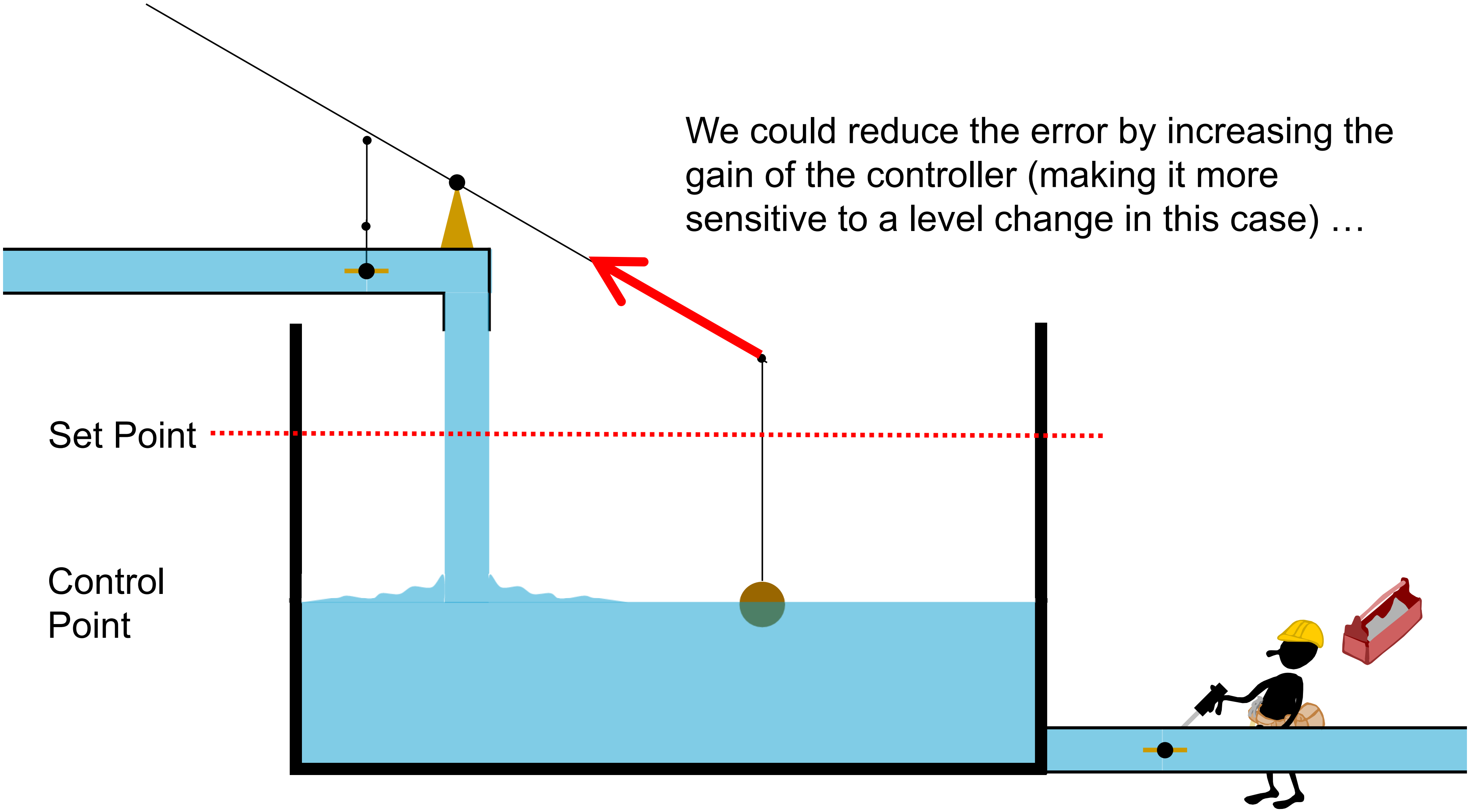
The proportional band is the change in the process variable that causes the controlled variable to go through its full range



As long as the demand does not exceed the capacity of the delivery system (i.e. steady state can be achieved inside the proportional band) the system will be under control

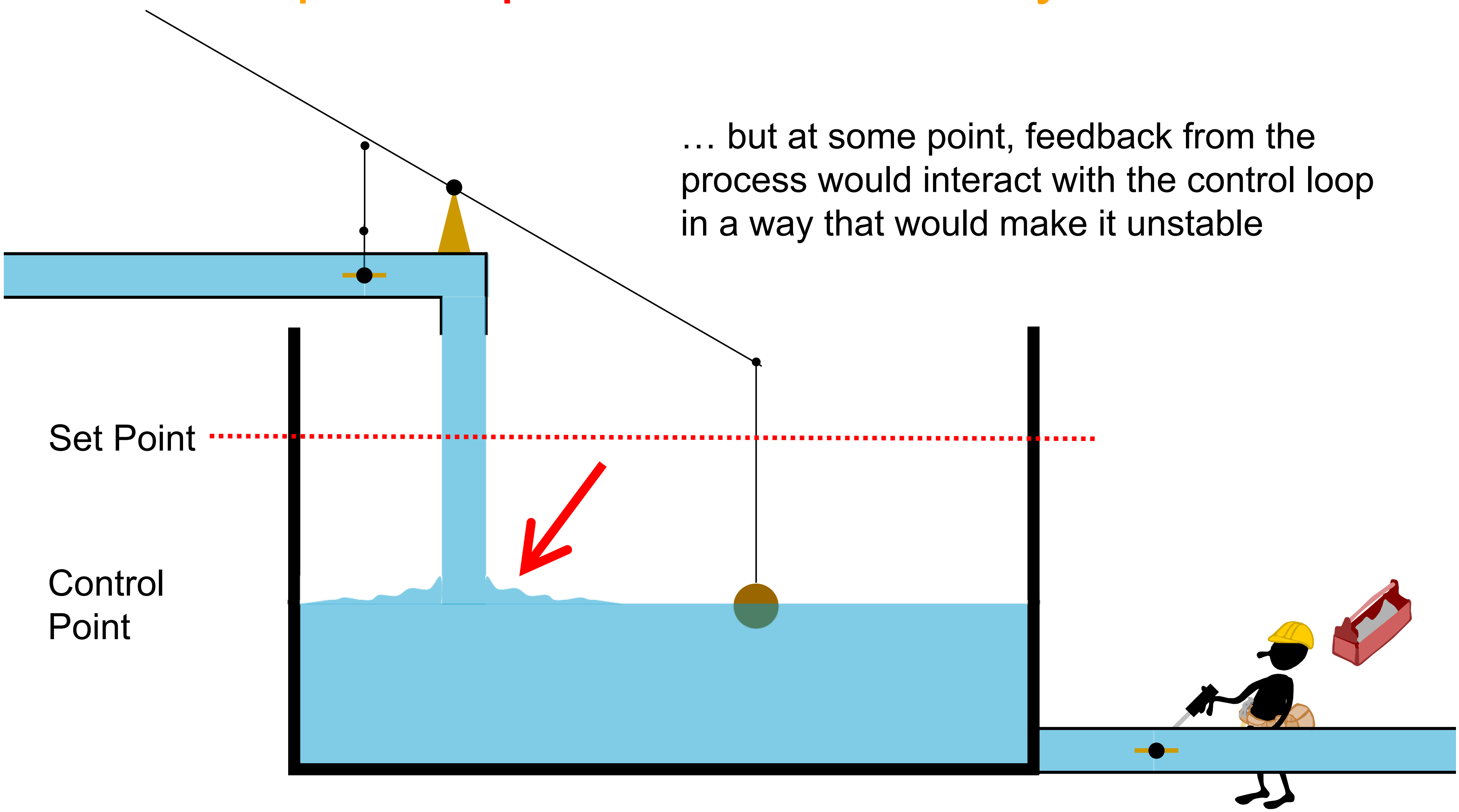
A Simple Proportional Control System

We could reduce the error by increasing the gain of the controller (making it more sensitive to a level change in this case) …



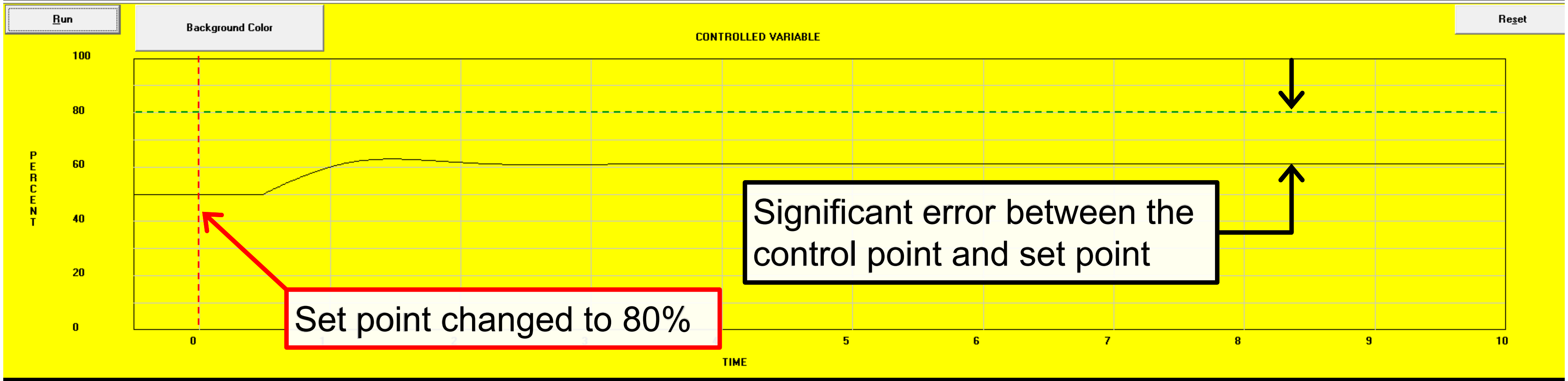
A Simple Proportional Control System

… but at some point, feedback from the process would interact with the control loop in a way that would make it unstable



The Impact of Narrowing Throttling Range

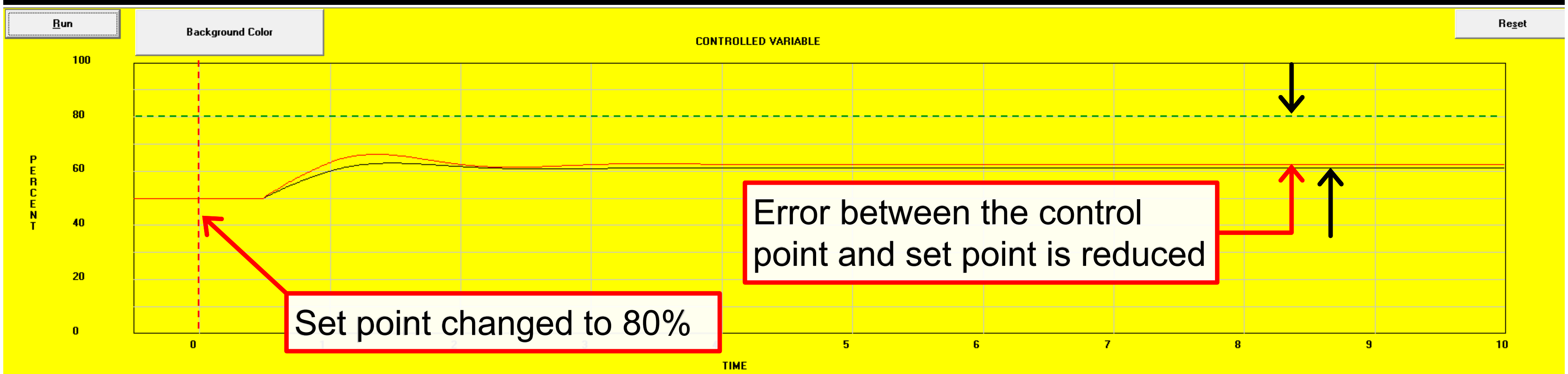
Proportional band =400% and set point changed to 80% (black line)



The Impact of Narrowing Throttling Range

Proportional band =400% (black line)

Proportional band =300% and set point changed to 80% (red line)

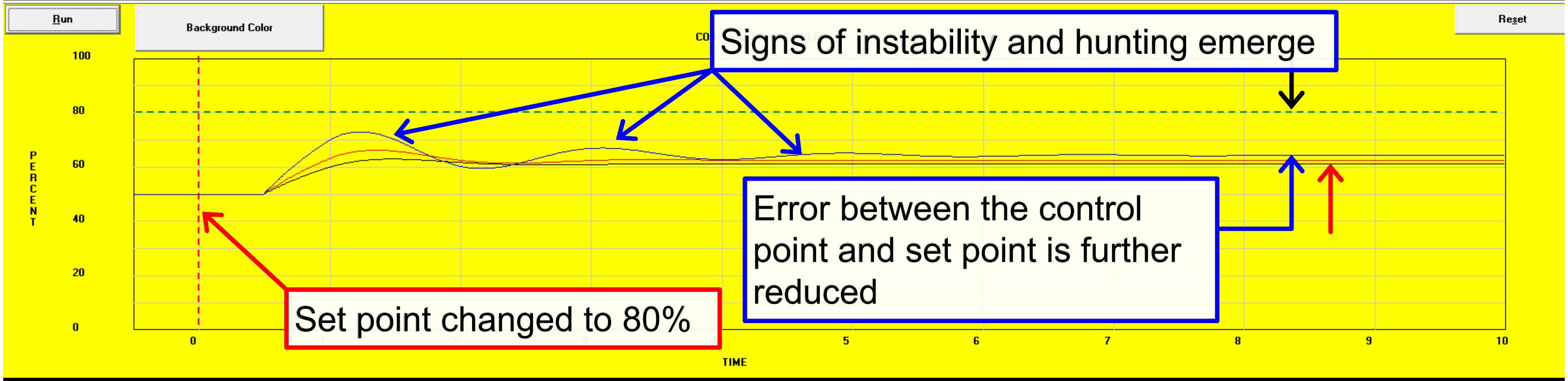


The Impact of Narrowing Throttling Range

Proportional band =400% (black line)

Proportional band =300% (red line)

Proportional band =200% and set point changed to 80% (blue line)



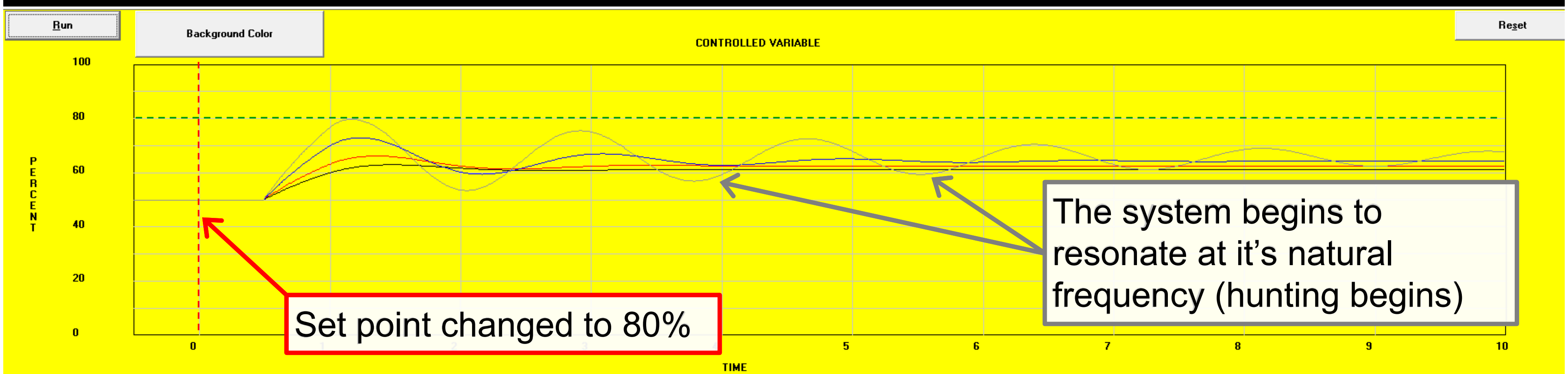
The Impact of Narrowing Throttling Range

Proportional band =400% (black line)

Proportional band =300% (red line)

Proportional band =200% (blue line)

Proportional band =150% and set point changed to 80% (gray line)



The Impact of Narrowing Throttling Range

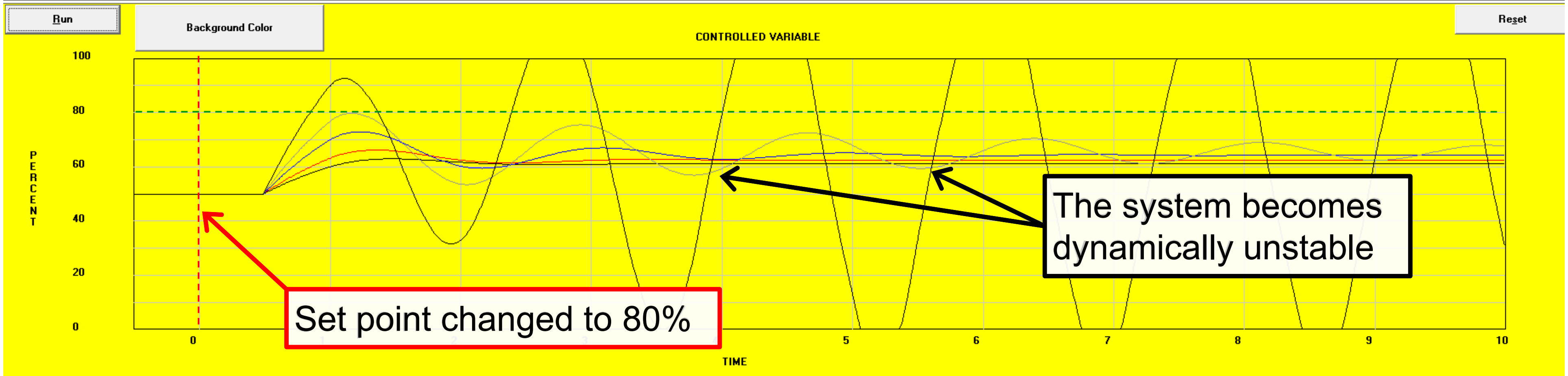
Proportional band =400% (black line)

Proportional band =300% (red line)

Proportional band =200% (blue line)

Proportional band =150% ((gray line)

Proportional band =100% and set point changed to 80% (second black line)



Bottom Lines On Proportional Control

1. All proportional control processes will show a difference between set point and control point (a.k.a. error) under all operating conditions other than one very specific condition
2. The error can be reduced by narrowing down the throttling range
3. There is a limit to how much you can narrow the throttling range with out hunting
4. The limit is a function of the physics of the control system; things like lags, play in the linkage system, the nature of the process, etc.

Control System Building Blocks

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Inputs	Measure the process variable
Outputs	Adjust the controlled variable
Control Process	Logic and algorithms that tries to bring the controlled variable into agreement with the set point
Set Point	Our requirements for the process that is under control, which can be fixed or variable

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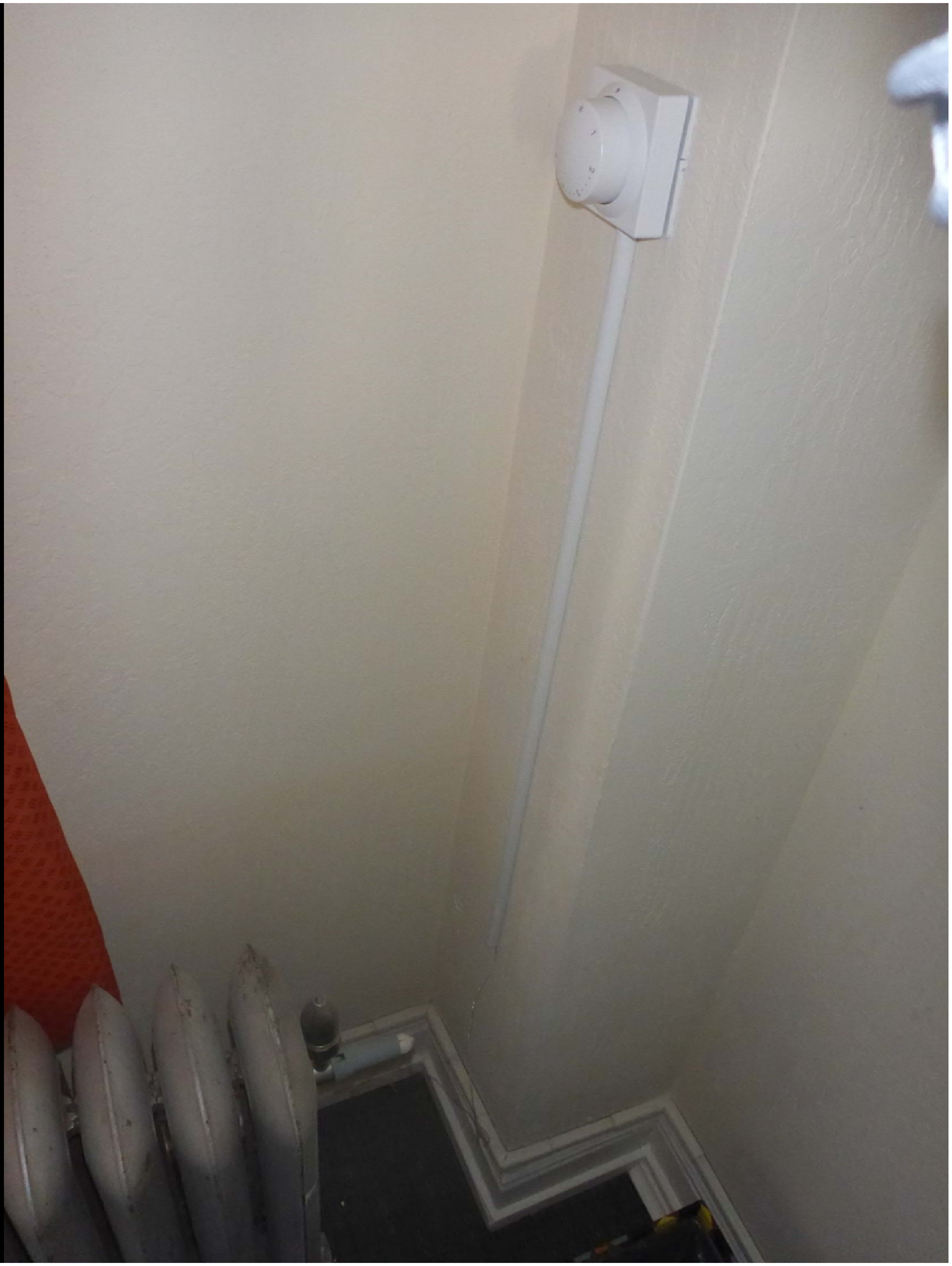
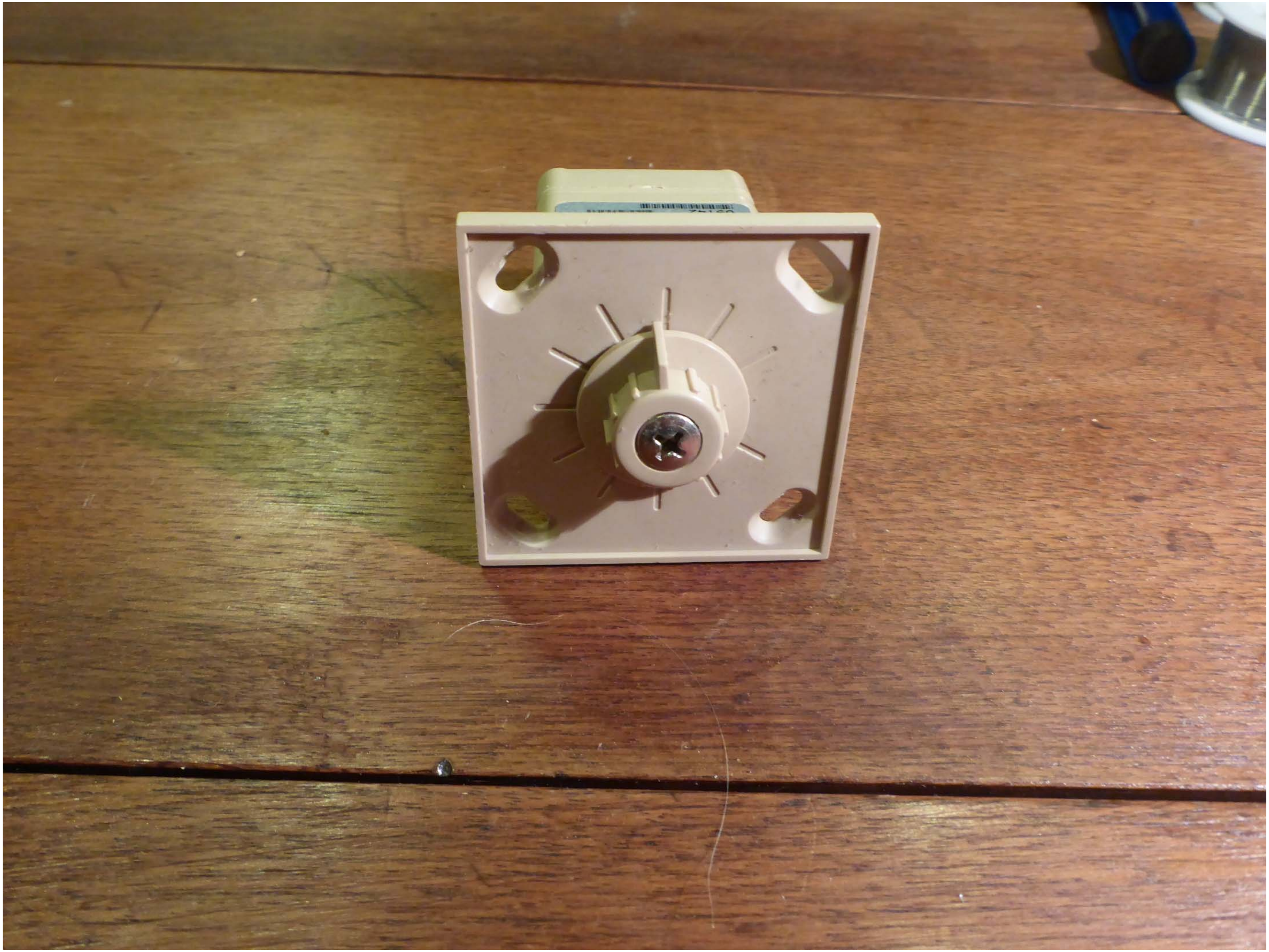
Set Point	Our requirements for the process that is under control, which can be fixed or variable

A Set Point Adjustment



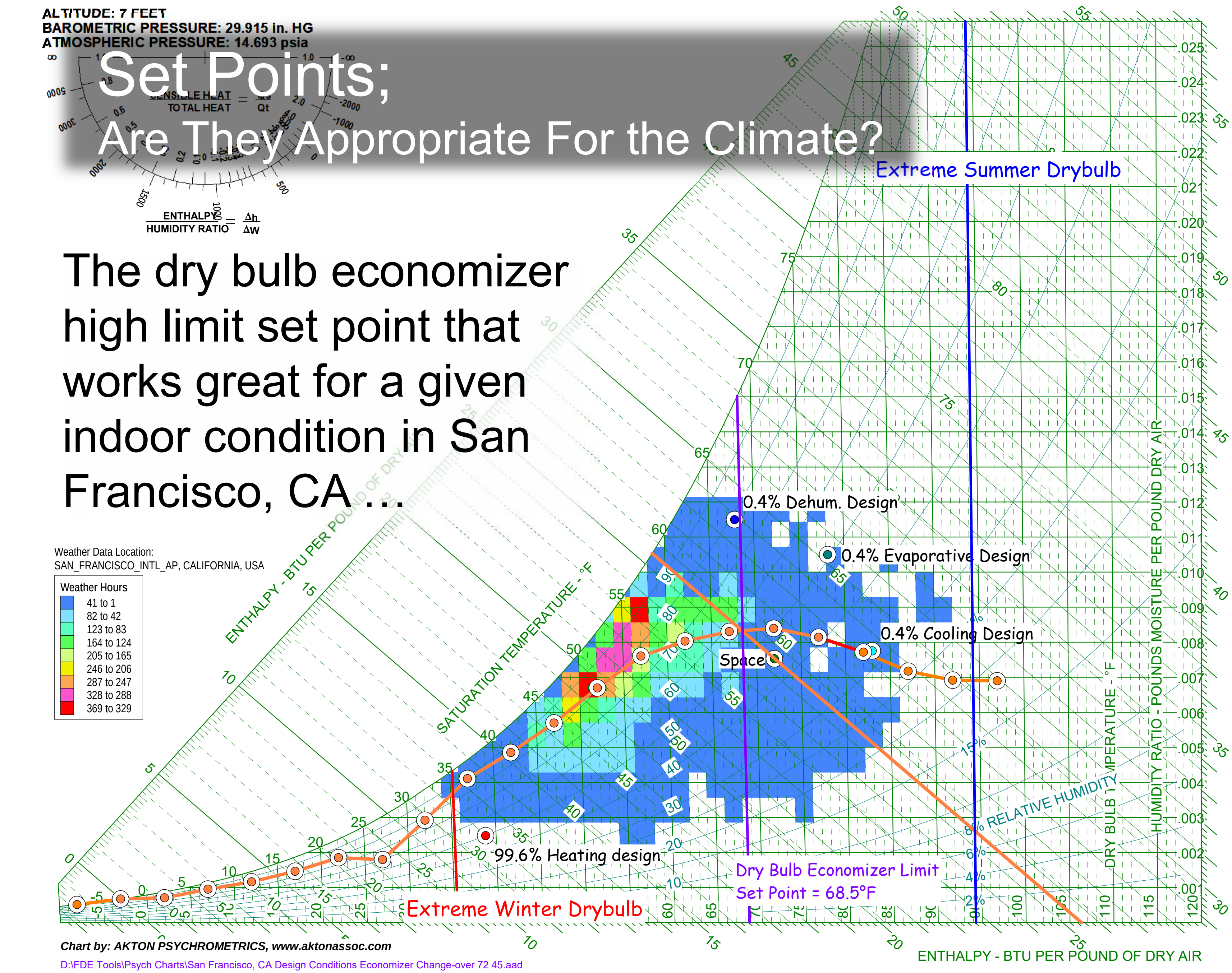


Set Points

Are They Appropriate for the Climate?

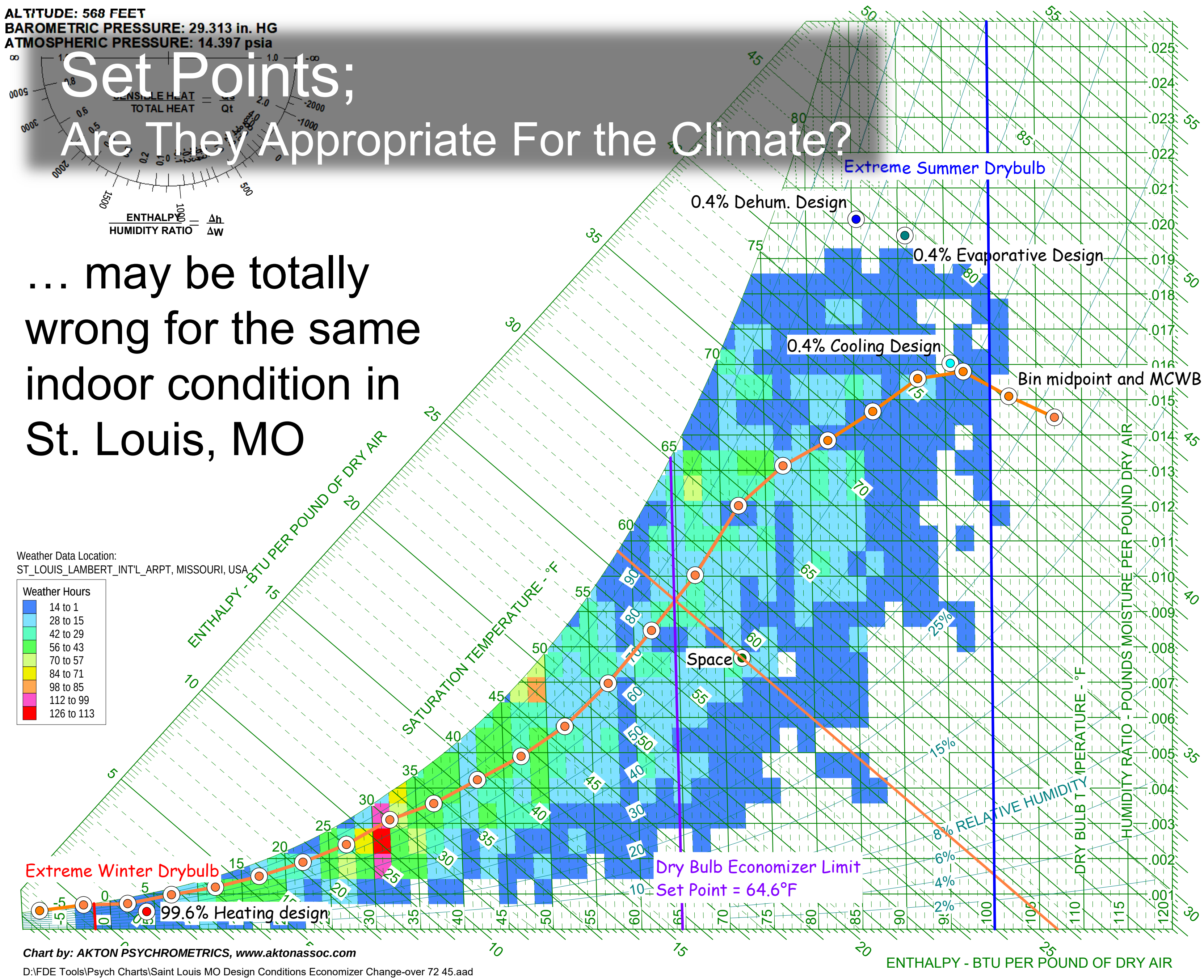
Set Points;
Are They Appropriate For the Climate?

The dry bulb economizer high limit set point that works great for a given indoor condition in San Francisco, CA …



Set Points; Are They Appropriate For the Climate?

… may be totally wrong for the same indoor condition in St. Louis, MO

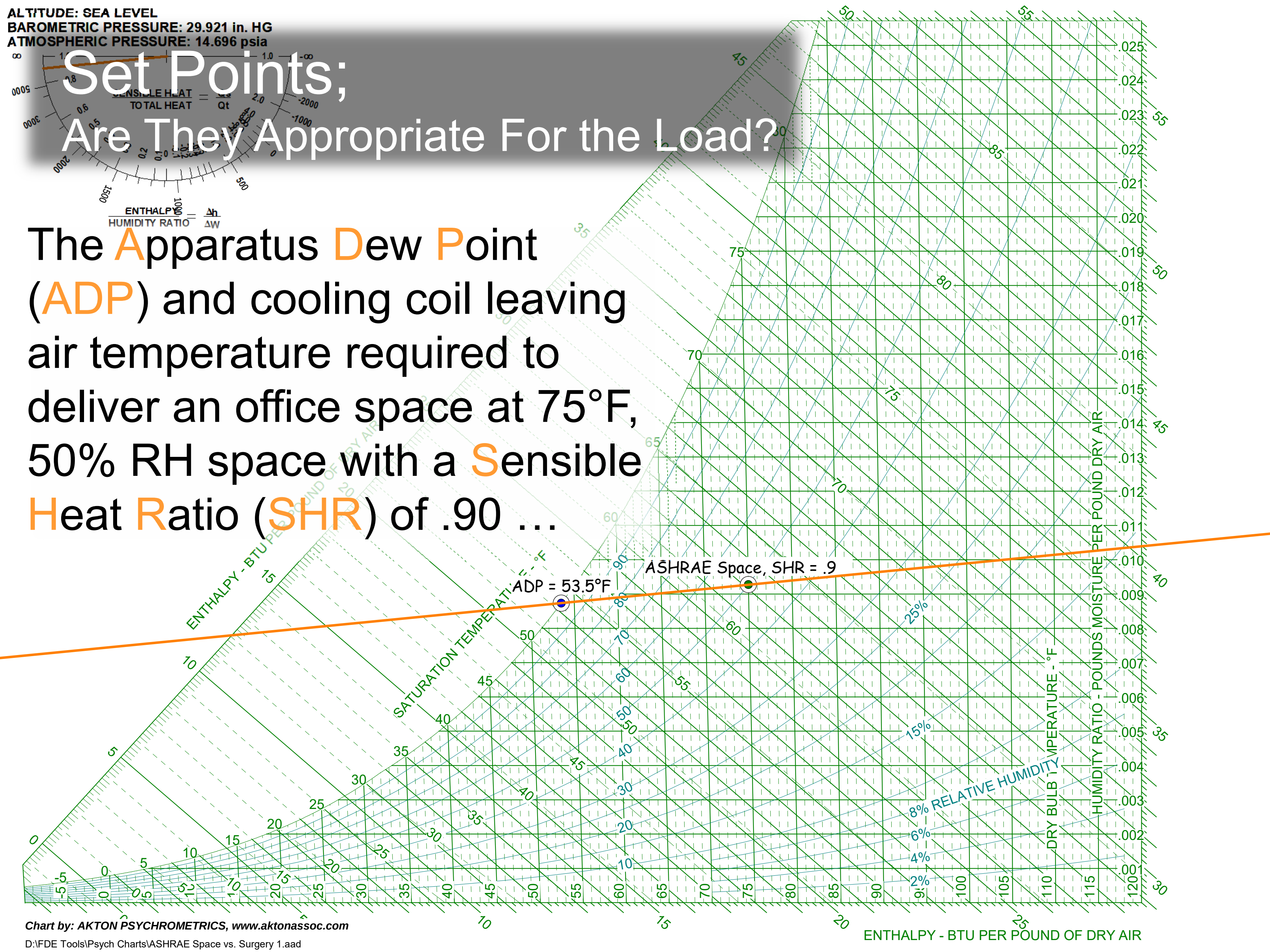


Set Points

Are They Appropriate for the Load?

Set Points;
Are They Appropriate For the Load?

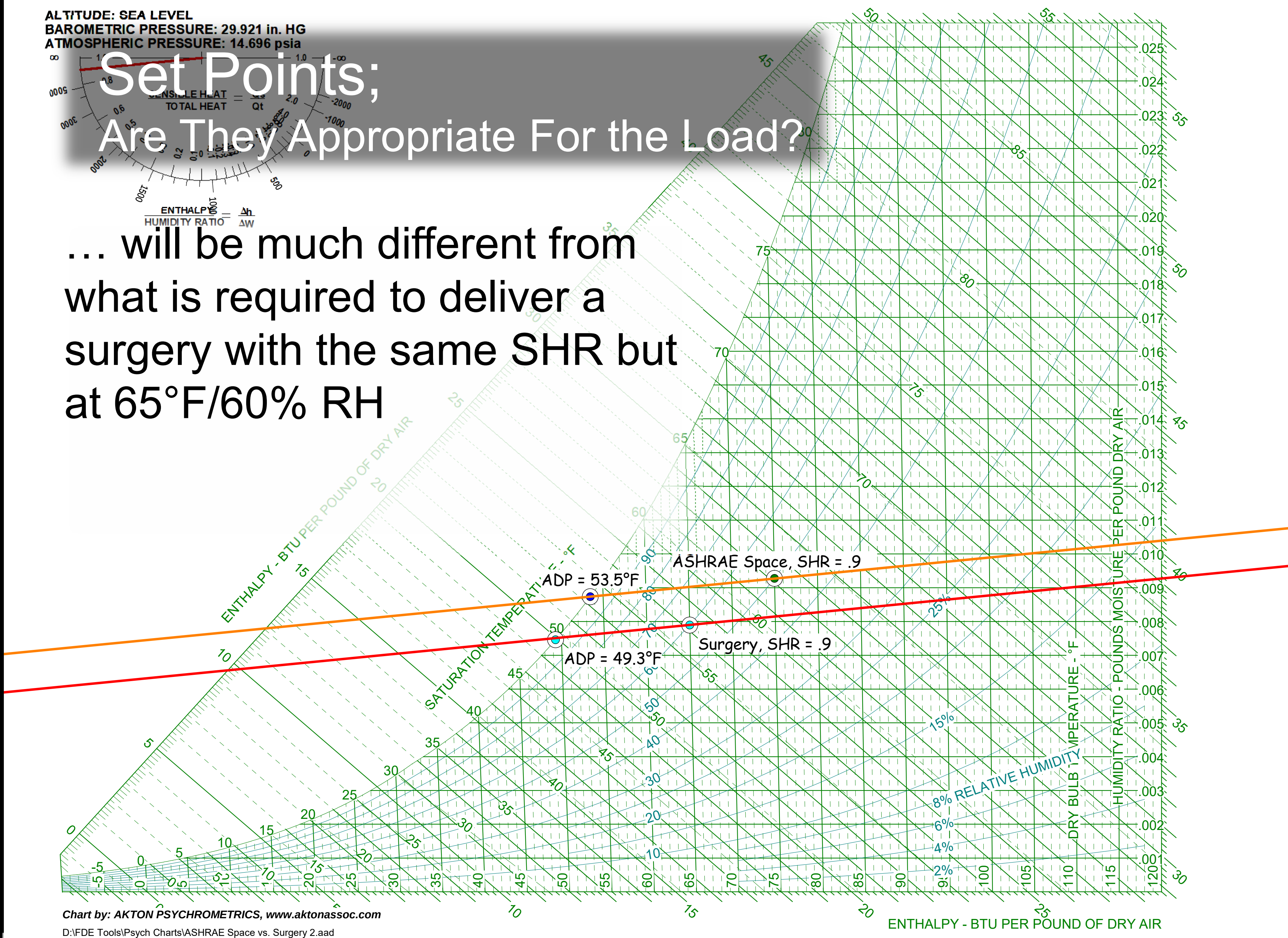
The Apparatus Dew Point (ADP) and cooling coil leaving air temperature required to deliver an office space at 75°F, 50% RH space with a Sensible Heat Ratio (SHR) of .90 …



Set Points;

Are They Appropriate For the Load?

… will be much different from what is required to deliver a surgery with the same SHR but at 65°F/60% RH



Set Points;

Set Point Reset; Not 1 Size Fits All?

- In the San Francisco Bay area, it is not uncommon to see Air Handling Unit (AHU) Leaving Air Temperature (LAT) reset schedules that reset the LAT to 65°F (or higher) under low load conditions
- The same reset schedule may be a really bad idea in hot and humid climates like St. Louis, Missouri or Honolulu Hawaii

Set Points

Are They Appropriate for the Equipment Selections?

Set Points;

Are They Appropriate for the Equipment Selection?

Two Cooling Towers Selected for the Same Load Requirement

- Best first cost tower
    - 60 bhp
    - 69.5 gpm/hp
    - $7,230 per year for fan energy
- Best life cycle cost tower
    - 40 bhp
    - 105.8 gpm/hp
    - $4,810 per year for fan energy
    - Fan energy savings = $2,420 per year

UPDATE™ Version 5.2.0
Product Data: 11/14/2016 (Current)

11/26/2016 12:54:44 PM

Job Information

Region	North America
Product Type	Cooling Towers
Electrical Source	60 Hz
Labor Rate	50 USD/h

Selected By

Facility Dynamics Engineering
NW Satellite Office
8560 North Buchanan Avenue
DSellers@FacilityDynamics.com
David Sellers
Tel 503-286-1494

SPX Cooling Technologies Contact

TraneOregon
7257 SW Kable Lane
Portland, OR
ddriver@trane.com
Tel 503-620-8031

Design Conditions

Solve For	Capacity
Tolerance Under Design	5 %
Number of Cells	2
Tower Water Flow	3450 gpm
Hot Water Temperature	86 °F
Cold Water Temperature	76 °F
Total Heat Load	17216000 Btu/h
Wet-Bulb Temperature	66 °F

Evaluation Parameters

Energy Cost	0.08 $/kWh
Annual Operating Time	2000 h
Evaluation Period	1 years
Interest Rate	10 %
Cold Water Set Point	76 °F
Average Wet-Bulb	66 °F
Range at Avg. Wet-Bulb	10 °F
Maximum Wet-Bulb	66 °F
Wet-Bulb Profile	Linear
Fan Operation	Single-Speed
Motor Efficiency	90 %

Advanced

Sound Requirements

Calculation	Single Cell
Location	Air Inlet
Distance from Product	5 ft
Maximum SPL	NA

Product
NC Steel

Sound Location
Air Inlet Face

Selections

Model	Cells	Status	Fan Motor Output BHp	Total Fan Motor Output BHp	Capacity	Cost Ratio	ASHRAE 90.1 Perf. gpm/Hp	Fan Energy Cost $	Pump Energy Cost $	dBA Single Cell
NC8405UAN2	2	Caution	50.0	100.0	99.2%	0.92	41.5	12050	1667	84
NC8405ULN2	2	Caution	50.0	100.0	97.9%	0.92	41.0	12050	1667	82
NC8405TAS2	2	Caution	40.0	80.0	99.0%	1.00	51.7	9640	1667	84
NC8405UAS2	2	CTI	50.0	100.0	103.5%	1.00	43.2	12010	1667	84
NC8405TLS2	2	Caution	40.0	80.0	97.2%	1.00	50.9	9640	1667	81
NC8405ULS2	2	CTI	50.0	100.0	102.3%	1.01	42.7	12020	1667	82
NC8407SAN2	2	CTI	30.0	60.0	100.0%	1.03	70.2	7230	1667	81
NC8407SLN2	2	Caution	30.0	60.0	99.3%	1.04	69.5	7230	1667	78
NC8407TAN2	2	CTI	40.0	80.0	109.2%	1.04	57.3	9520	1667	83
NC8407UAN2	2	CTI	50.0	100.0	117.4%	1.05	49.2	11790	1667	85
NC8407TLN2	2	CTI	40.0	80.0	105.3%	1.06	55.3	9570	1667	80
NC8407ULN2	2	CTI	50.0	100.0	115.6%	1.06	48.4	11810	1667	83
NC8407VAN2	2	CTI	60.0	120.0	123.1%	1.10	42.9	14070	1667	86
NC8407RAS2	2	Caution	25.0	50.0	98.8%	1.11	83.1	6030	1667	80
NC8407VLN2	2	CTI	60.0	120.0	121.2%	1.11	42.2	14090	1667	84
NC8407SAS2	2	CTI	30.0	60.0	104.8%	1.11	73.4	7180	1667	81
NC8407RLS2	2	Caution	25.0	50.0	97.4%	1.12	81.9	6030	1667	75
NC8407SLS2	2	CTI	30.0	60.0	106.0%	1.12	74.0	7170	1667	78
NC8407TAS2	2	CTI	40.0	80.0	114.2%	1.13	59.8	9470	1667	83
NC8409QAN2	2	CTI	20.0	40.0	100.7%	1.13	105.8	4810	1667	74

Set Points;
Are They Appropriate for the Equipment Selection?

Two Cooling Towers Selected for the Same Load Requirement

- Best first cost tower
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- Best life cycle cost tower
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  - 105.8 gpm/hp
  - $4,810 per year for fan energy
  - Fan energy savings = $2,420 per year

Its likely that capturing the energy savings will require different set points for control processes related to the cooling tower fan operation

Facility Dynamics Engineering

Set Point Bottom Lines

Control logic may be a *one size fit's all* proposition for similar system types and configurations

- The decision tree for operating a large VAV system can probably be applied to any similar system

- The decision tree for staging up the cooling towers for a variable flow, water cooled, primary only chiller plant can probably be applied to any similar system

Set Point Bottom Lines

The set points used by the *one size fit's all* decision tree will need to be tailored to the climate, load characteristics and equipment characteristics for each application

- The economizer high limit set point associated with the logic for a large VAV system in San Francisco, CA will be different for that same logic applied in St. Louis, MO

- The cooling tower staging and condenser water reset schedule will be different for a for a variable flow, water cooled, primary only chiller plant that has a mix of chiller types and sizes as compared to a plant with identical machines

Control System Building Blocks

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Inputs	Measure the process variable
Outputs	Adjust the controlled variable
Control Process	Logic and mechanisms that tries to bring the controlled variable into agreement with the set point
Set Point	Our requirements for the process that is under control, which can be fixed or variable

Control System Building Blocks

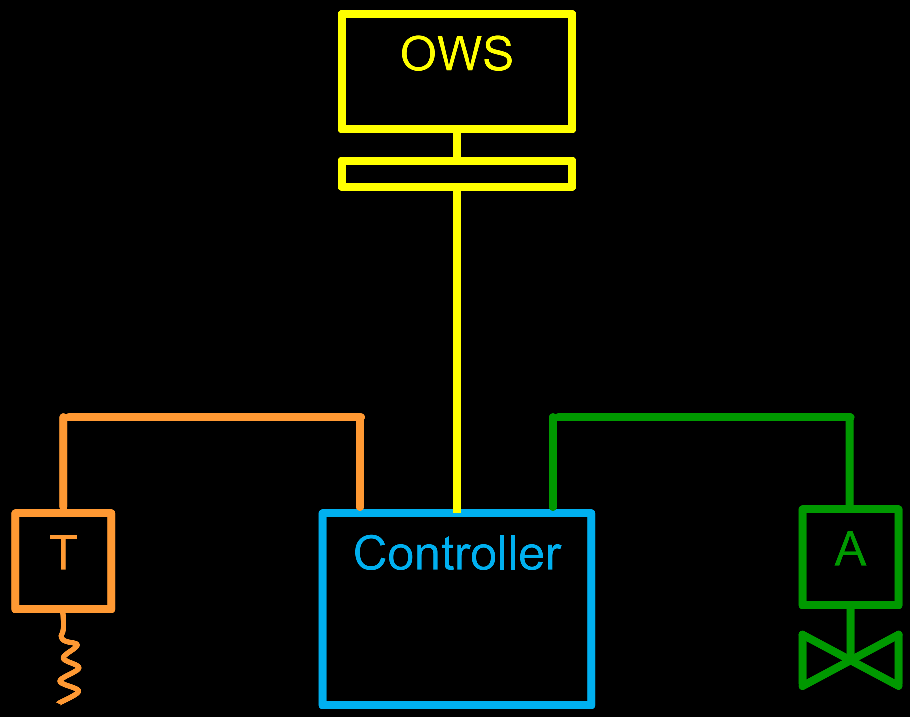
Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Inputs

Outputs

Control Process

Set Point



Control System Building Blocks

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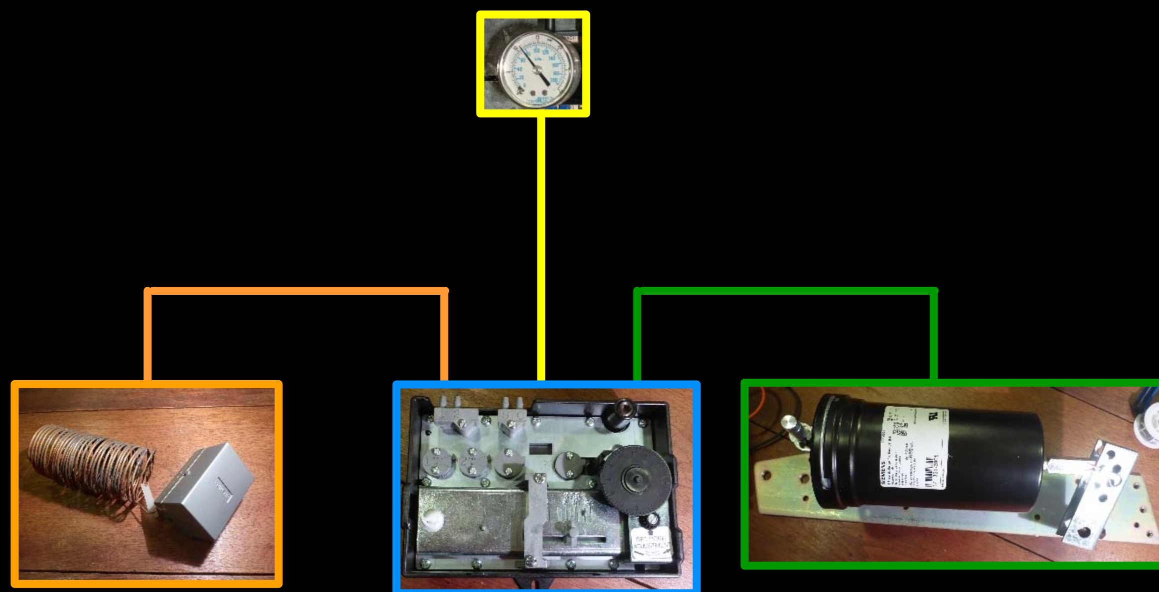
Inputs

Outputs

Control Process

Set Point

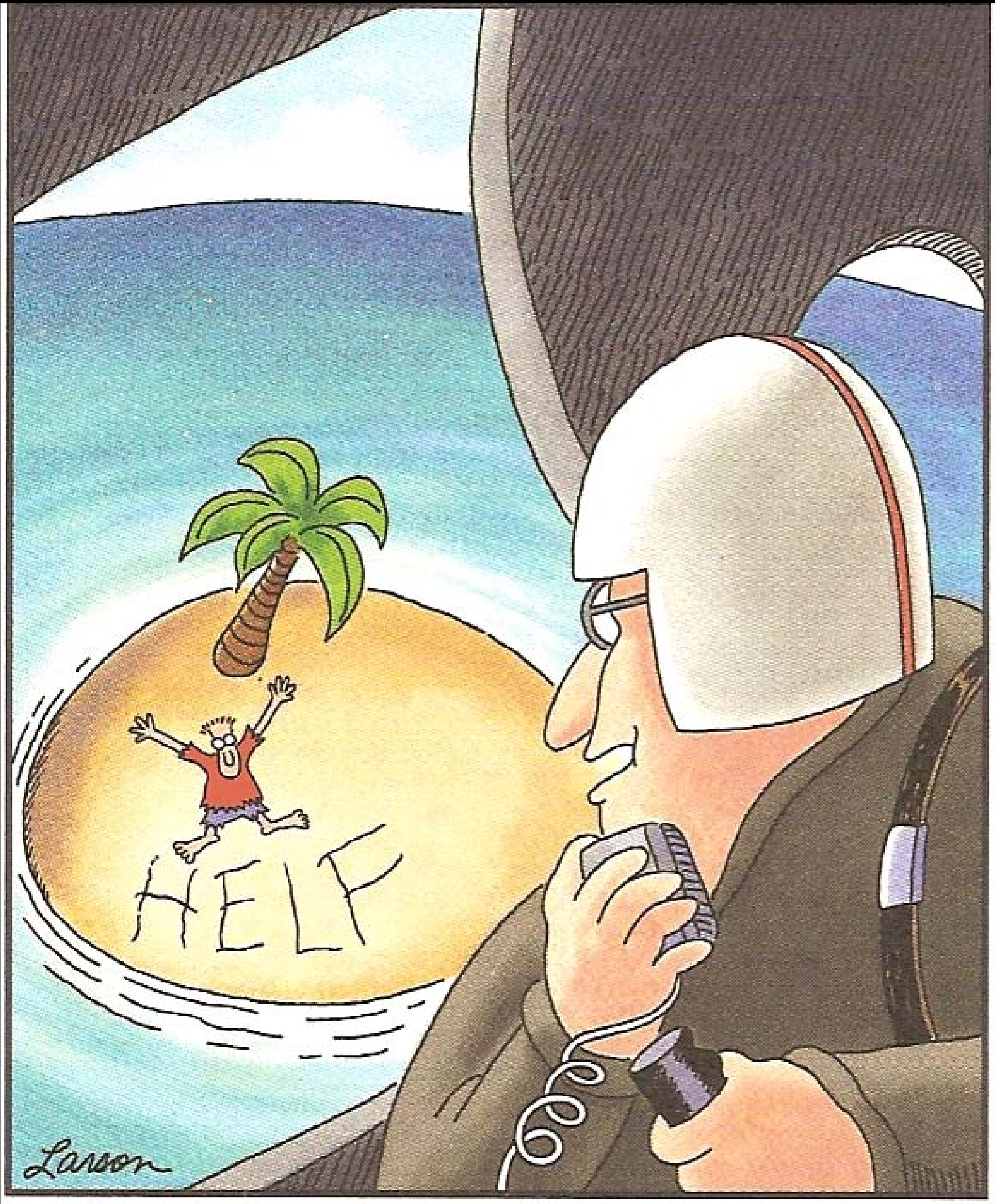


Bottom Lines

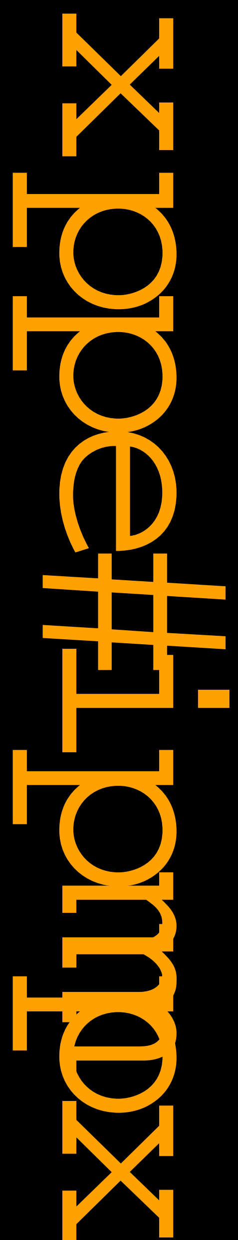
- Repeatable, Reliable, Robust control sequences and logic are essential to successfully capturing the design intent
- To be successful:
  - Capture all of the details associated with the design intent
  - Support the logic with repeatable, reliable, robust hardware
  - Support the logic with a physical configuration that will allow it to work as intended

Writing it All Down

- Documenting your sequence is an *Excellent* idea
- Using the English language to do it may provide a few challenges



"Wait! Wait! Cancel that. … I guess it says 'helf.'"



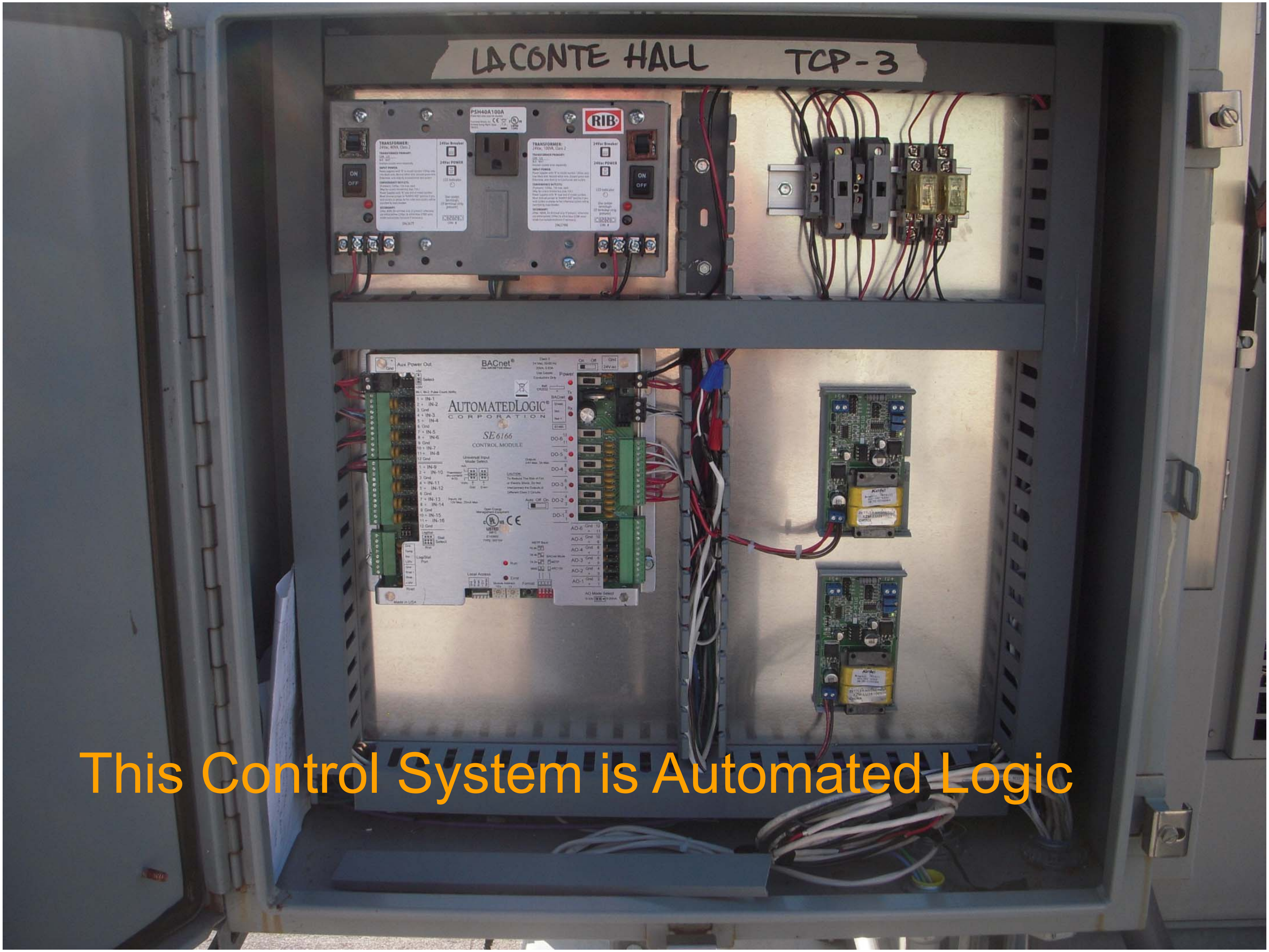
Does the text to the left say

Molly Poom

or

Wood Hollow?


THE MIRAGE
BEATLES
LOVE
THE MIRAGE
Clear Communication is Important



This Control System is Automated Logic

This Control System is Automated Logic

But in the general sense, so is this one

But in the general sense, so is this one, and this one

A Few Resources

Articles on Developing Control System Design and Logic Sequences

https://www.av8rdas.com/magazine-articles.html#Controls

https://www.av8rdas.com/magazine-articles.html#Lessons

Logic Diagram Tool with Examples

https://www.av8rdas.com/logic-diagram-tool.html

Examples of Control and Logic Standards

https://www.av8rdas.com/control-and-logic-diagram-standards.html

Logic Diagram Tools with Simulation Capability

https://www.av8rdas.com/eikon-for-educators-and-windlgc.html

Preparing for Next Weeks Class

1. Read through the article Jay Santos wrote about how to develop a control sequence. It is the file named CSE (02-2008_-_writing_control_sequences_vweb.pdf) which is located with several other articles at the first link in the previous slide.
2. Using the techniques Jay discusses:
   a. Consider a VAV reheat terminal
   b. Consider an air handling system with an air side economizer
3. Put together a bullet point or outline sequence of how you would go about controlling them
   a. What is the primary input required?
   b. What other inputs are required?
   c. What needs to be sequenced and how?
   d. Are their any interlocks required?

Preparing for Next Weeks Class
(Continued)

4. If you need a refresher on how a VAV reheat terminal works, you can review the *Terminal Unit Basics* slide module that is included with the Variable Air Volume Systems; Design Performance and Commissioning Issues class materials at this location.

   https://www.av8rdas.com/pacific-energy-center-design-performance-and-commissioning-issues-classes.html#VAV

5. If you need a refresher on how an air side economizer works, you will find several modules in the Economizers; Design Performance and Commissioning Issues class materials that will bring you up to speed. The files are located at this location.

   https://www.av8rdas.com/pacific-energy-center-design-performance-and-commissioning-issues-classes.html#Economizers

   You may also find these blog posts to be helpful:

   https://av8rdas.wordpress.com/category/economizers/page/2/