Facility Dynamics Engineering

Lags and the Two Thirds Rule

A Mentoring Story

Presented By:

David Sellers, Facility Dynamics Engineering

Senior Engineer

The Two Thirds Rule Pros and Cons

A Mentoring Story

Mentors:

MCI Building

St. Louis, Missouri

Perimeter Induction System

Tom Lillie

Horizon Engineering

David St. Clair

Straight Line Controls

Tom Lillie Courtesy Linked-in; David St. Clair courtesy Judy St. Clair

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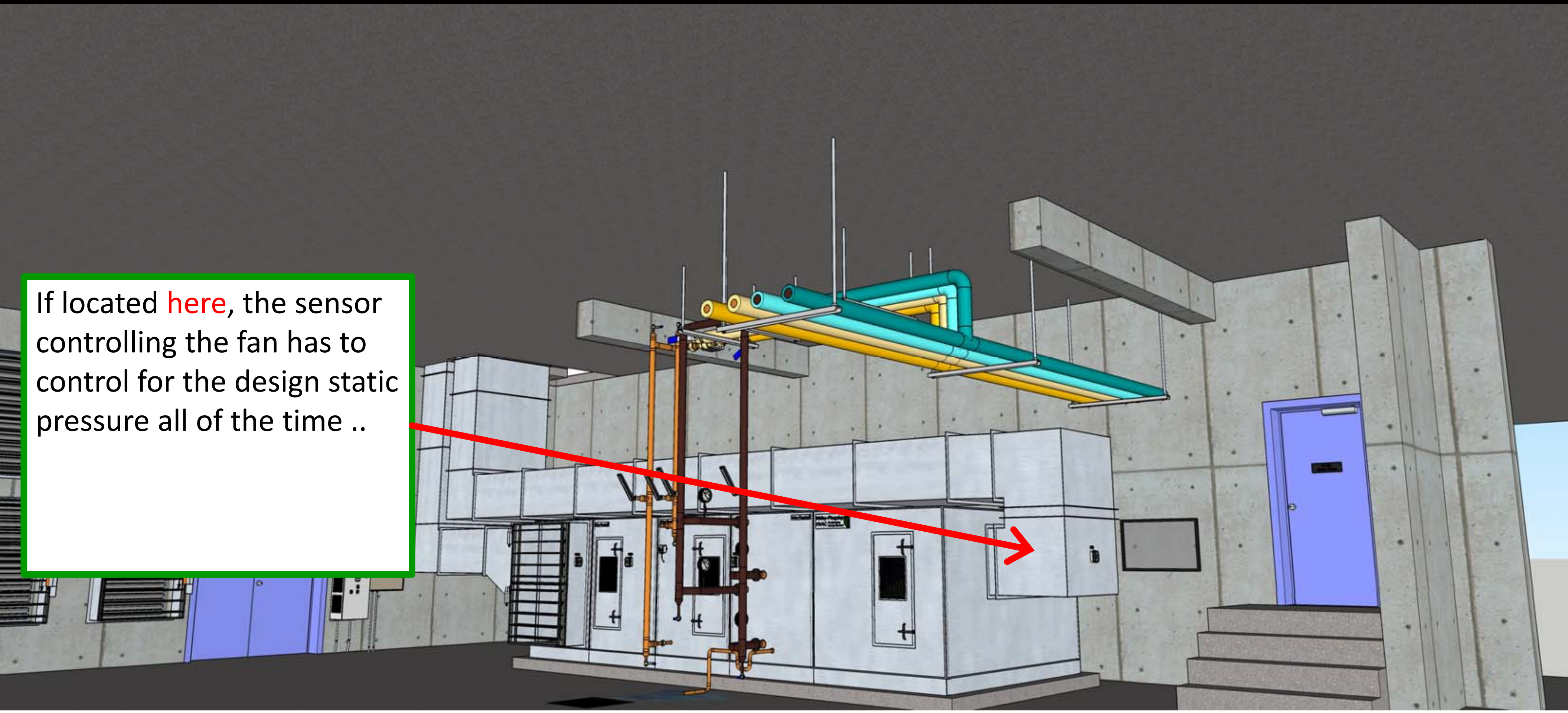

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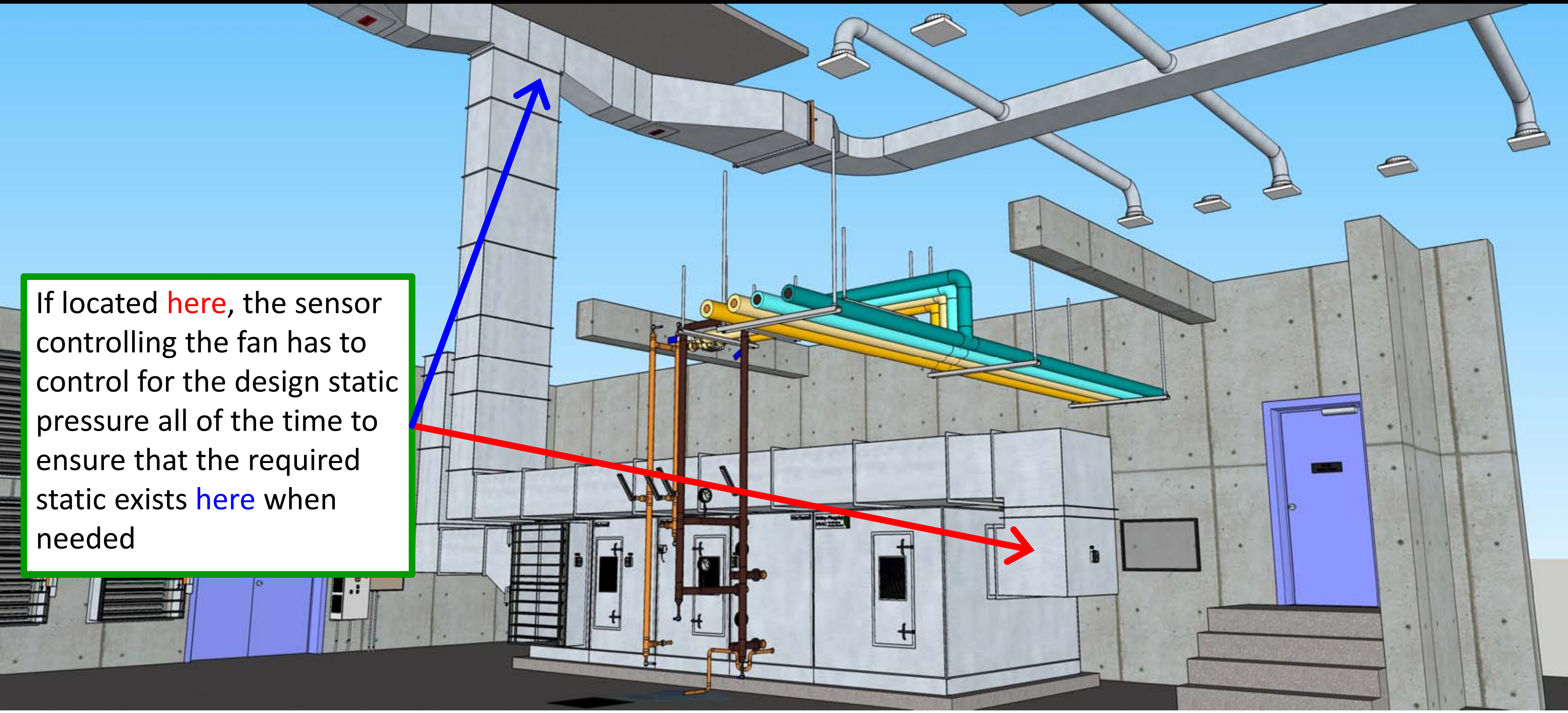

If located here, the sensor controlling the fan has to control for the design static pressure all of the time to ensure that the required static exists here when needed

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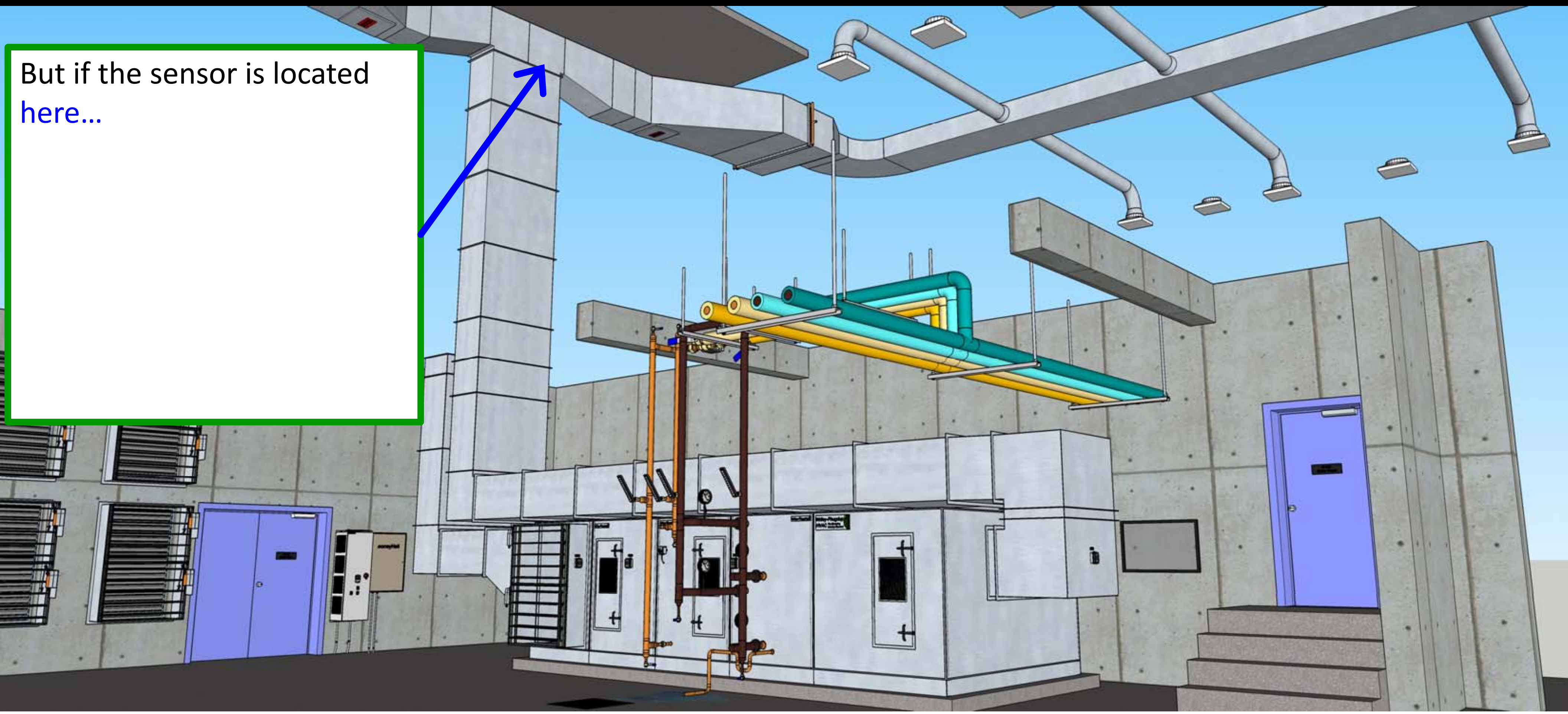

But if the sensor is located here…

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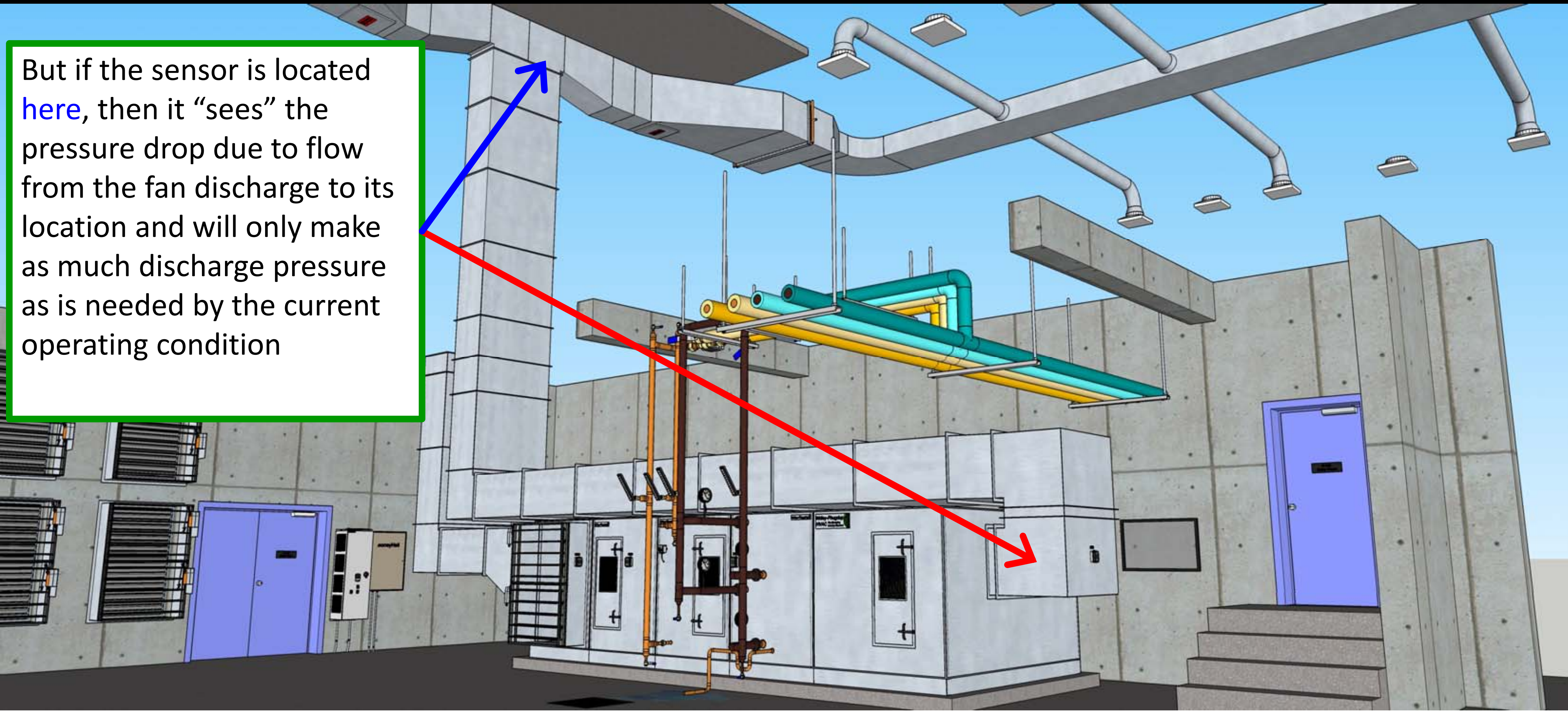

But if the sensor is located here, then it "sees" the pressure drop due to flow from the fan discharge to its location and will only make as much discharge pressure as is needed by the current operating condition

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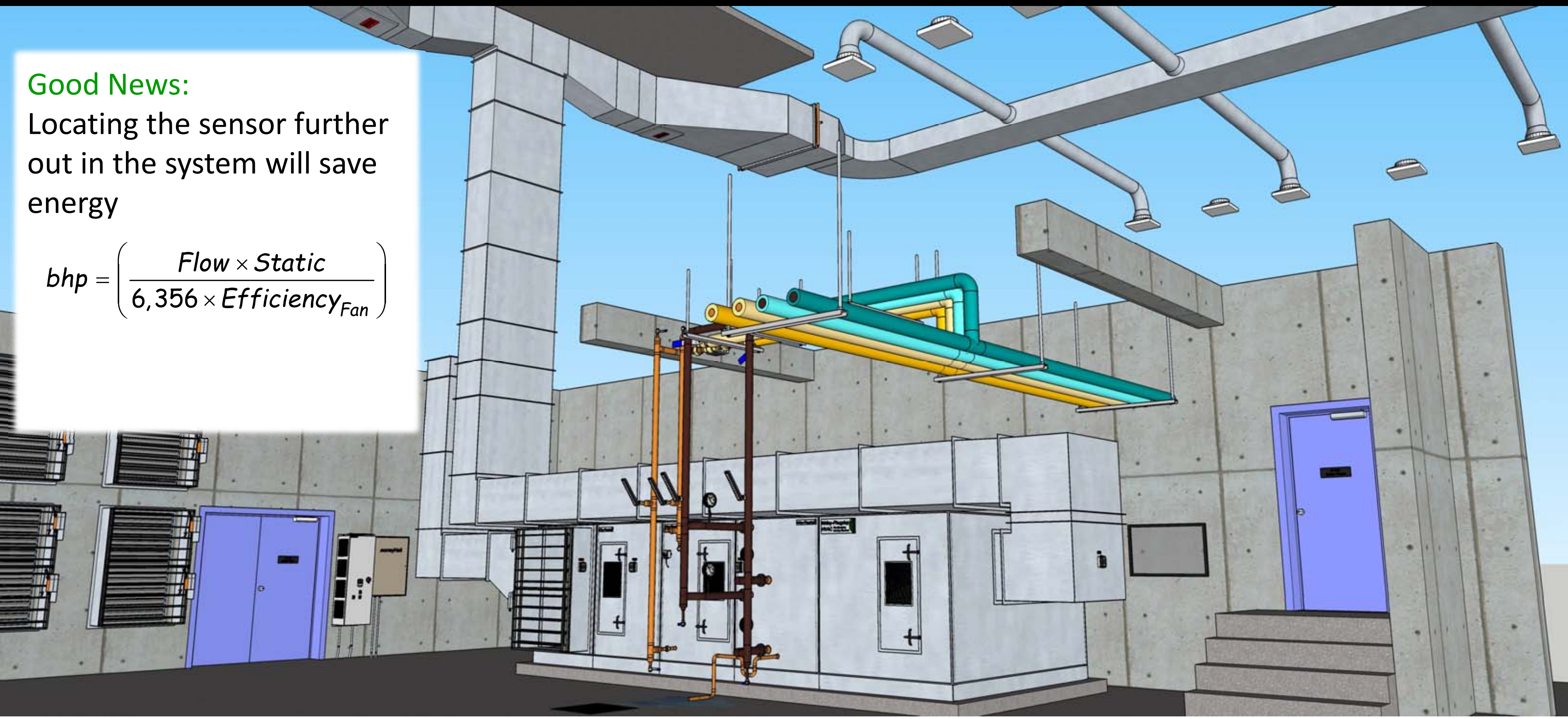
Good News:

Locating the sensor further out in the system will save energy

$$bhp = \left(\frac{Flow \times Static}{6{,}356 \times Efficiency_{Fan}} \right)$$



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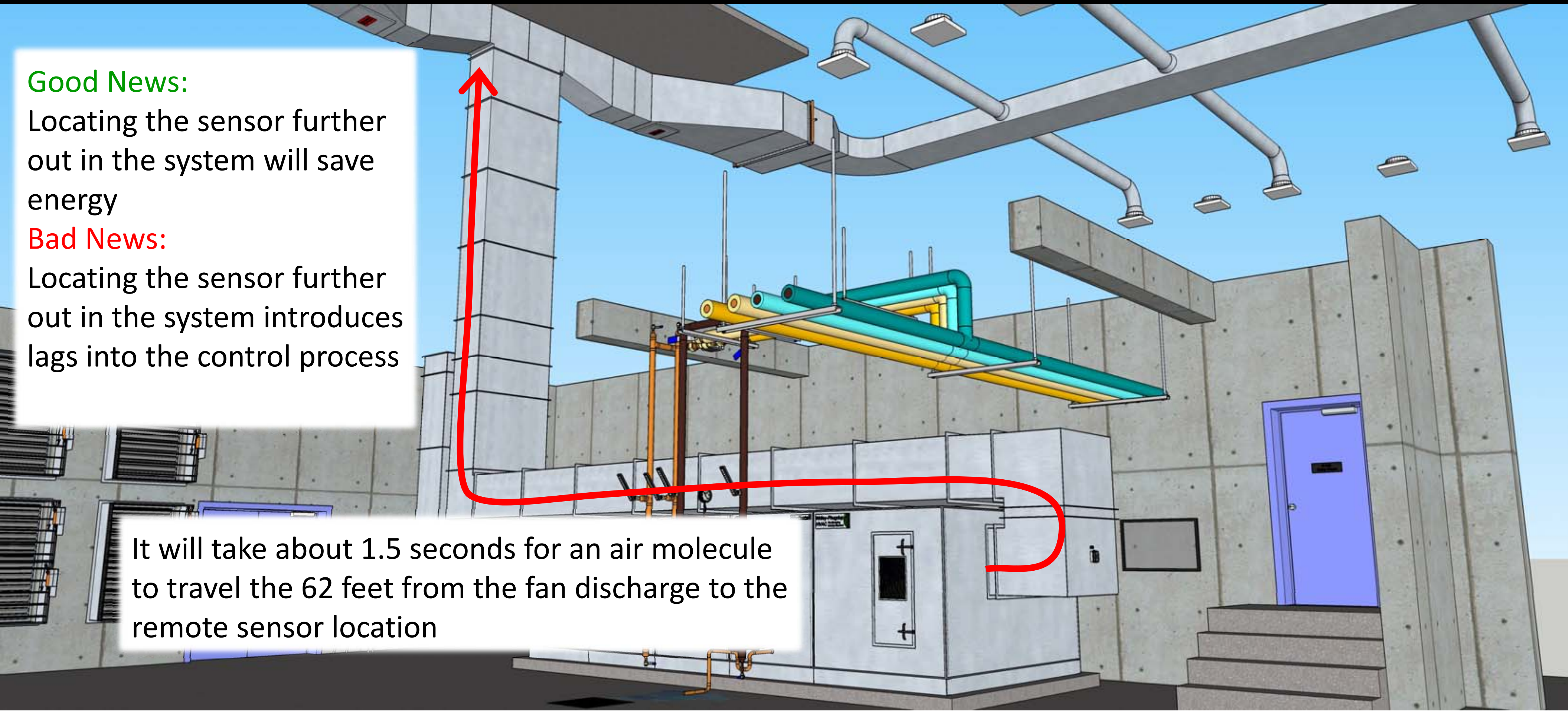

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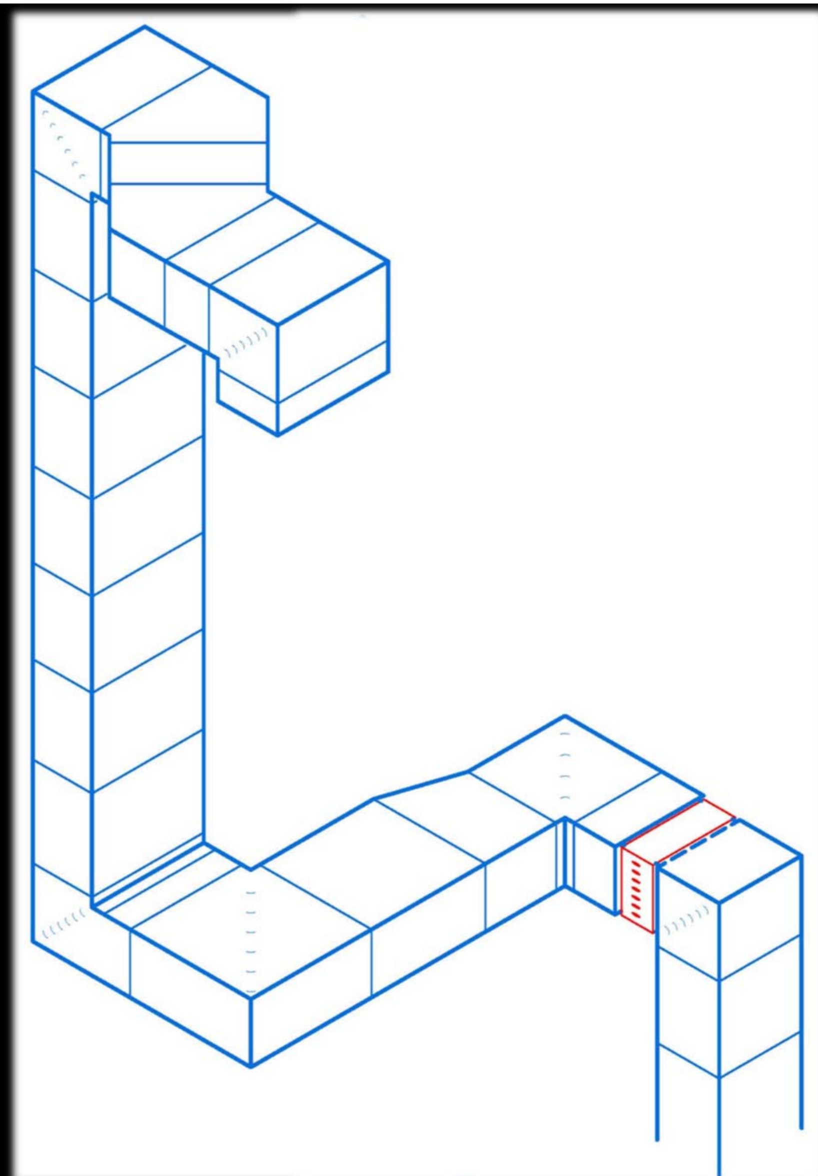
In a high rise building, that problem will get worse (about 500 feet and about 12 seconds for this scale example)



VAV System Design

Understanding and Reducing Air System Noise

The Big Bang Theory

The lags introduced into a control process by locating the sensor at a remote point in the system might cause you to blow up the discharge duct near the supply fan if you don't understand lags

This will create a big bang

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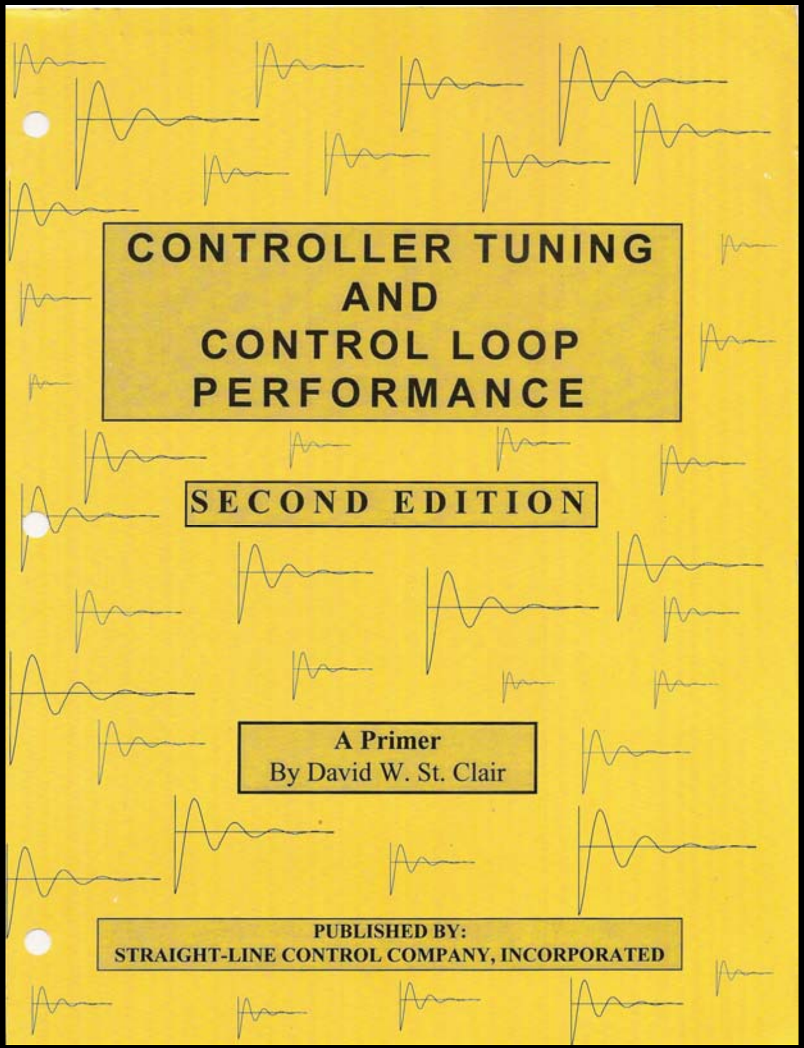
The Big Bang Theory

Proof:

1. Learn about PID principles from David St. Clair's book



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The Big Bang Theory

Proof:

1. Learn about PID principles from David St. Clair's book
2. Fail to fully comprehend his discussion about lags

Thermal Process Lags

This is a rather broad-brush category meant to include everything but measurement lags. Process lags, such as heat exchangers, are not only complex, but the variety of equipment is broad. These factors combine to discourage trying to condense the field to typical numbers. Lags get longer as the surface-to-volume (mass) ratio decreases. They cover the gamut from a few seconds to hours.

Typical Natural Periods

While there are exceptions, control loops on the same **type** of variable tend to have the same natural periods. Flow loops will have a natural period of 1 or 2 seconds if transmission lags are short, going up to 5 to 10 seconds for long pneumatic lines. Flow should be back to normal, after an upset, within a very short time, say 5 to 10 seconds for the faster loops. Pressure loops fall in the same category. They will be fast. The gain on pressure loops frequently can be much higher than on flow loops. Temperature loops tend to be much slower, as you would expect after this dissertation on lags. Their natural periods will typically fall in the range of, say, half a minute to several minutes. There would be many exceptions. Composition control loops tend to be slower still, with natural periods of several minutes to several hours.

IT ALL DEPENDS ON THE LAGS!

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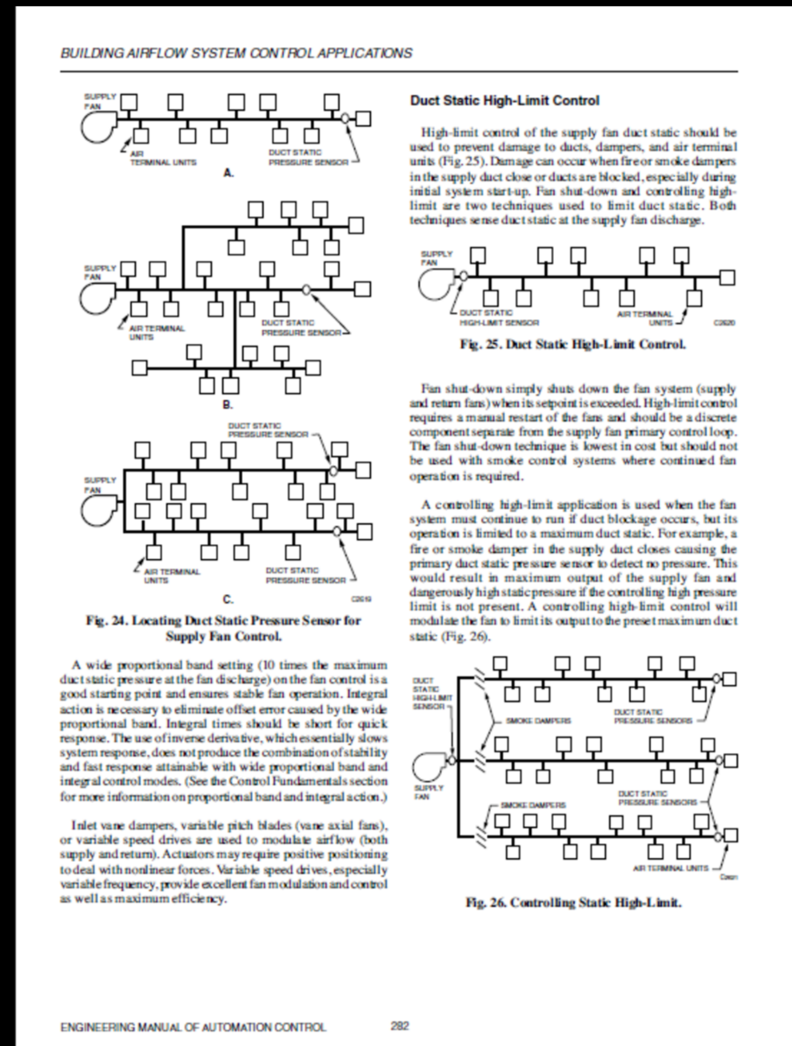
The Big Bang Theory

Proof:

1. Learn about PID principles from David St. Clair’s book
2. Fail to fully comprehend his discussion about lags
3. Comprehend and embrace the two thirds rule



BUILDING AIRFLOW SYSTEM CONTROL APPLICATIONS

Fig. 24. Locating Duct Static Pressure Sensor for Supply Fan Control.

A wide proportional band setting (10 times the maximum duct static pressure at the fan discharge) on the fan control is a good starting point and ensures stable fan operation. Integral action is necessary to eliminate offset error caused by the wide proportional band. Integral times should be short for quick response. The use of inverse derivative, which essentially slows system response, does not produce the combination of stability and fast response attainable with wide proportional band and integral control modes. (See the Control Fundamentals section for more information on proportional band and integral action.)

Inlet vane dampers, variable pitch blades (vane axial fans), or variable speed drives are used to modulate airflow (both supply and return). Actuators may require positive positioning to deal with nonlinear forces. Variable speed drives, especially variable frequency, provide excellent fan modulation and control as well as maximum efficiency.

Duct Static High-Limit Control

High-limit control of the supply fan duct static should be used to prevent damage to ducts, dampers, and air terminal units (Fig. 25). Damage can occur when fire or smoke dampers in the supply duct close or ducts are blocked, especially during initial system start-up. Fan shut-down and controlling high-limit are two techniques used to limit duct static. Both techniques sense duct static at the supply fan discharge.

Fig. 25. Duct Static High-Limit Control.

Fan shut-down simply shuts down the fan system (supply and return fans) when its setpoint is exceeded. High-limit control requires a manual restart of the fans and should be a discrete component separate from the supply fan primary control loop. The fan shut-down technique is lowest in cost but should not be used with smoke control systems where continued fan operation is required.

A controlling high-limit application is used when the fan system must continue to run if duct blockage occurs, but its operation is limited to a maximum duct static. For example, a fire or smoke damper in the supply duct closes causing the primary duct static pressure sensor to detect no pressure. This would result in maximum output of the supply fan and dangerously high static pressure if the controlling high pressure limit is not present. A controlling high-limit control will modulate the fan to limit its output to the preset maximum duct static (Fig. 26).

Fig. 26. Controlling Static High-Limit.

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The Big Bang Theory

Proof:

1. Learn about PID principles from David St. Clair’s book
2. Fail to fully comprehend his discussion about lags
3. Comprehend and embrace the two thirds rule
4. Install very nice TSBA pneumatic controls on VAV system serving 13 story high-rise with large two pipe transmitter and PI controller

The Two Thirds Rule Pros and Cons

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The Big Bang Theory

Proof:

5. Start up system for first time
6. Trip out on discharge static safety
7. Sneak set point up
8. Trip out on discharge static safety
9. Sneak set point up
10. Create big bang

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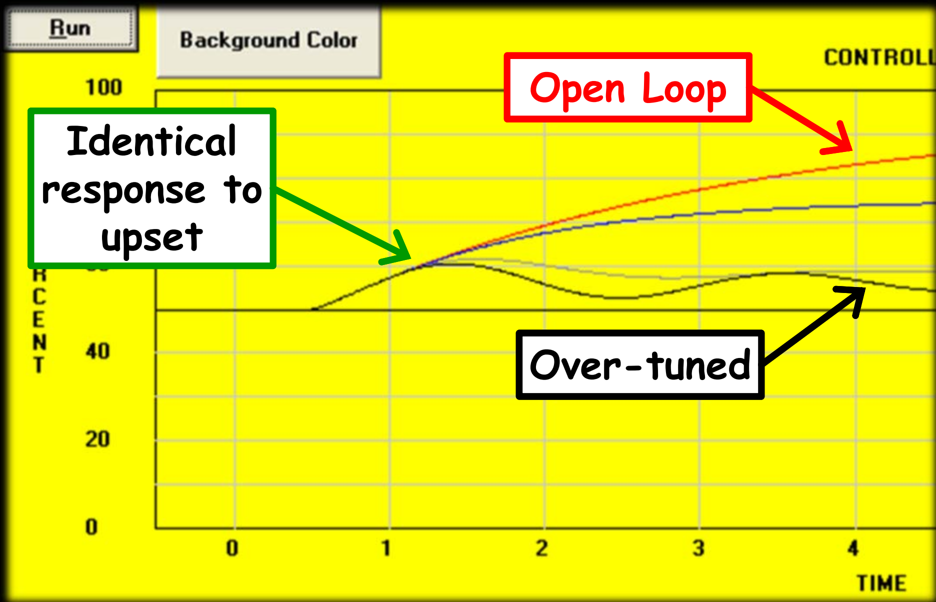
11. Comprehend what David meant as fan spins down



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Proof:

5. Start up system for first time
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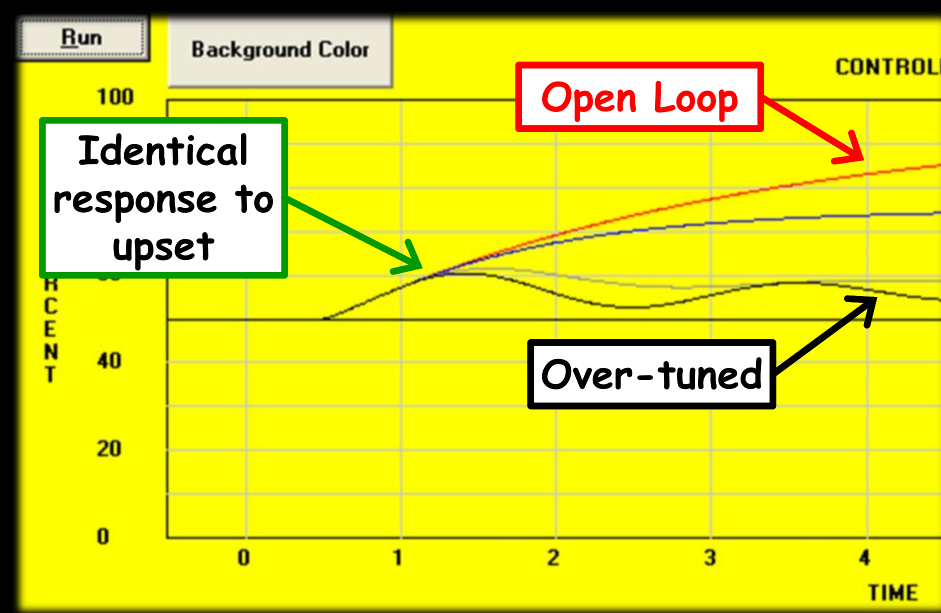
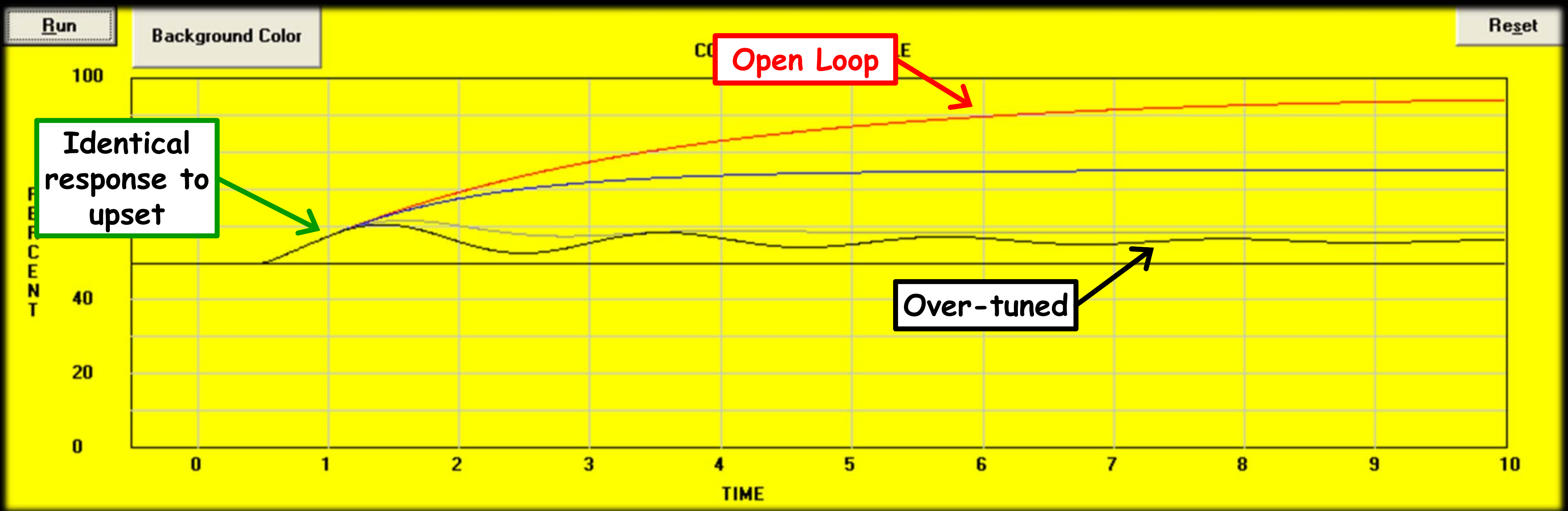
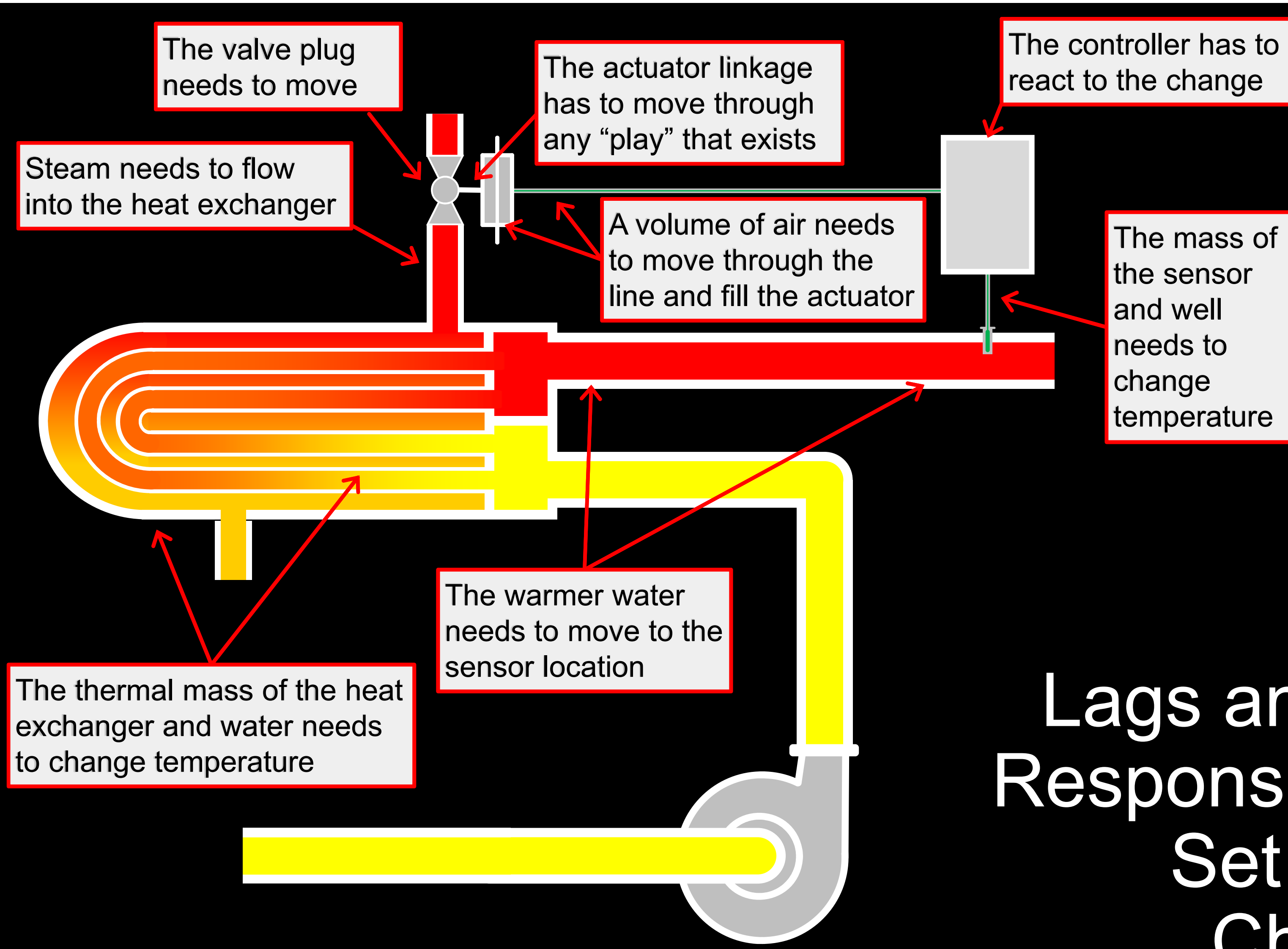
8. Trip out on discharge static safety
9. Sneak set point up
10. Create big bang
11. Comprehend what David meant as fan spins down
12. Call Tom



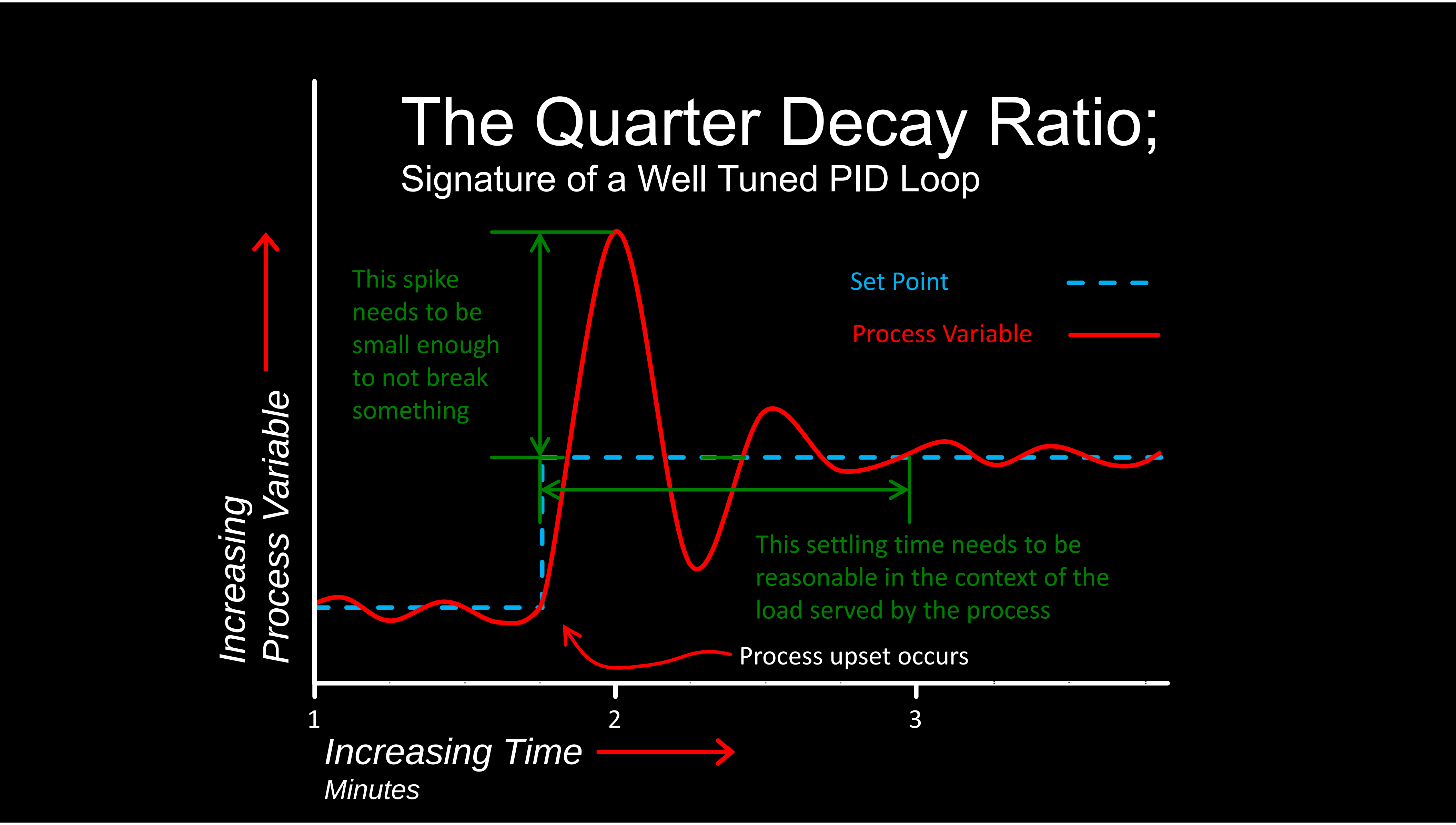
It All Depends on the Lags

David W. St. Clair



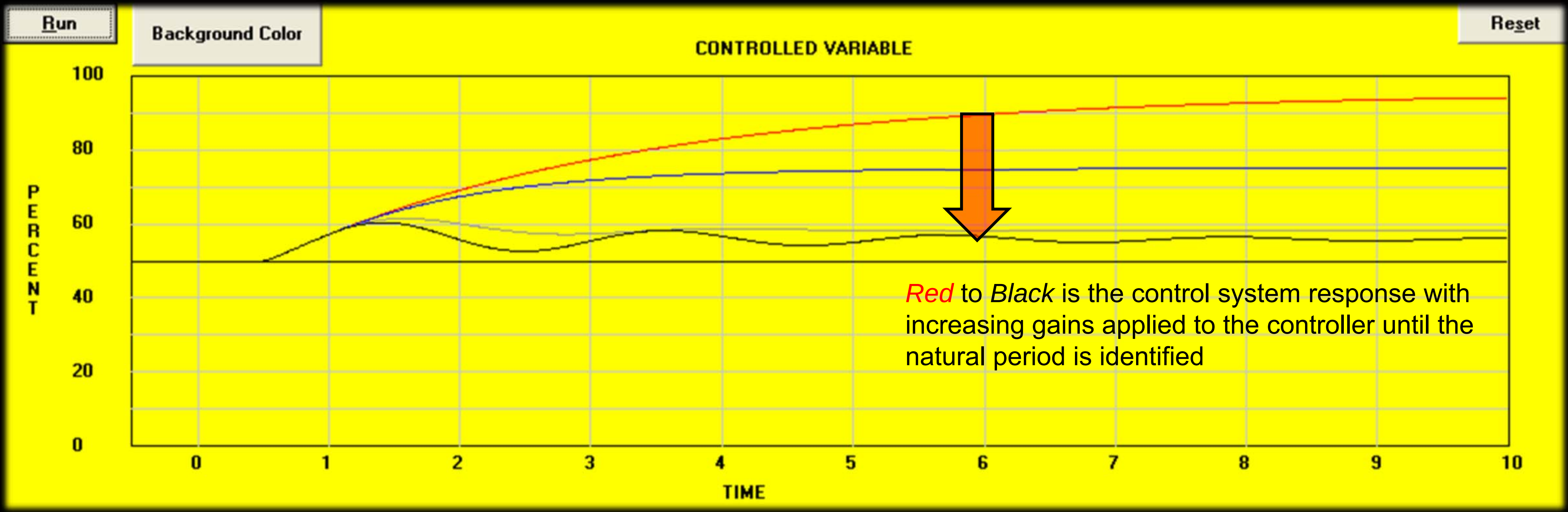


Lags and the Response to a Set Point Change



The Quarter Decay Ratio;
Signature of a Well Tuned PID Loop
This spike
needs to be
small enough
to not break
something
Set Point
Process Variable
Increasing
Process Variable
This settling time needs to be
reasonable in the context of the
load served by the process
Process upset occurs
1
2
3
Increasing Time
Minutes

Some Observations



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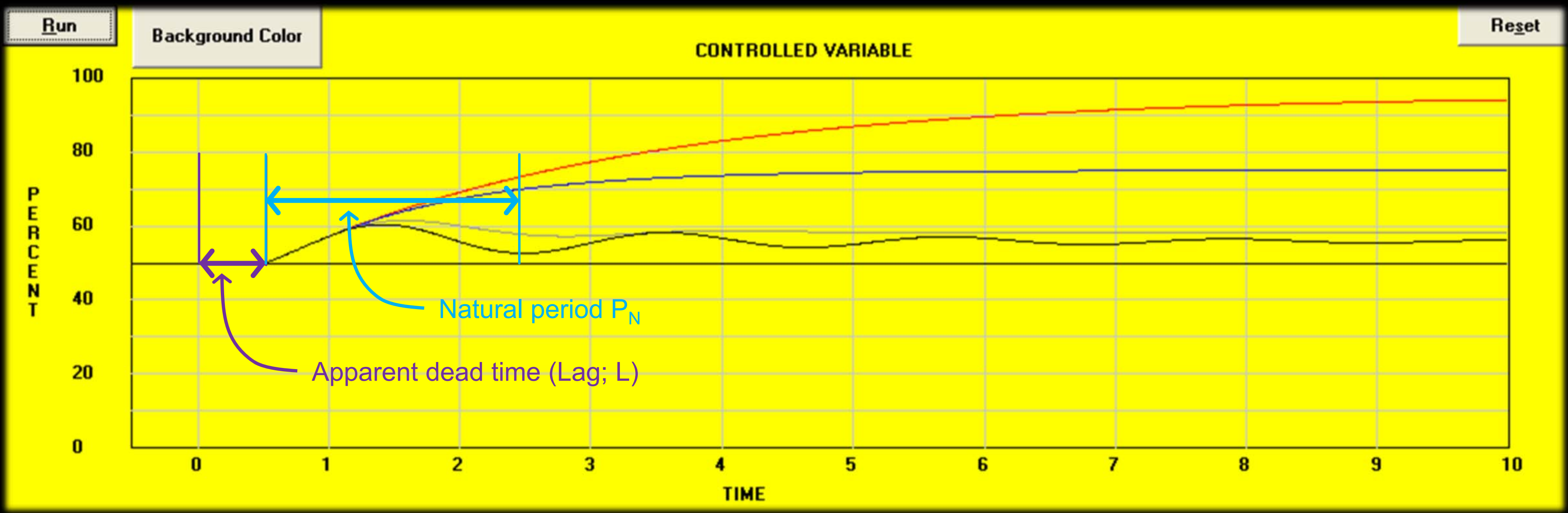

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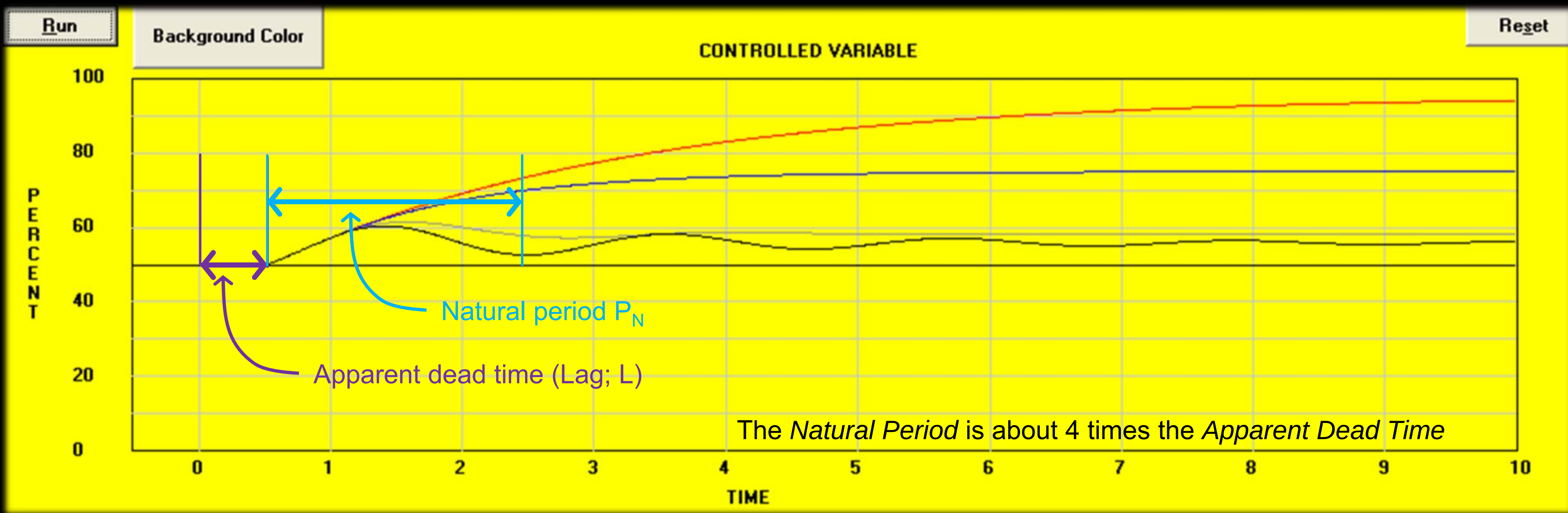

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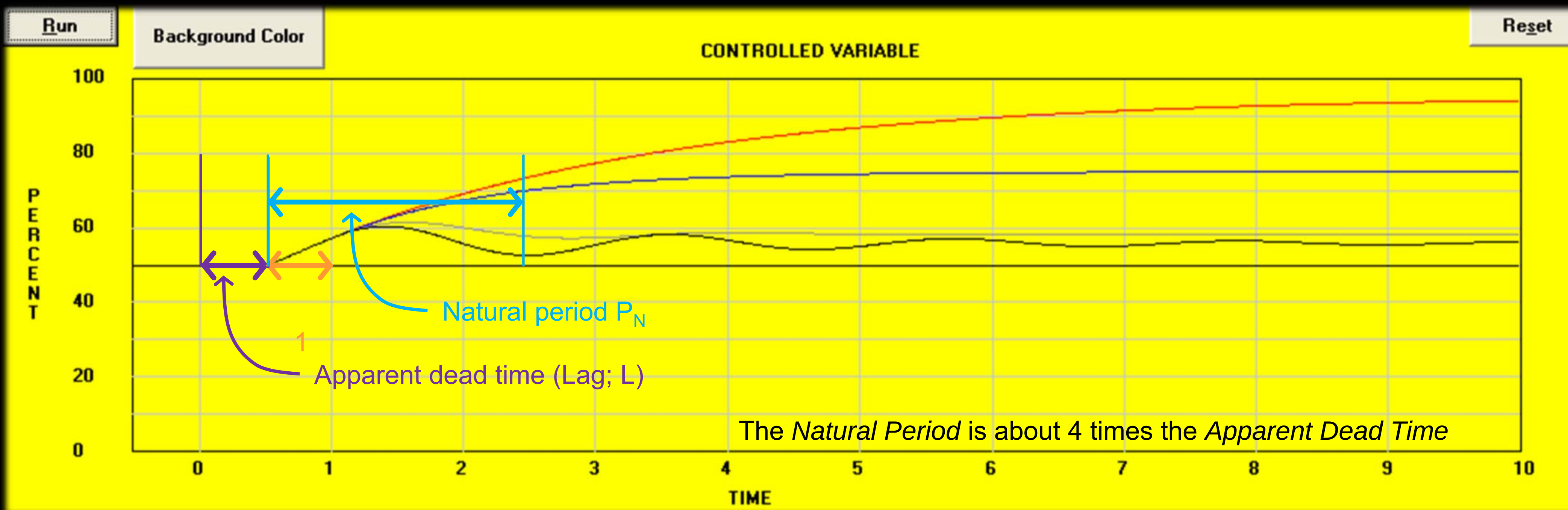

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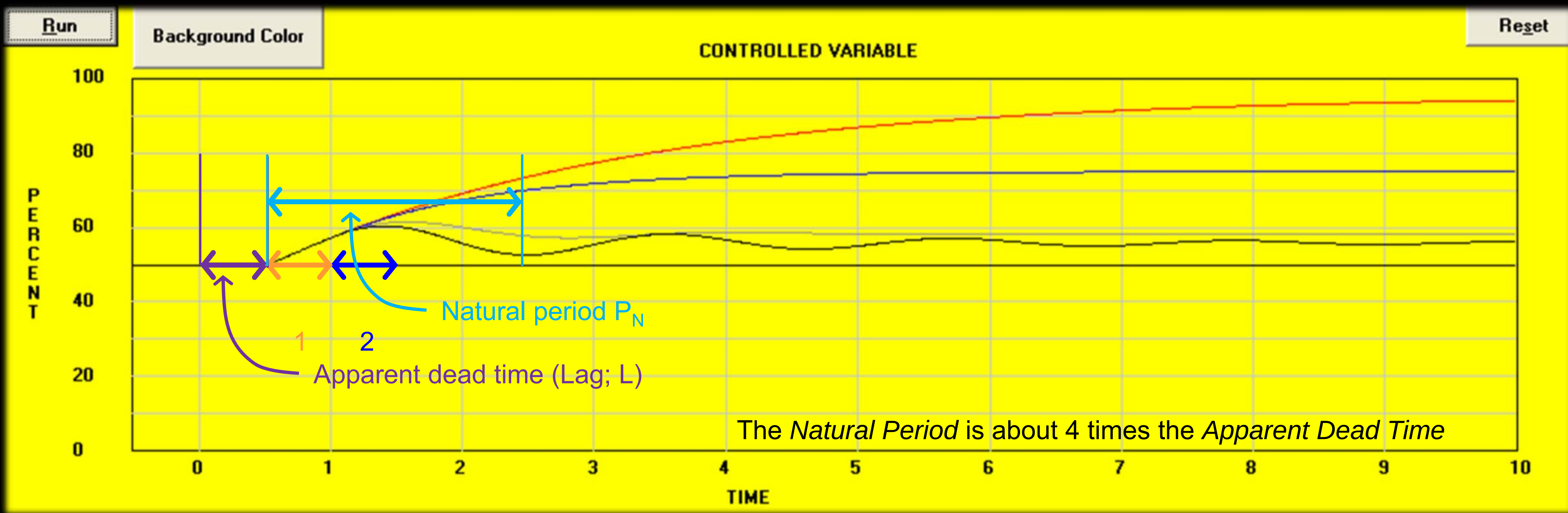

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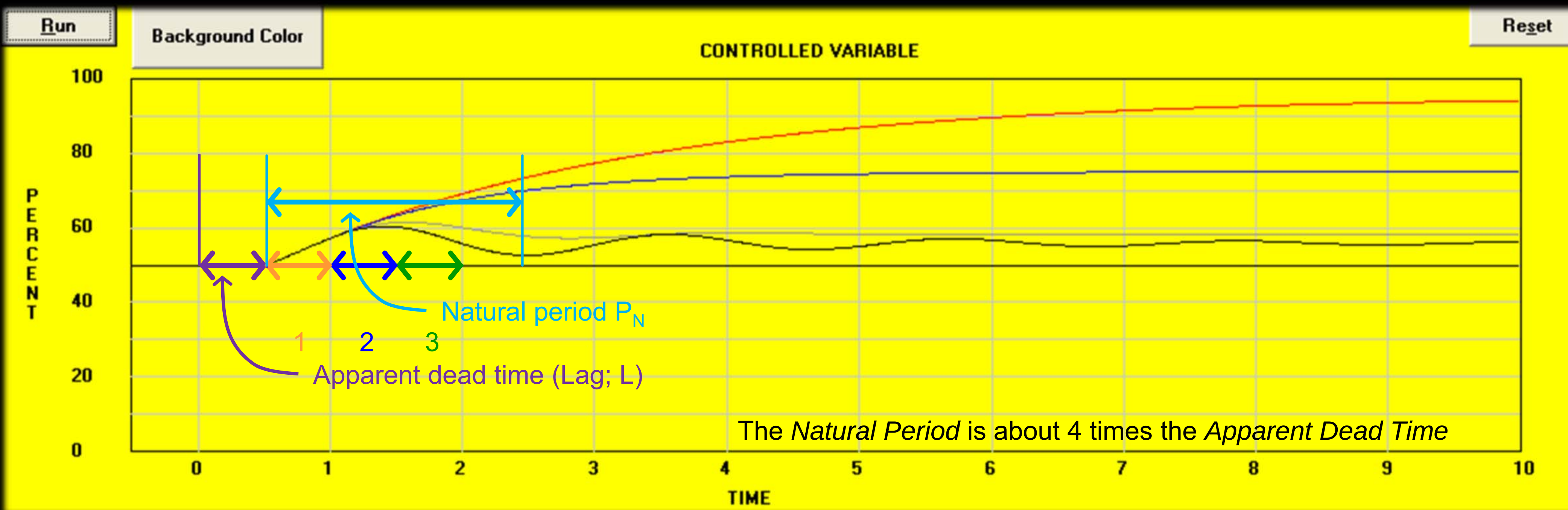

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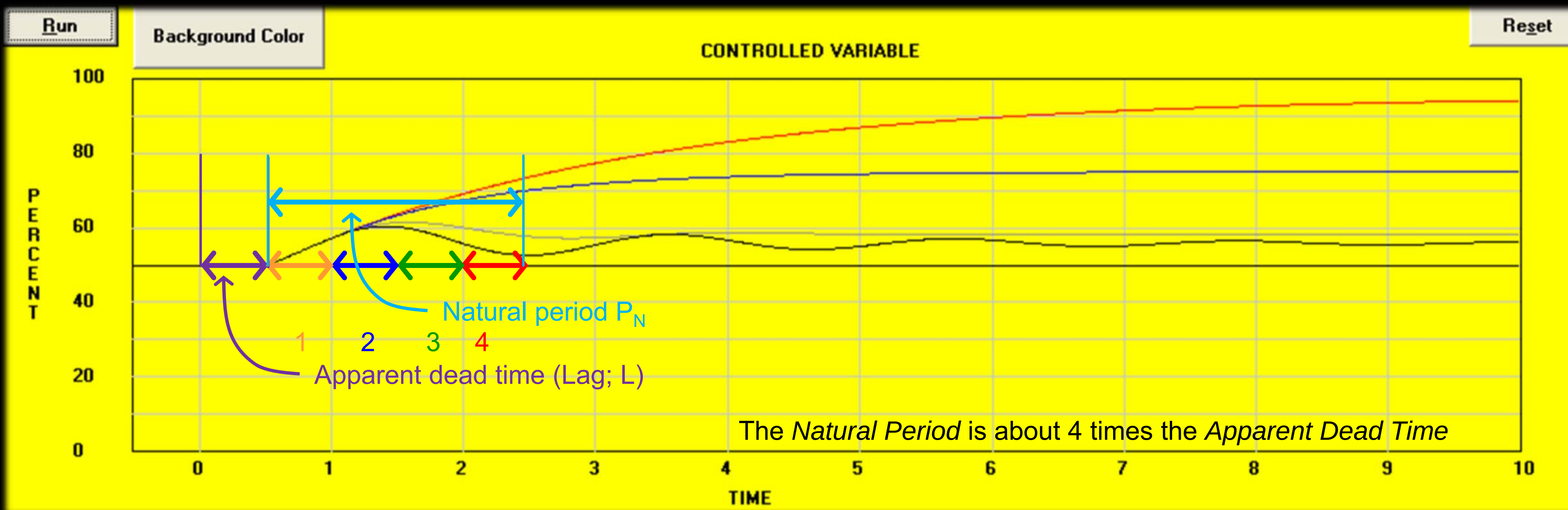

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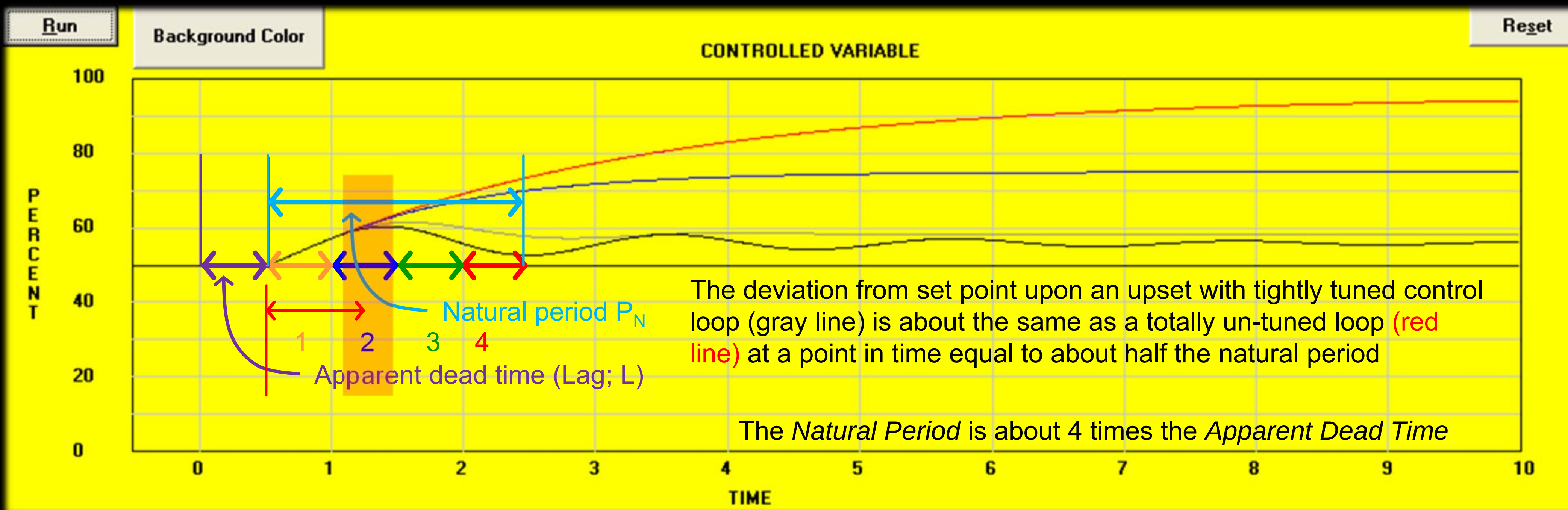

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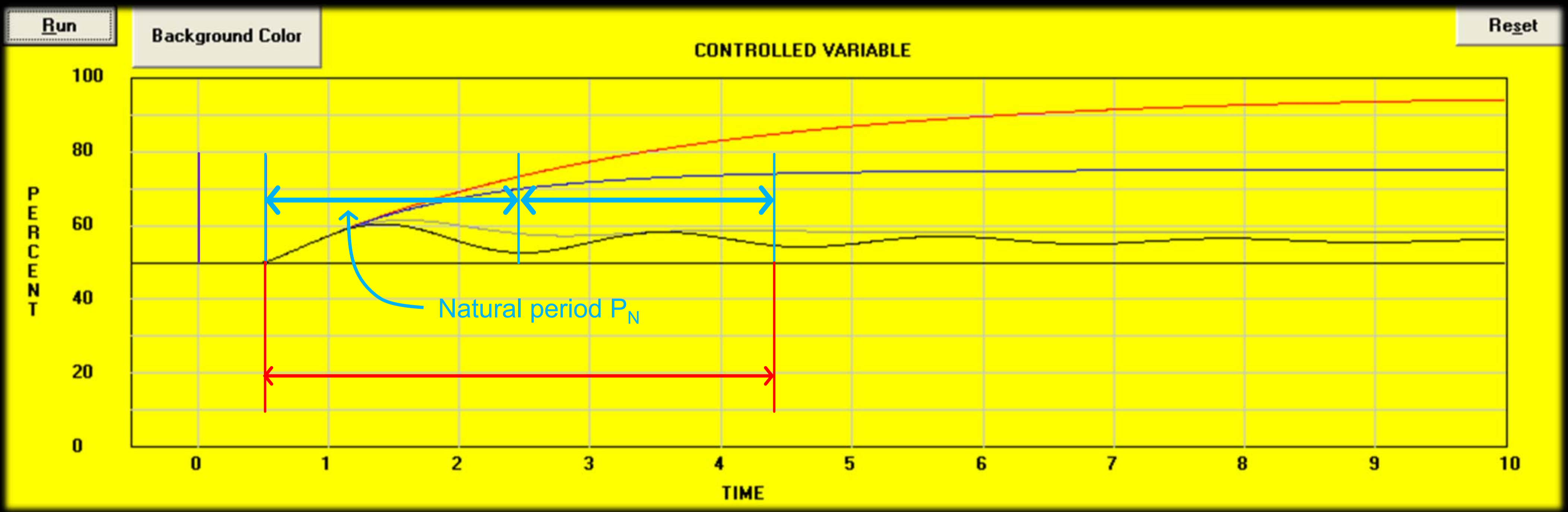
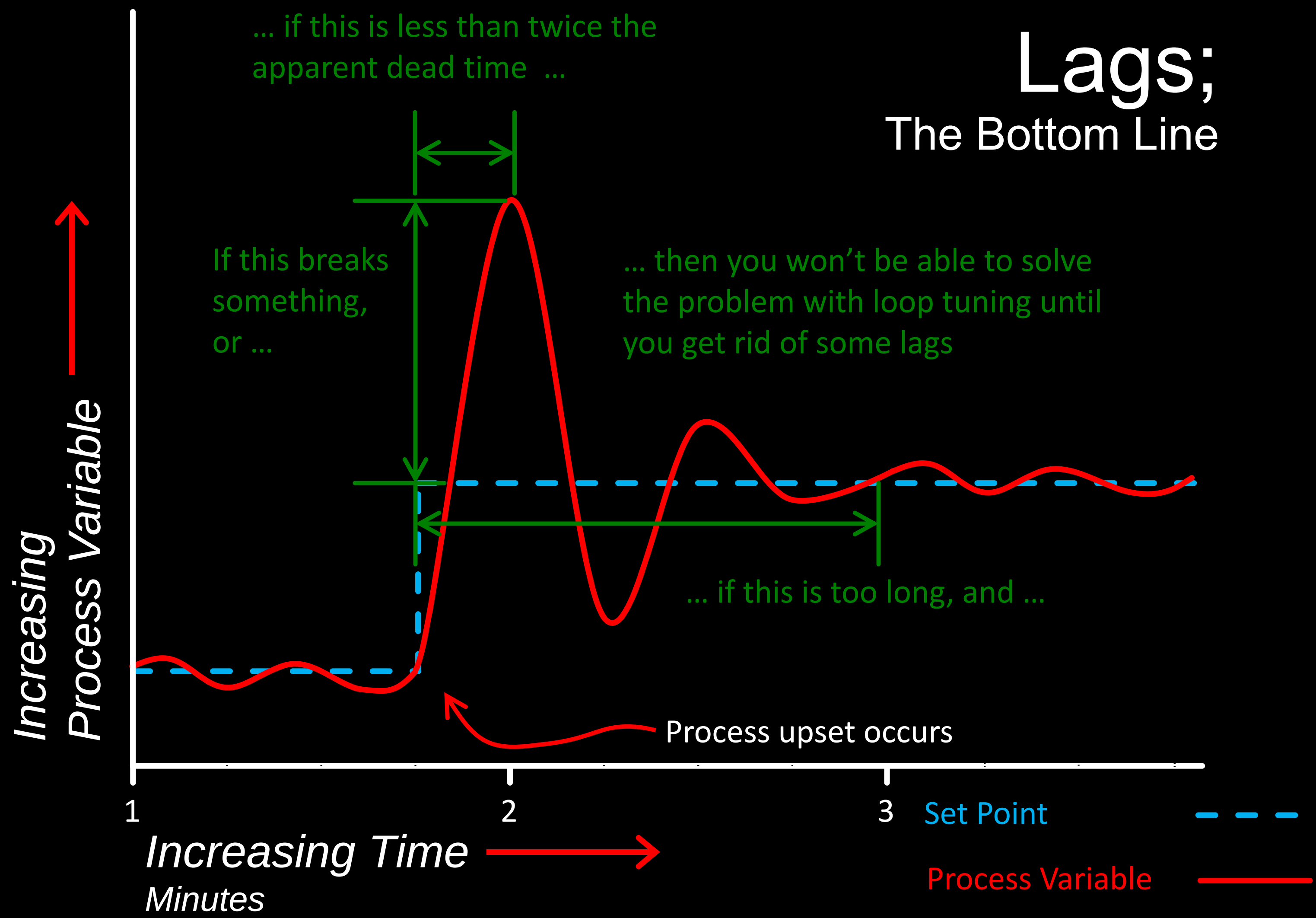


Lags;
The Bottom Line



Getting Rid of Lags;

Sometimes It's Easier than Others

Easier

1. Add positioning relays to valve and damper actuators
2. Install faster actuators (particularly applicable to electric actuators)
3. Reduce the thermal lag associated with wells by not using them
4. Use tighter linkages to minimize hysteresis
5. Use ramps instead of acceleration and deceleration times in VFDs

Harder

1. Reducing transportation times
2. Reducing the thermal lags associated with the size of the machinery (mass of coils, fans, duct, pipe, etc.)

A Bit More About Ramps

Acceleration and Deceleration times

- Apply all of the time, any time there is a change in the process
  - An acceleration setting of1hz/second slows things down at start up and any time there is a change between control point and set point
  - This introduces a permanent lag into the control process

Ramps

- Only apply when the set point is outside some window relative to the control point
  - Ramps will only apply if the difference between the set point and control point is large
  - If the set point and control point are inside the window, then the lag drops out of the picture
  - As a result, the response to a minor variation in set point is much faster than the response to a step change