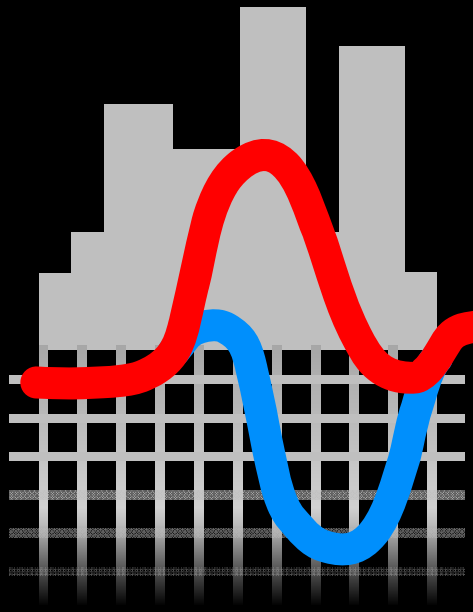

Facility Dynamics
ENGINEERING

Controlling Analog Processes

Open Loop vs. Closed Loop Tuning Method

Presented By:

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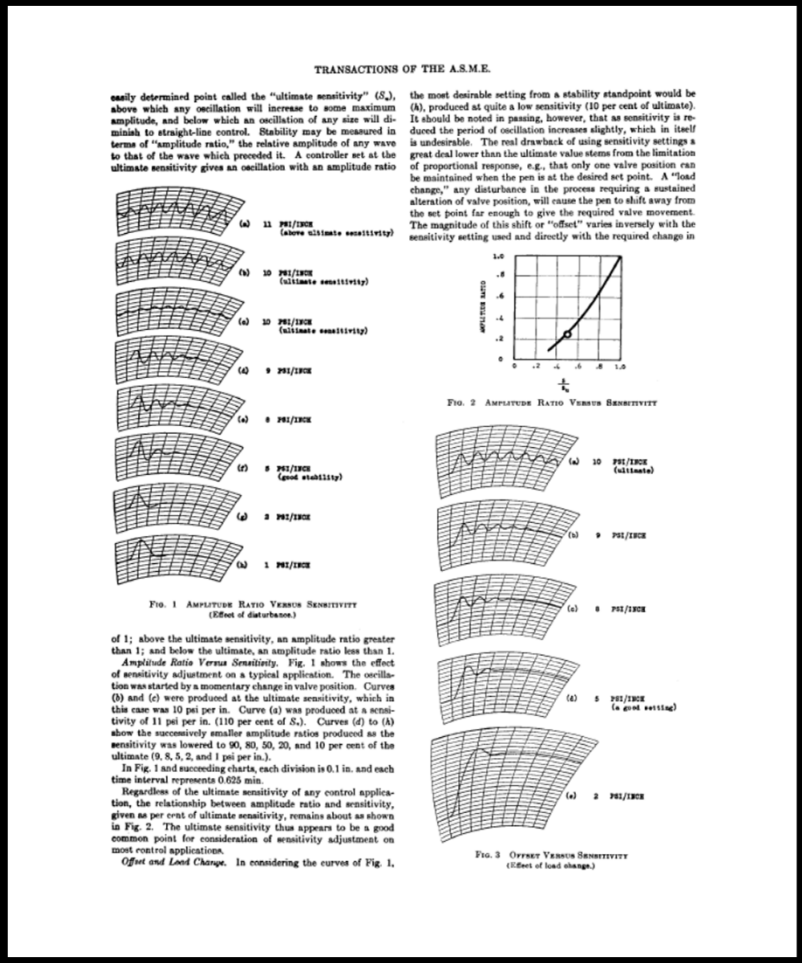
Senior Engineer

NAVFAC, San Diego

PID Controller Tuning

Roots of the process are in *Optimum Settings for Automatic Controllers*

- John G. Ziegler
- Nathan B. Nichols
- 1940
- Ziegler-Nichols Method



TRANSACTIONS OF THE A.S.M.E.

easily determined point called the "ultimate sensitivity" (S_u), above which any oscillation will increase to some maximum amplitude, and below which an oscillation of any size will diminish to straight-line control. Stability may be measured in terms of "amplitude ratio," the relative amplitude of any wave to that of the wave which preceded it. A controller set at the ultimate sensitivity gives an oscillation with an amplitude ratio

(a) 11 PSI/INCH (above ultimate sensitivity)
(b) 10 PSI/INCH (ultimate sensitivity)
(c) 10 PSI/INCH (ultimate sensitivity)
(d) 9 PSI/INCH
(e) 8 PSI/INCH
(f) 5 PSI/INCH (good stability)
(g) 3 PSI/INCH
(h) 1 PSI/INCH

FIG. 1 AMPLITUDE RATIO VERSUS SENSITIVITY (Effect of disturbance.)

of 1; above the ultimate sensitivity, an amplitude ratio greater than 1; and below the ultimate, an amplitude ratio less than 1.

Amplitude Ratio Versus Sensitivity. Fig. 1 shows the effect of sensitivity adjustment on a typical application. The oscillation was started by a momentary change in valve position. Curves (b) and (c) were produced at the ultimate sensitivity, which in this case was 10 psi per in. Curve (a) was produced at a sensitivity of 11 psi per in. (110 per cent of S_u). Curves (d) to (h) show the successively smaller amplitude ratios produced as the sensitivity was lowered to 90, 80, 50, 20, and 10 per cent of the ultimate (9, 8, 5, 2, and 1 psi per in.).

In Fig. 1 and succeeding charts, each division is 0.1 in. and each time interval represents 0.625 min.

Regardless of the ultimate sensitivity of any control application, the relationship between amplitude ratio and sensitivity, given as per cent of ultimate sensitivity, remains about as shown in Fig. 2. The ultimate sensitivity thus appears to be a good common point for consideration of sensitivity adjustment on most control applications.

Offset and Load Change. In considering the curves of Fig. 1, the most desirable setting from a stability standpoint would be (h), produced at quite a low sensitivity (10 per cent of ultimate). It should be noted in passing, however, that as sensitivity is reduced the period of oscillation increases slightly, which in itself is undesirable. The real drawback of using sensitivity settings a great deal lower than the ultimate value stems from the limitation of proportional response, e.g., that only one valve position can be maintained when the pen is at the desired set point. A "load change," any disturbance in the process requiring a sustained alteration of valve position, will cause the pen to shift away from the set point far enough to give the required valve movement. The magnitude of this shift or "offset" varies inversely with the sensitivity setting used and directly with the required change in

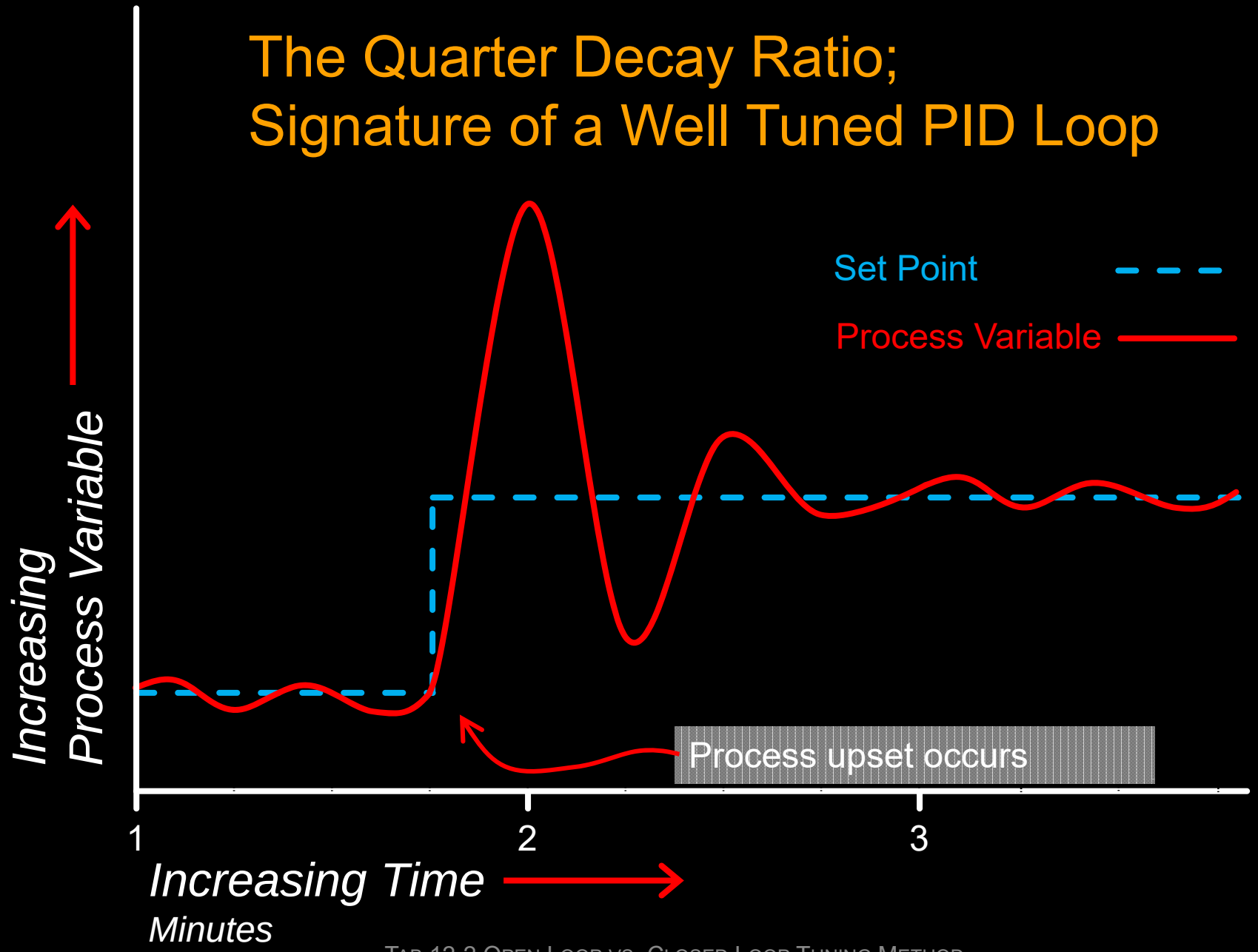
FIG. 2 AMPLITUDE RATIO VERSUS SENSITIVITY

(a) 10 PSI/INCH (ultimate)
(b) 9 PSI/INCH
(c) 8 PSI/INCH
(d) 5 PSI/INCH (a good setting)
(e) 2 PSI/INCH

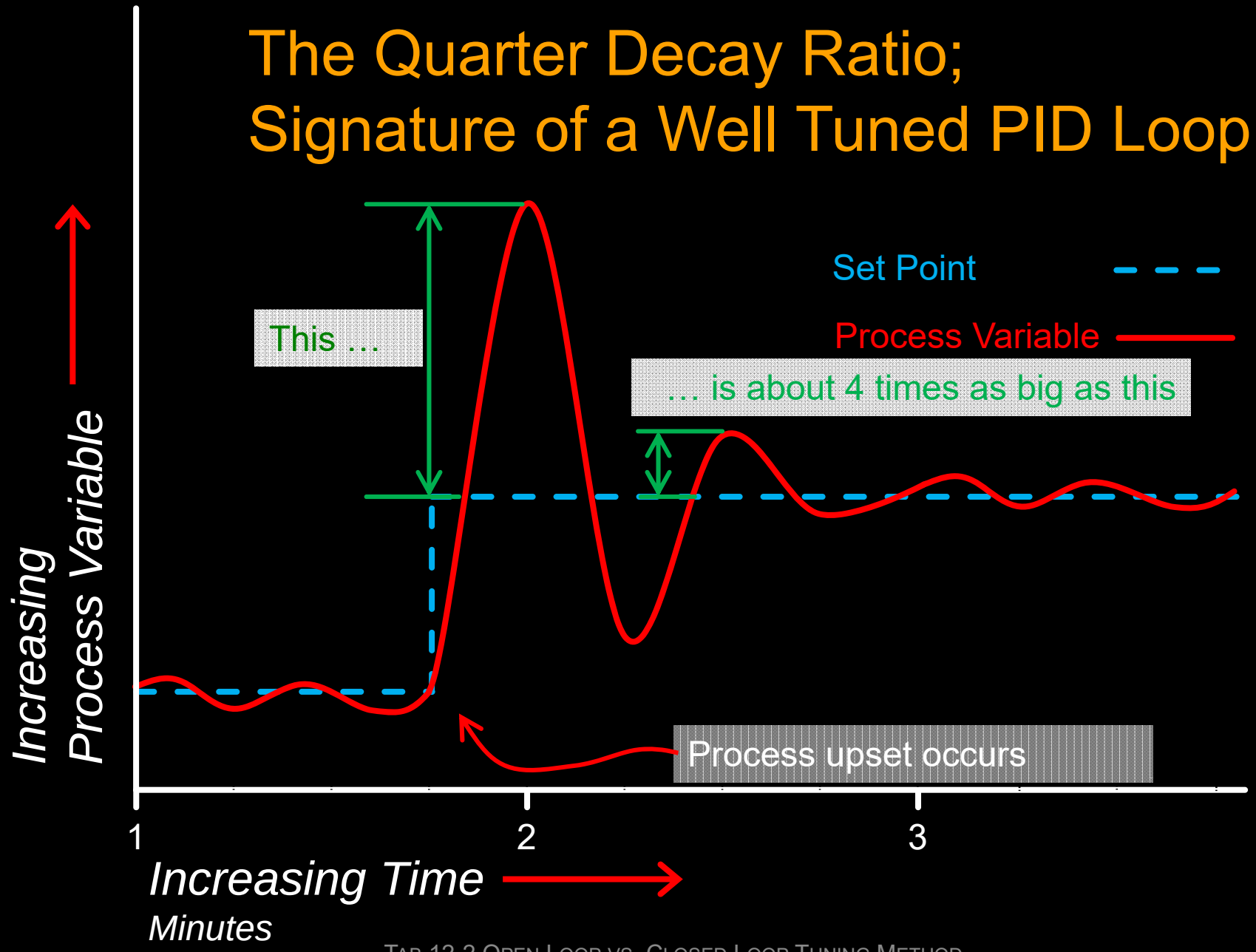
FIG. 3 OFFSET VERSUS SENSITIVITY (Effect of load change.)

Image courtesy Control Engineering Magazine

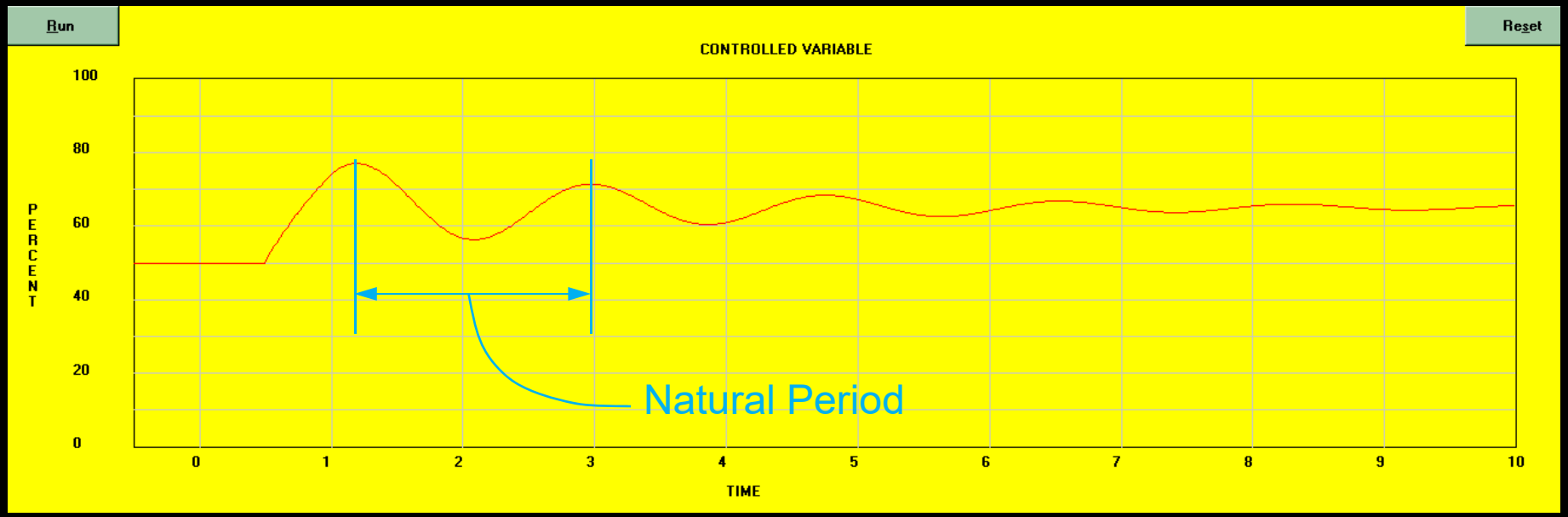
The Quarter Decay Ratio; Signature of a Well Tuned PID Loop



The Quarter Decay Ratio; Signature of a Well Tuned PID Loop



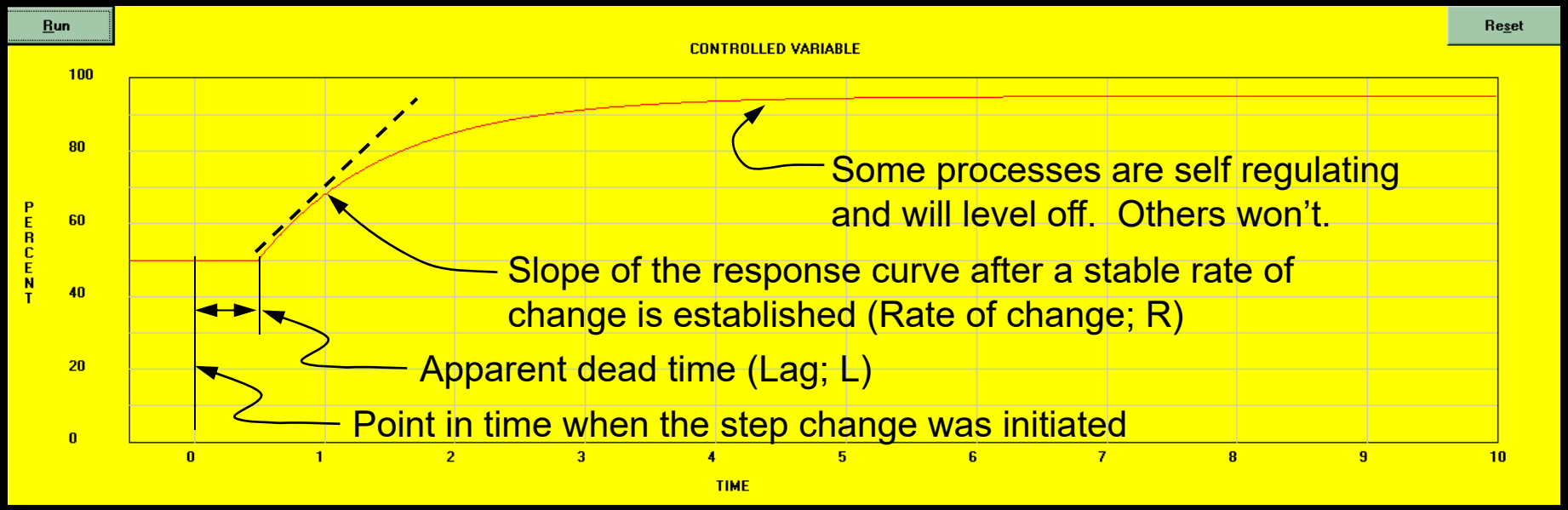
Closed Loop Tuning Method



With the system under automatic control, determine the Natural Period

- Proportional gain = ¼ to ½ of the ultimate gain producing the Natural Period
- Integral time in minutes per repeat = 1.2 times the Natural Period
- Derivative time in minutes = 1/8 of the Natural Period

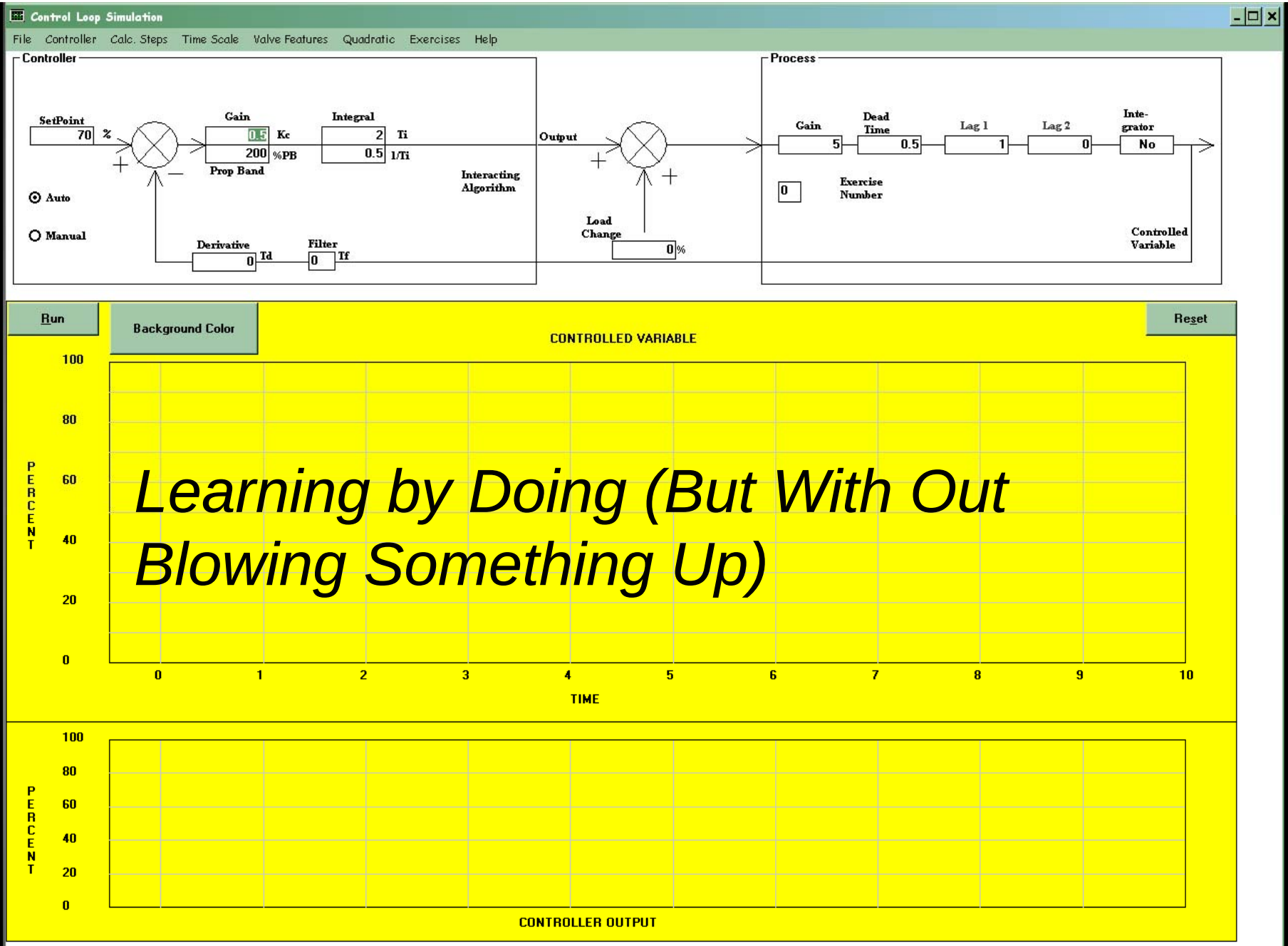
Open Loop Tuning Method



Also useful for troubleshooting

With the system under manual control, insert a step change and observe the response curve. Set the controller as follows:

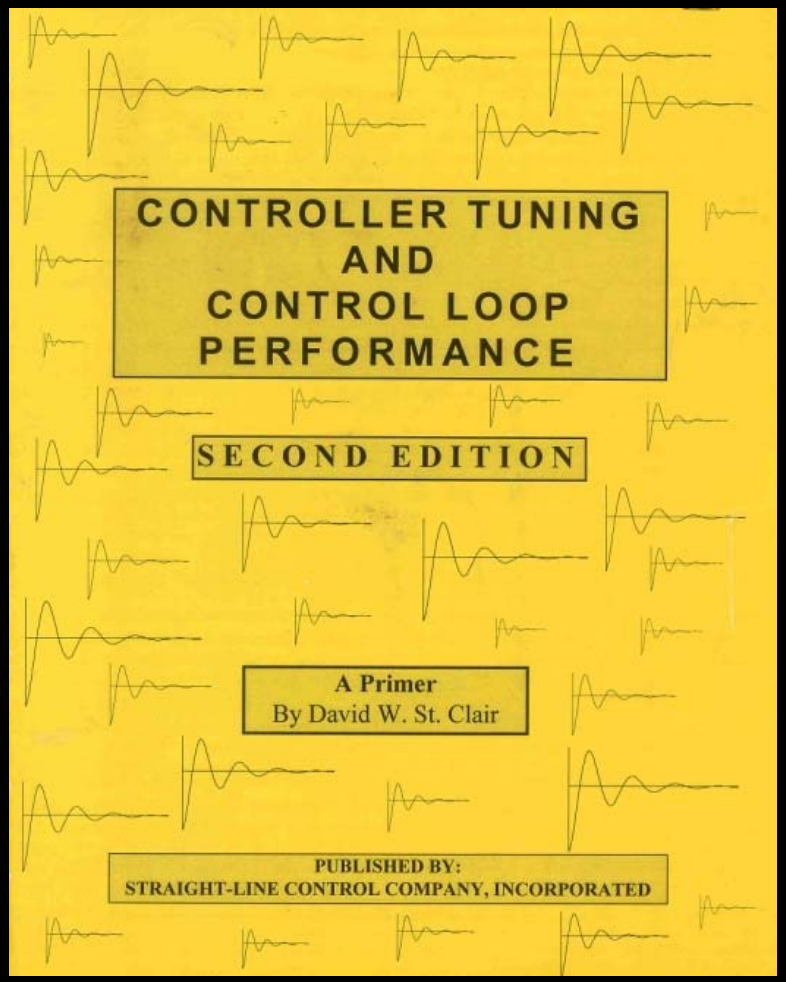
- Proportional gain = 1/(RL) to 1/(2 RL)
- Integral time in minutes per repeat = 5 times the apparent dead time
- Derivative time in minutes = ½ the apparent dead time.


Control Loop Simulation
File Controller Calc. Steps Time Scale Valve Features Quadratic Exercises Help
Controller
SetPoint
70 %
Gain
0.5 Kc
200 %PB
Prop Band
Integral
2 Ti
0.5 1/Ti
Interacting Algorithm
Auto
Manual
Derivative
0 Td
Filter
0 Tf
Output
Load Change
0 %
Process
Gain
5
Dead Time
0.5
Lag 1
1
Lag 2
0
Inte-grator
No
0
Exercise Number
Controlled Variable
Run
Background Color
Reset
CONTROLLED VARIABLE
PERCENT
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10
TIME
Learning by Doing (But With Out Blowing Something Up)
CONTROLLER OUTPUT

Tuning Resources

Controller Tuning and Control Loop Performance by David W. St. Clair

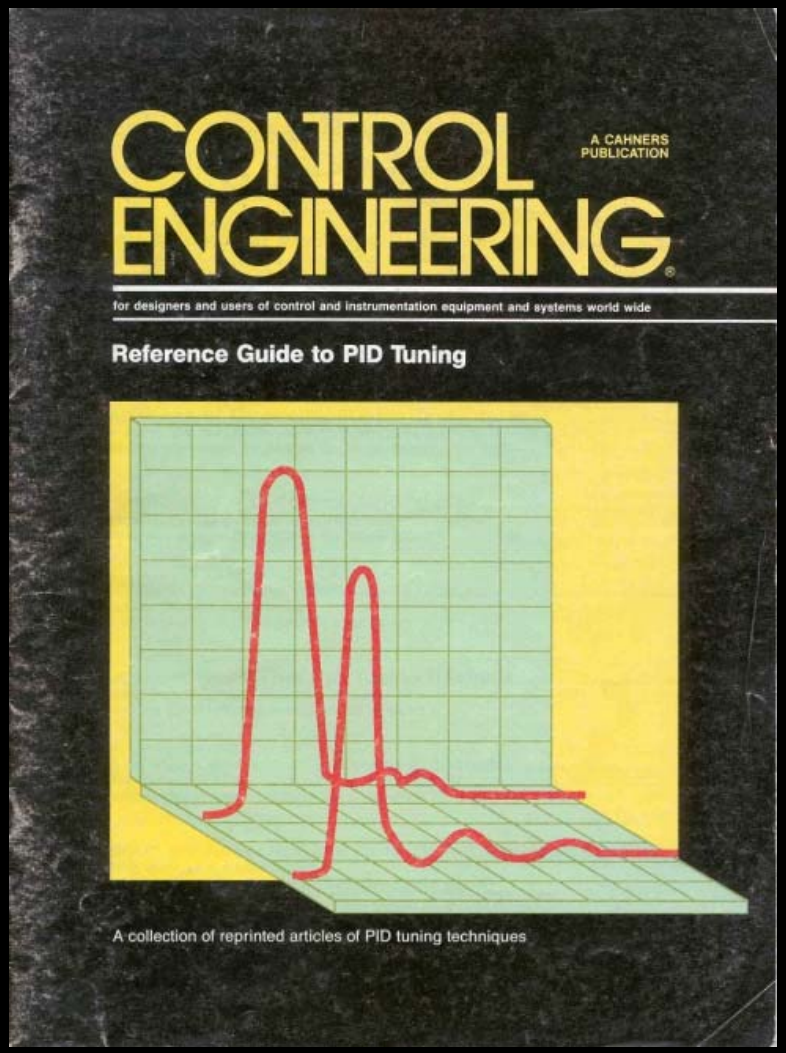
- Judy St. Clair
  Straight Line Control, LLC
  6326 4th Avenue South
  Richfield, MN 55423
  USA
  Phone:612-869-6814
  Fax: 612-869-2761
  jastclair@pro-ns.net
  http://www.straightlinecontrol.com



Tuning Resources

Reference Guide to PID Tuning

- Available from the publishers of Control Engineering
- See *A Field Perspective on Engineering Blog Post for Links*



Tuning Resources

See *An Overview of Proportional plus Integral plus Derivative Control and Suggestions for Its Successful Application and Implementation* from the proceedings of the 2001 International Conference on Enhanced Building Operations