PID TUNING

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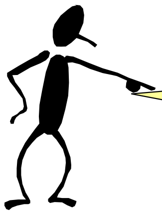

When I complete this chapter, I want to be able to do the following.

- Explain the performance goals that we seek to achieve via tuning.
- Apply a tuning procedure using the process reaction curve.
- Further improve performance by fine tuning

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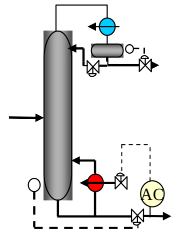
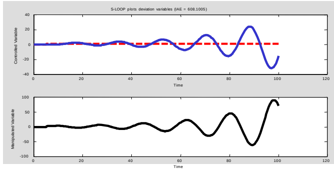
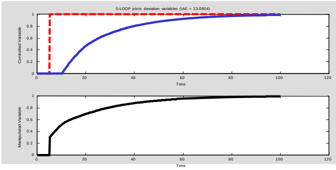
Is there an easier way than trial &error?



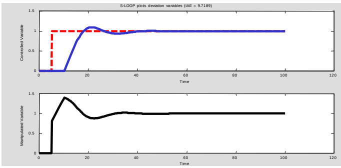
$$MV(t) = K_c\left[E(t) + \frac{1}{T_I}\int_0^{\infty} E(t')dt' - T_d \frac{d\,CV}{dt}\right] + I$$



Trial 1: unstable, lost $25,000



Trial 2: too slow, lost $3,000



Trial n: OK, finally, but took way too long!!

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- How do we apply the same equation to many processes?
- How to achieve the dynamic performance that we desire?

TUNING!!!

A trial and error approach - why we don’t use it

$$MV(t) = K_c\left[E(t) + \frac{1}{T_I}\int_0^{\infty} E(t')dt' - T_d \frac{d\,CV}{dt}\right] + I$$

The adjustable parameters are called <u>tuning constants</u>. We can match the values to the process to affect the dynamic performance

PID TUNING

Good control performance by PID controller can be achieve with a proper choice of tuning parameter constants, but poor performance and even instability can result from a poor choice of values.

- Some features for controller tuning
  - Define performance issues
  - Easy-to-use correlation
  - Provide a general calculation approach
  - Provide relationships between process dynamic model parameters and controller tuning constants

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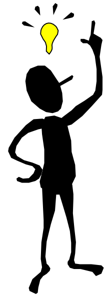
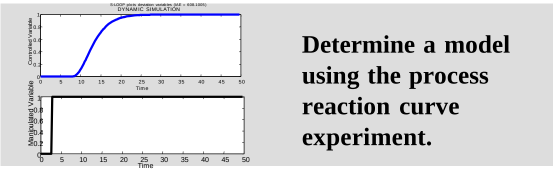
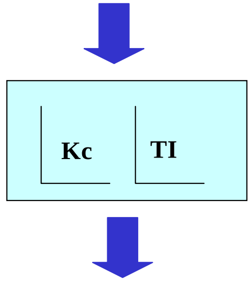


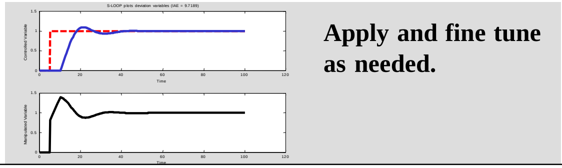
Yes, we can prepare good correlations!



Determine a model using the process reaction curve experiment.



Determine the initial tuning constants from a correlation.



Apply and fine tune as needed.

Define the tuning problem
1. Process Dynamics
2. Measured variable
3. Model error
4. Input forcing
5. Controller
6. Performance measures

PID TUNING

Define the tuning problem

1. Process → Dynamics
2. Measured variable
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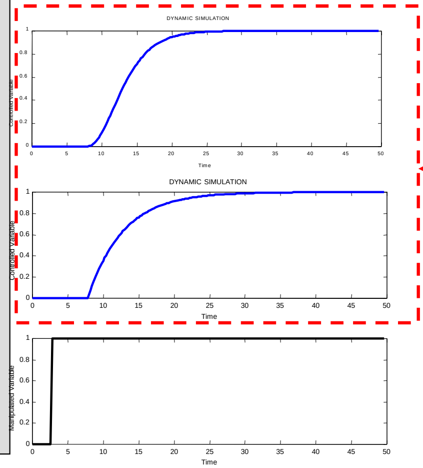
The PID controller will function successfully for a wide range of feedback process dynamics



We will develop tuning correlations for these dynamics.

- Most commonly occurring
- Fit model using process reaction curve
- Other processes can be controlled with PID; need more trial and error

PID TUNING

Define the tuning problem

1. Process → Dynamics
2. Measured variable
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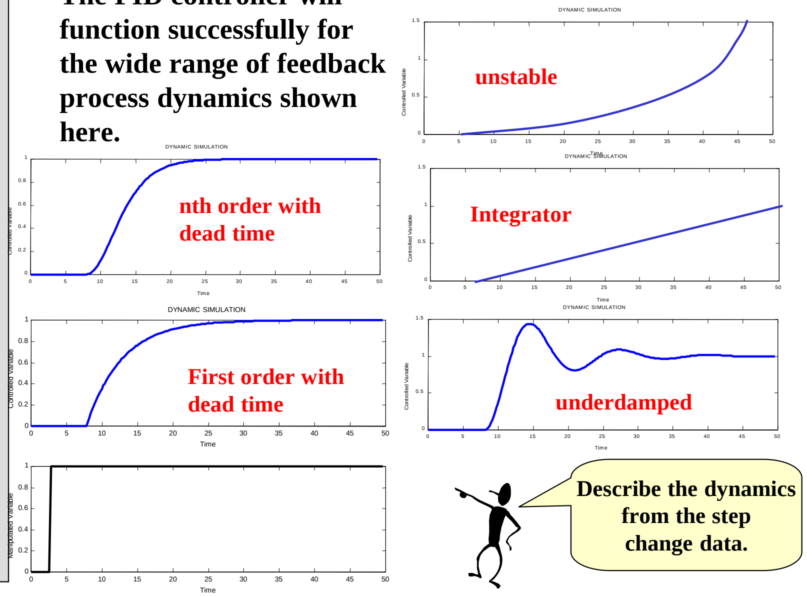
The PID controller will function successfully for the wide range of feedback process dynamics shown here.



Describe the dynamics from the step change data.

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Define the tuning problem

1. Process Dynamics
2. Measured variable →
3. Model error
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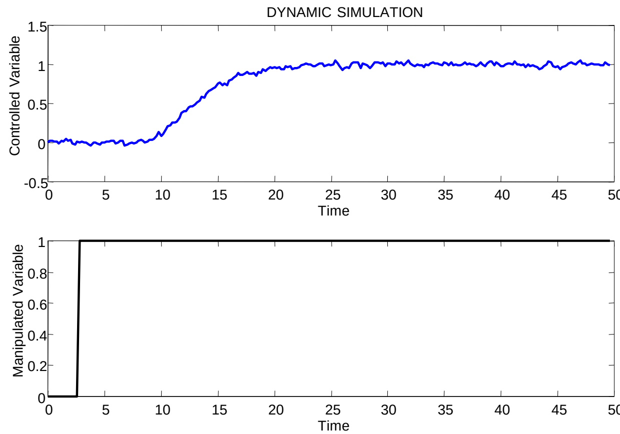
Realistic situation: The measured variable will include the effects of sensor noise and higher frequency process disturbances.



PID TUNING

Define the tuning problem
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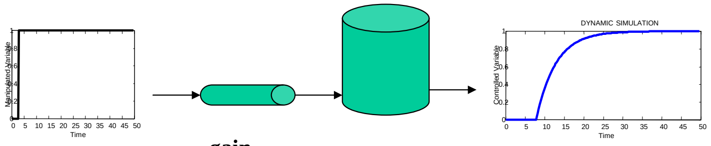
Model error (robustness): the ability of a control system to provide good performance when the plant dynamics change



gain: 1.5 - 2.5

Dead time: 3.75 - 6.25

$$G_P(s) = \frac{CV(s)}{MV(s)} = \frac{2.0 e^{-5s}}{10s + 1}$$

Time constant: 7.5 -1 2.5

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Define the tuning problem
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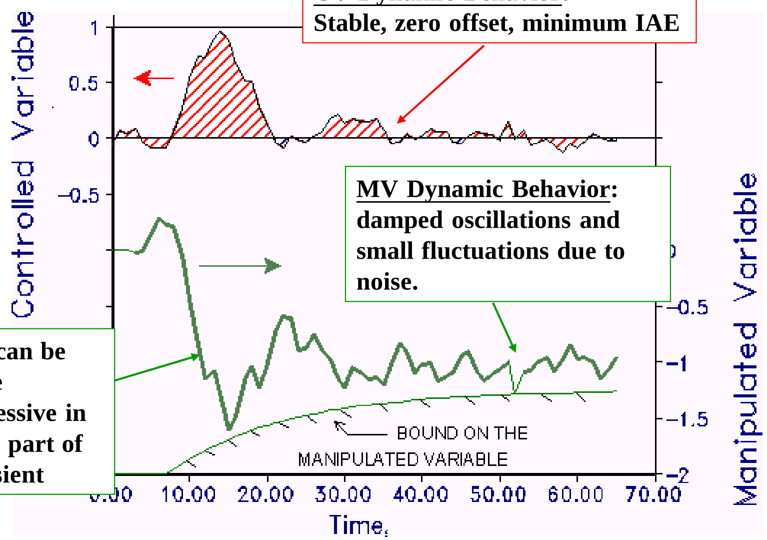

CV Dynamic Behavior: Stable, zero offset, minimum IAE

MV Dynamic Behavior: damped oscillations and small fluctuations due to noise.

MV can be more aggressive in early part of transient

PID TUNING

Define the tuning problem
1. Process Dynamics
2. Measured variable
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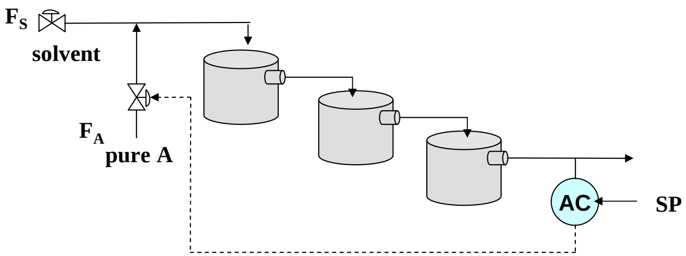
Realistic situation: We will consider the **PID controller**, which is used for nearly all single-loop (1CV, 1MV) controllers.

$$MV(t) = K_c \left[E(t) + \frac{1}{T_I} \int_0^{\infty} E(t')dt' - T_d \frac{d\,CV}{dt} \right] + I$$



PID TUNING

Define the tuning problem
1. Process Dynamics
2. Measured variable
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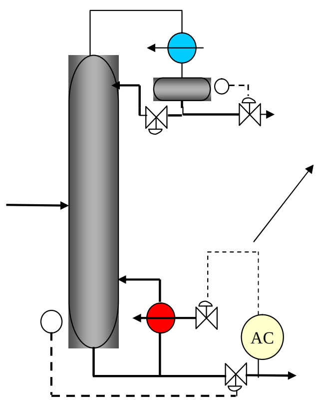
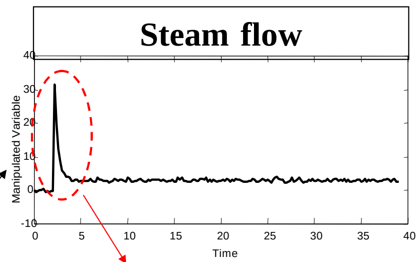
6. Performance measures →

Our primary goal is to maintain the CV near the set point. Besides not wearing out the valve, why do we have goals for the MV?





Large, rapid changes to the steam flow can damage the trays

PID TUNING

Define the tuning problem

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2. Measured variable
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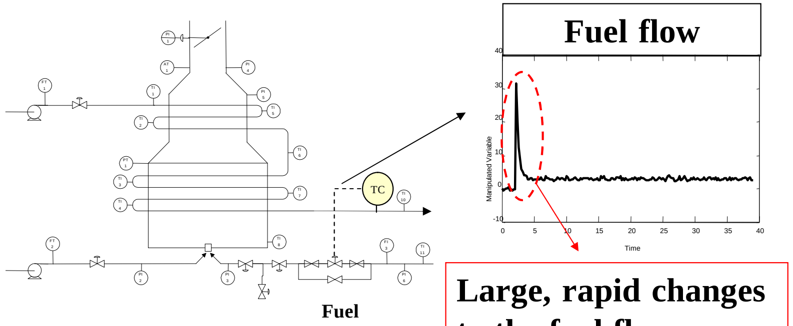
Our primary goal is to maintain the CV near the set point. Besides not wearing out the valve, why do we have goals for the MV?



Large, rapid changes to the fuel flow cause thermal stress that damages tubes.

PID TUNING

FINE TUNING: Process reaction curve and tuning charts provide a good method for tuning many (not all) PID loops. We need to learn how to fine tune loops to further improve performance based on current loop behavior - **WHY**?

- Some loops could have different performance objectives
- Some loops could have dynamics different from first order with dead time
- Could have been error in the process reaction curve, perhaps a disturbance occurred during the experiment.
- Plant dynamics can change due to changes in feed flow rate, reactor conversion, and so forth.

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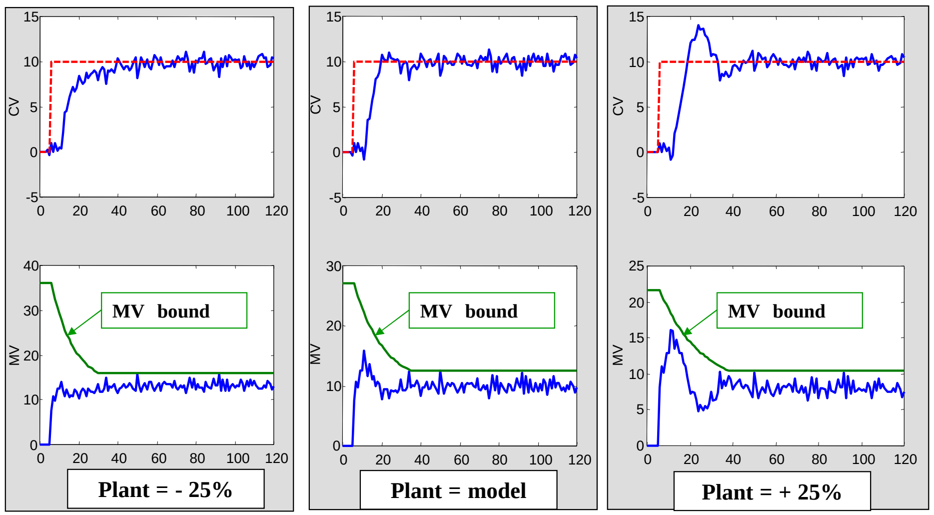
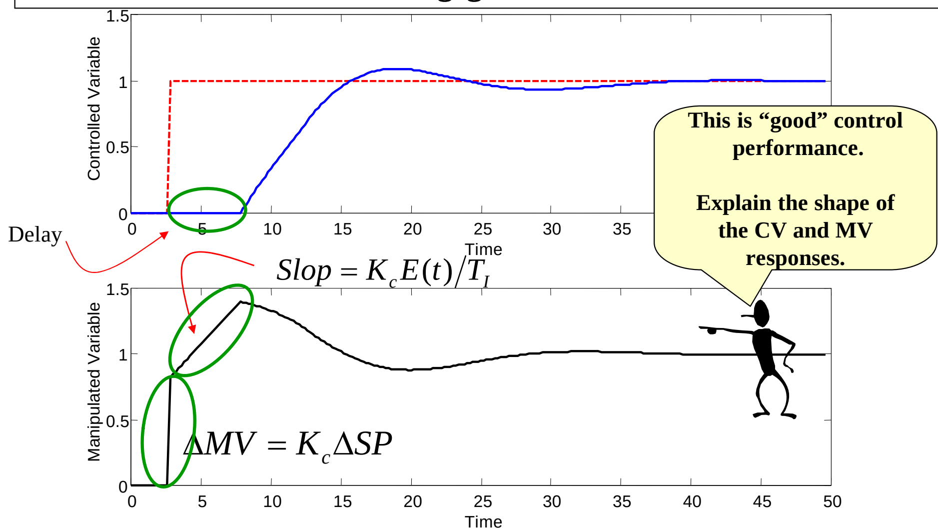
The tuning is not the best for any individual case, but it is the best for the range of possible dynamics - it is robust!



PID TUNING

FINE TUNING: Let's apply our understanding to build fine tuning guidelines.



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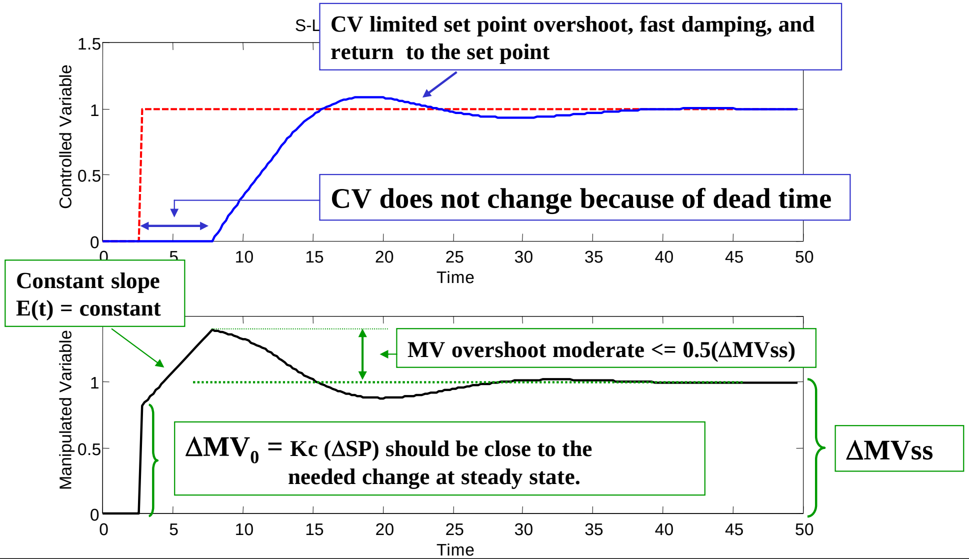
Note: this is a step change to the set point - good for diagnosis!



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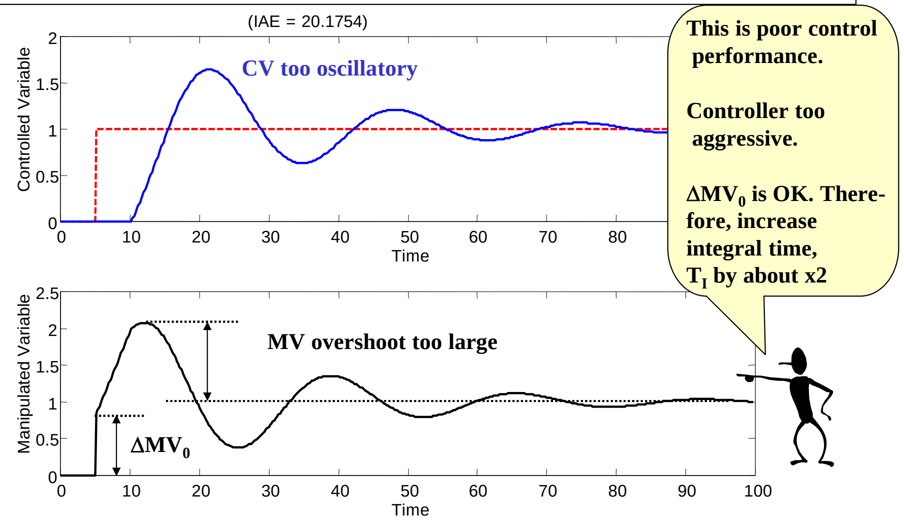
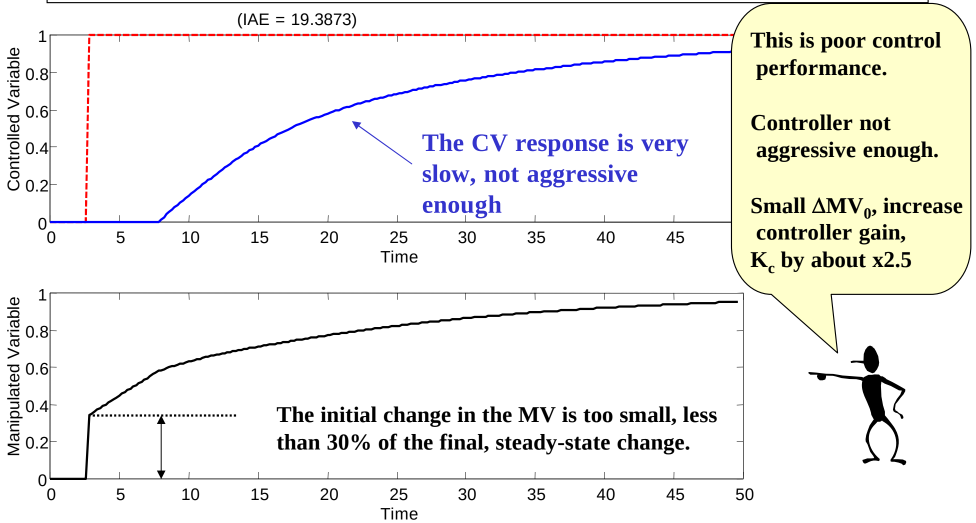
Apply the guidelines to the response below and suggest specific changes for improvement.



PID TUNING

Apply the **fine tuning guidelines** to the response below and suggest specific changes for improvement.



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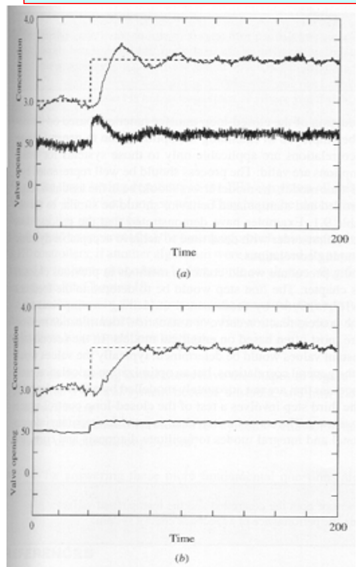


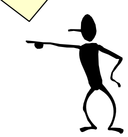
FIGURE 9.15

Dynamic responses of feedback control system in Example 9.7: (a) initial (IAE = 11.6); (b) after fine-tuning (IAE = 12.9).

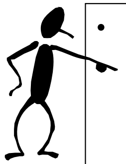
$$K_c = 45, \quad T_I = 11, \quad T_d = 0.8$$

$$K_c = 15, \quad T_I = 11, \quad T_d = 0$$

Analysis of the response of the controlled and manipulated variables to a step change in the set point provides valuable diagnostic information on the cause of good and poor control performance



CONCLUSIONS



- Control performance must be defined with respect to all important plant operating goals. In particular, desired behavior of the controlled and manipulated variables must be defined for expected disturbances, model errors, and noisy measurements
- A three-step tuning procedure
  1. system identification
  2. determine initial tuning constants
  3. test of the closed-loop control system and fine tuning
- The dynamic behavior of both the controlled and the manipulated variables is required for evaluating the performance of a feedback control system.
- Practically, the values from the optimization or correlations are used as initial values to be applied to the physical system and improved.