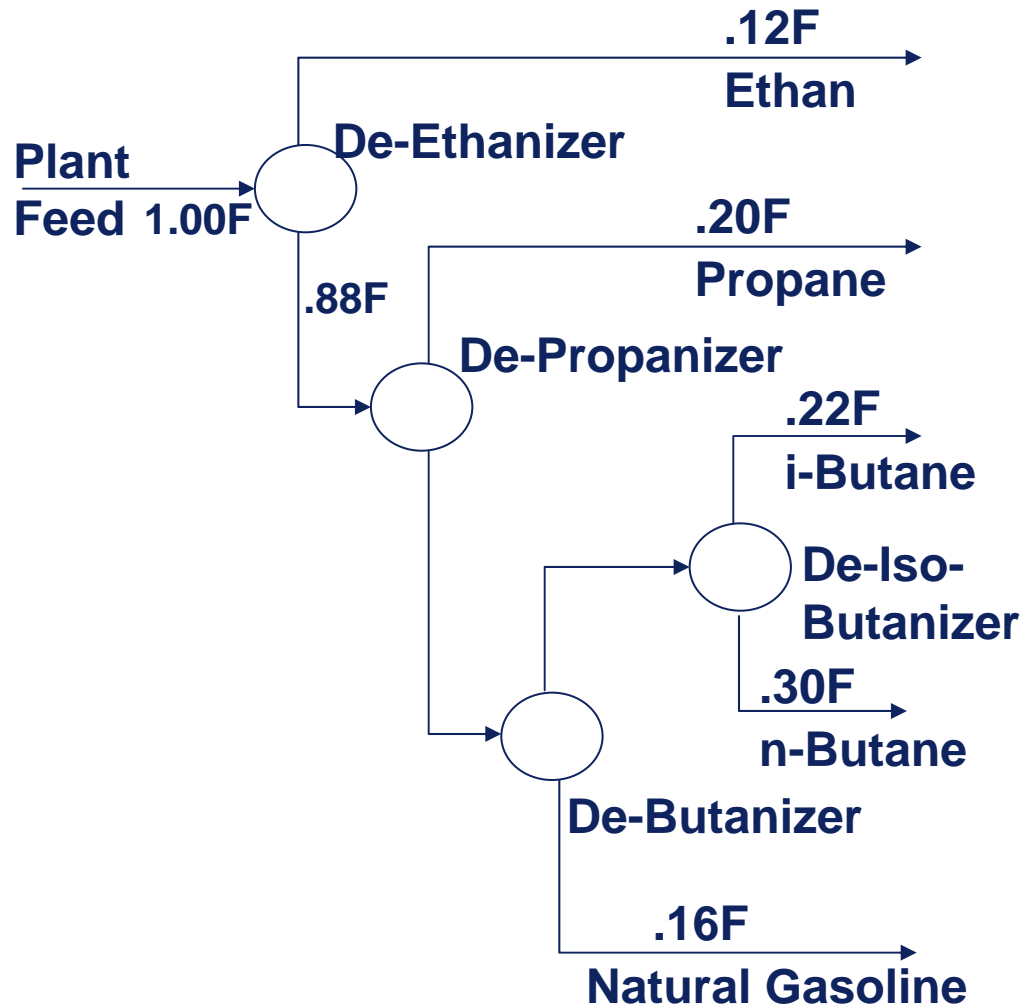


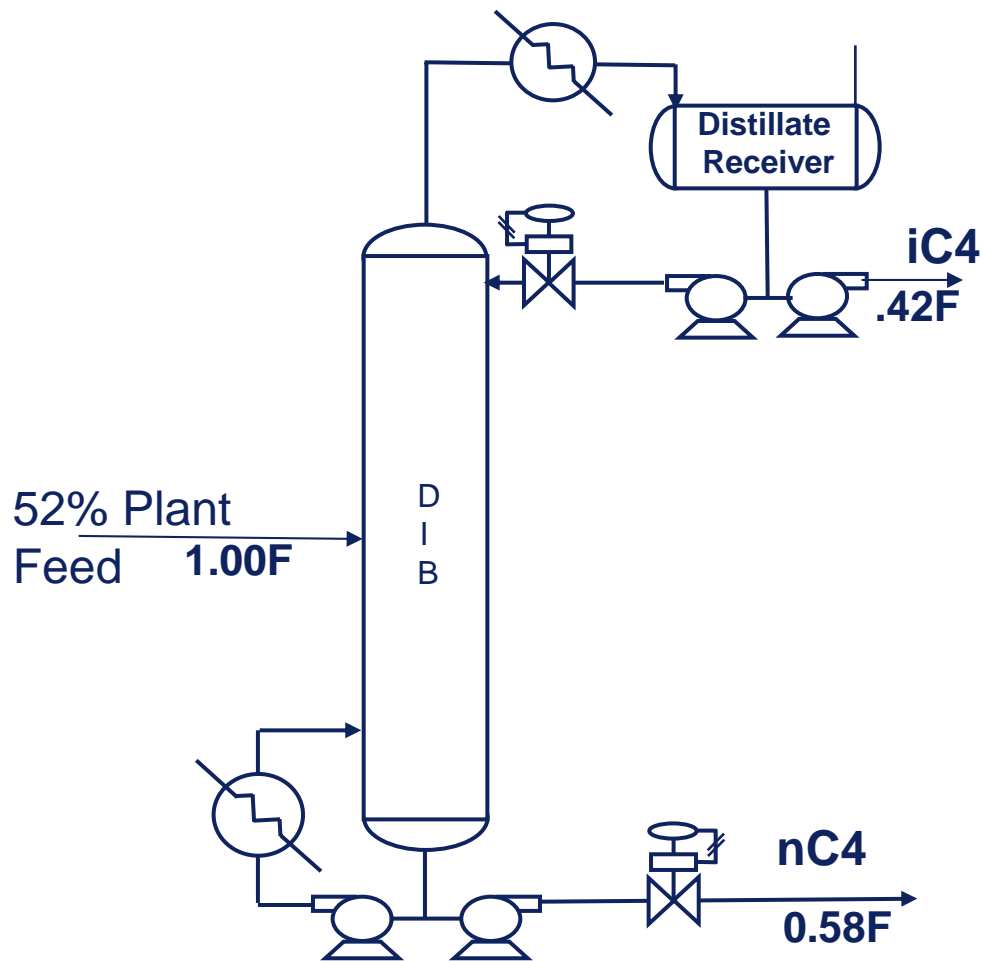
Process Characterization

Plant Process Flow



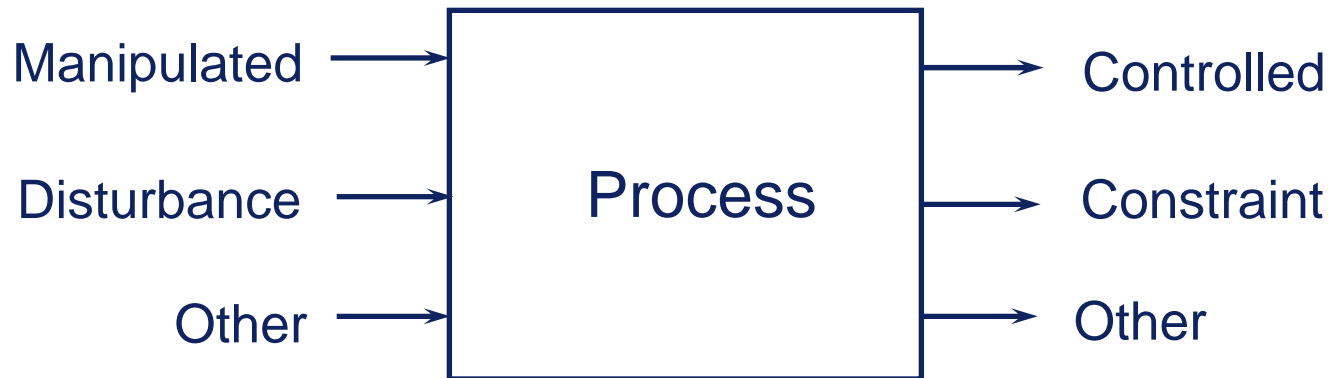
- A plant may be thought of as being made up of a series of processes.
- A good understanding of these processes is required to design a control system for the plant.
- In an existing installation, the plant operators can be a valuable source of information.
- Existing controls and measurements are identified on the piping and instrumentation (P&ID) diagram for the area.

De-isobutanizer Process Detail



Process Definition

A process is an arbitrary equipment configuration which acts on inputs to produce outputs.

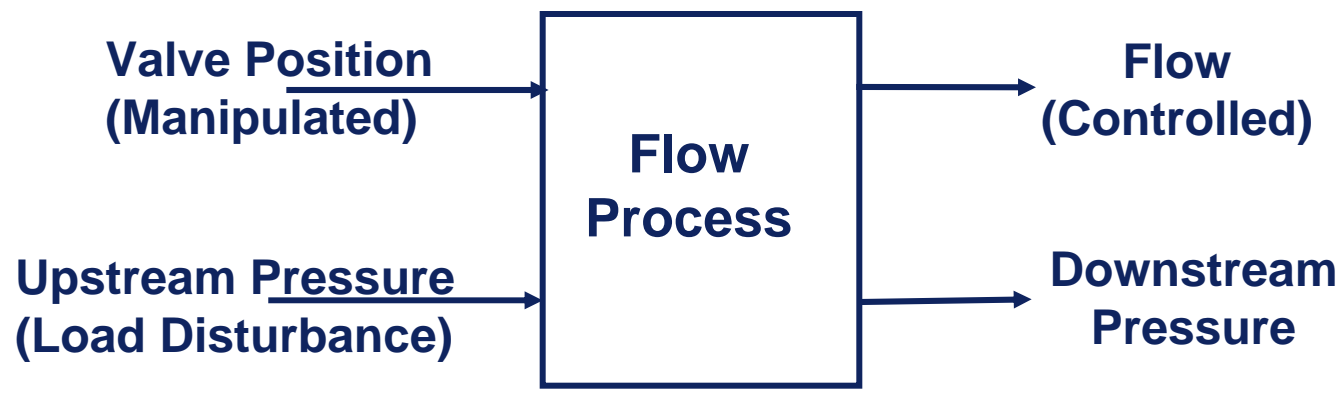
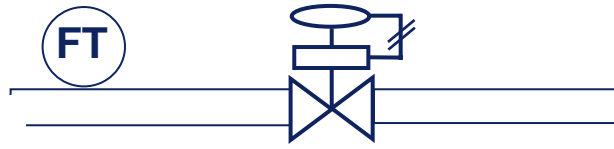


Process Terminology

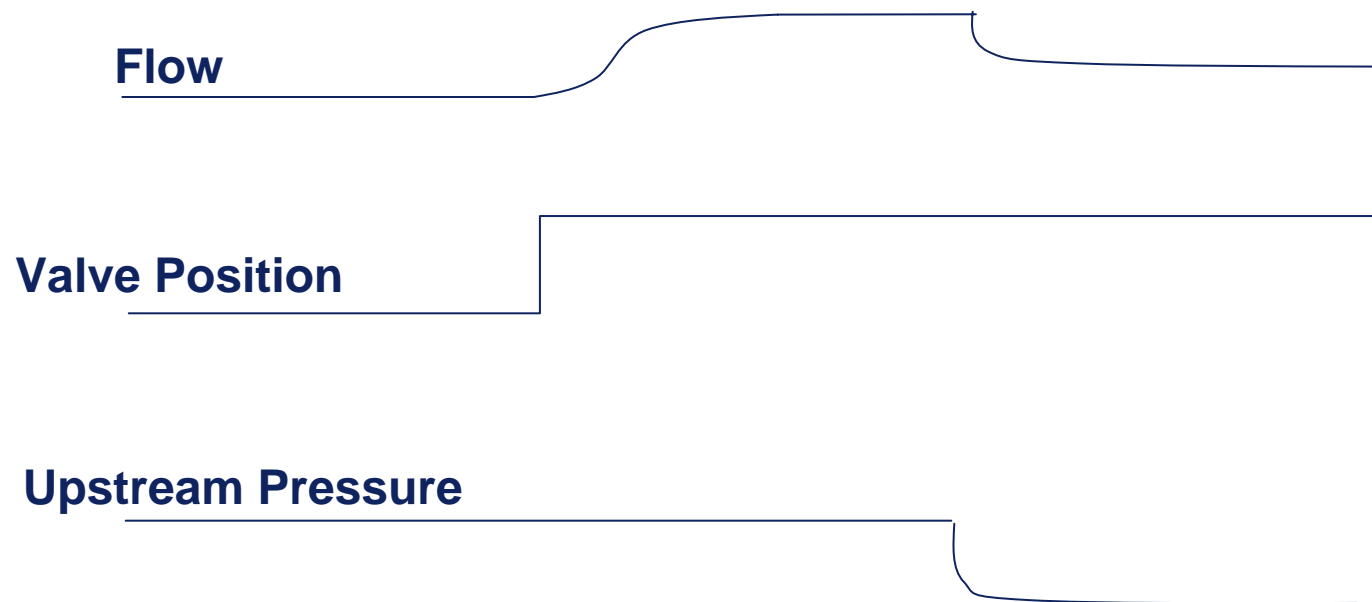
The following terms will be used in referencing process inputs and outputs.

- **Controlled** - process output which is to be maintained at a desired value by adjustment of a process input.
- **Setpoint** – The value at which the controlled parameter is to be maintained.
- **Manipulated** - process input which is adjusted to maintain the controlled output at setpoint.
- **Disturbance** - a process input (other than the manipulated parameter) which effects the controlled parameter.
- **Constraint** - process output which must be maintain within an operating range

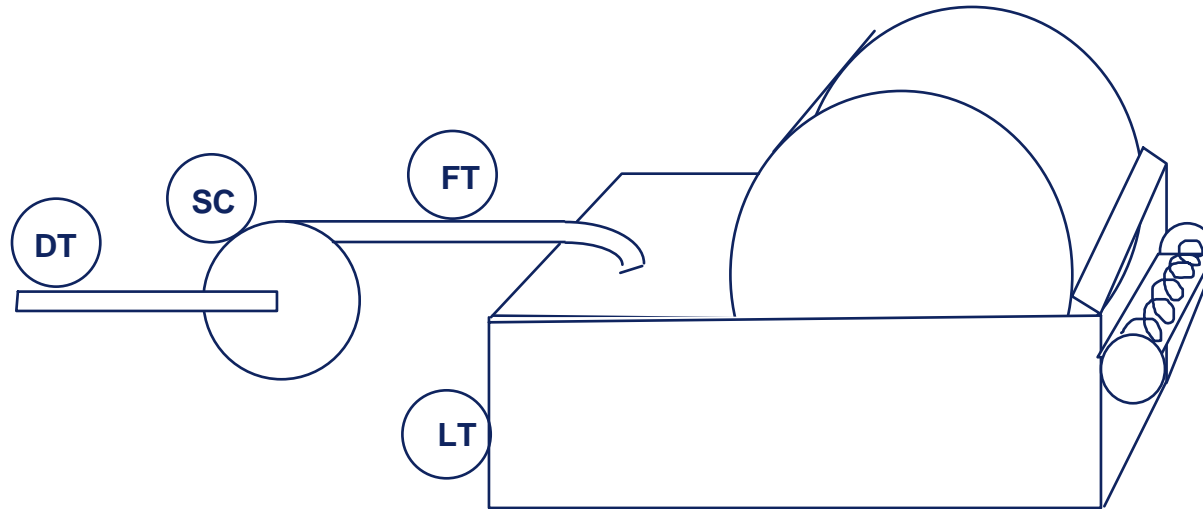
Process Example – Flow in Pipe



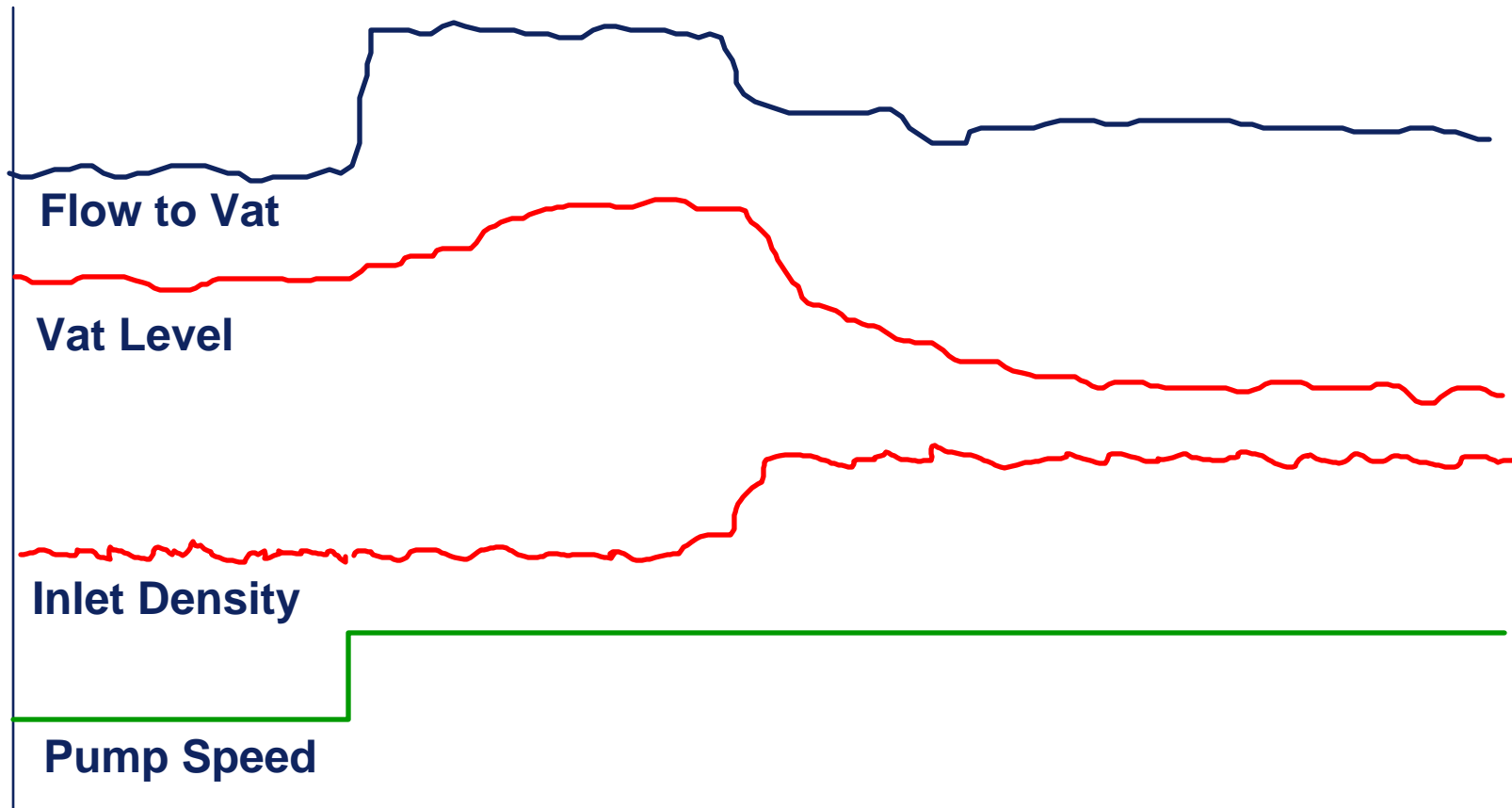
Flow Process – Response to Input Change



Process Example - Lime Mud Filter



Lime Filter – Response to Input Change



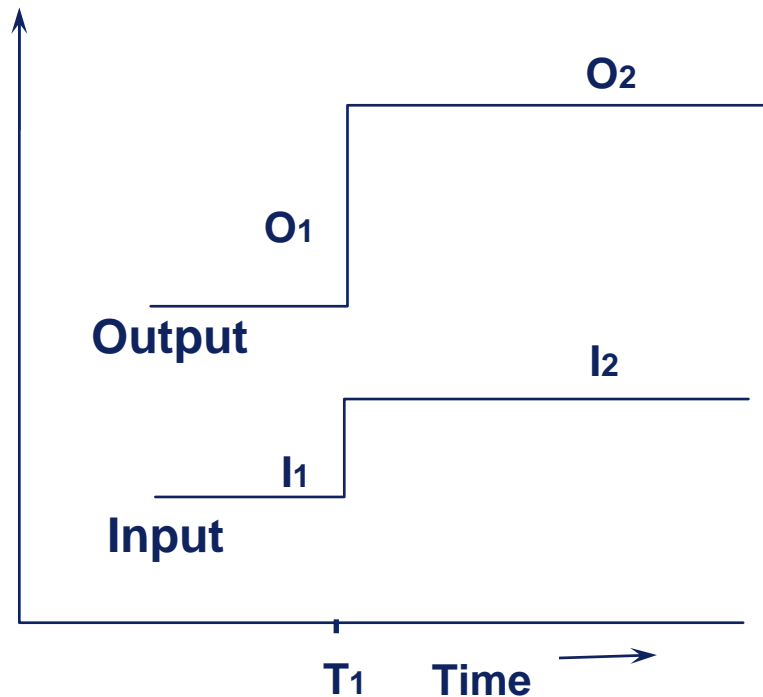
Characterizing Process Gain and Dynamic Response

- The dynamic response and gain of a process may be described in terms of how a process output response to a step change in a process input
- All other process inputs should be maintained at a constant value during this test i.e. so they have no impact of the output of interest.
- In an operating plant, it may be necessary to repeat the step test to get consistent results since not all inputs to the process can be maintained constant and often process noise is present

Pure Gain Process

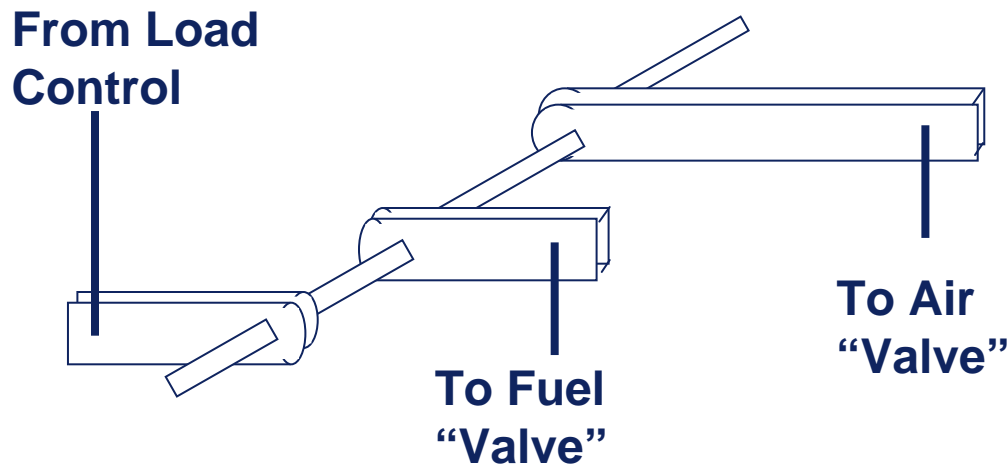
$$\text{Process Gain} = \frac{O_2 - O_1}{I_2 - I_1}$$

Note: Output and Input in % of scale



- When the process output tracks the process input except for a change in signal amplitude, the process is known as a pure gain.
- The change in signal amplitude is determined by the process gain.
- For a step change in process input, the process gain is defined as the change in the process output divided by the change in process input

Example – Pure Gain Process



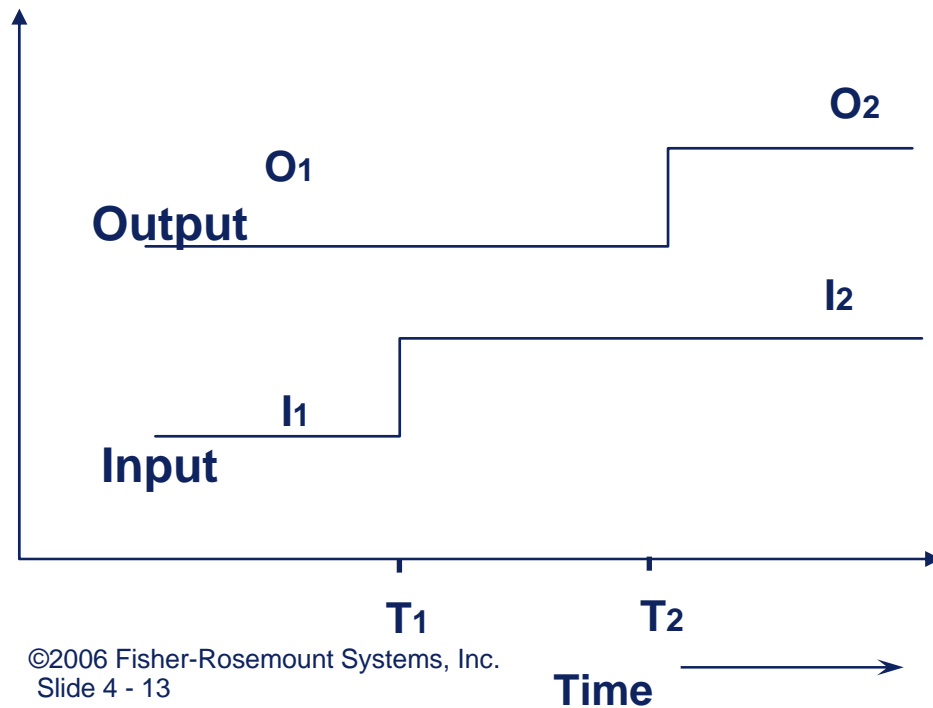
- An example of a pure gain process is the jack shaft used in some boiler combustion control systems.
- Gain is determined by the length of the lever arms attached to the jack shaft.

Pure Delay Process

$$\text{Gain} = \frac{O_2 - O_1}{I_2 - I_1}$$

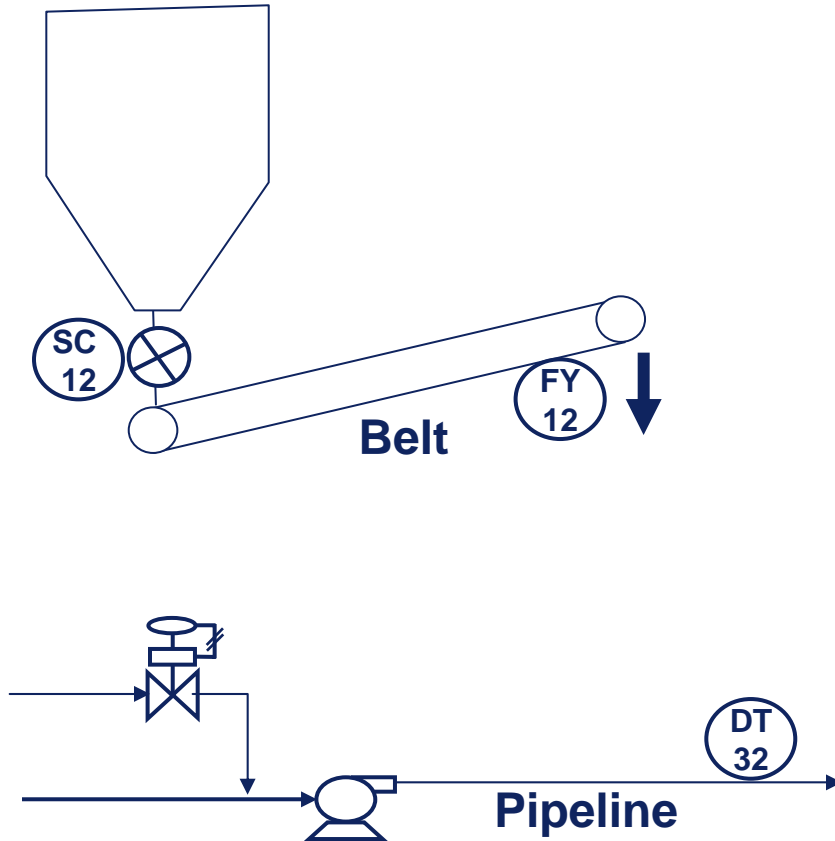
Note: Output and Input in % of scale

$$\text{Dead Time} = T_2 - T_1$$



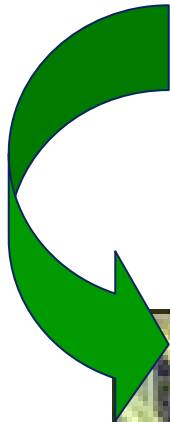
- When the process output tracks the process input except for a delay in the output signal, the process is known as a pure delay process.
- For a step change in the process input, process deadtime is defined as the time from the input changing until the first effect of the change is seen in the process output.

Example – Pure Delay Process



- Example of pure delay processes are a conveyor belt and a pipeline.
- Delay is the result of transport time and will vary with the speed of the belt or the flow rate through the pipe.

Paper Machine Example

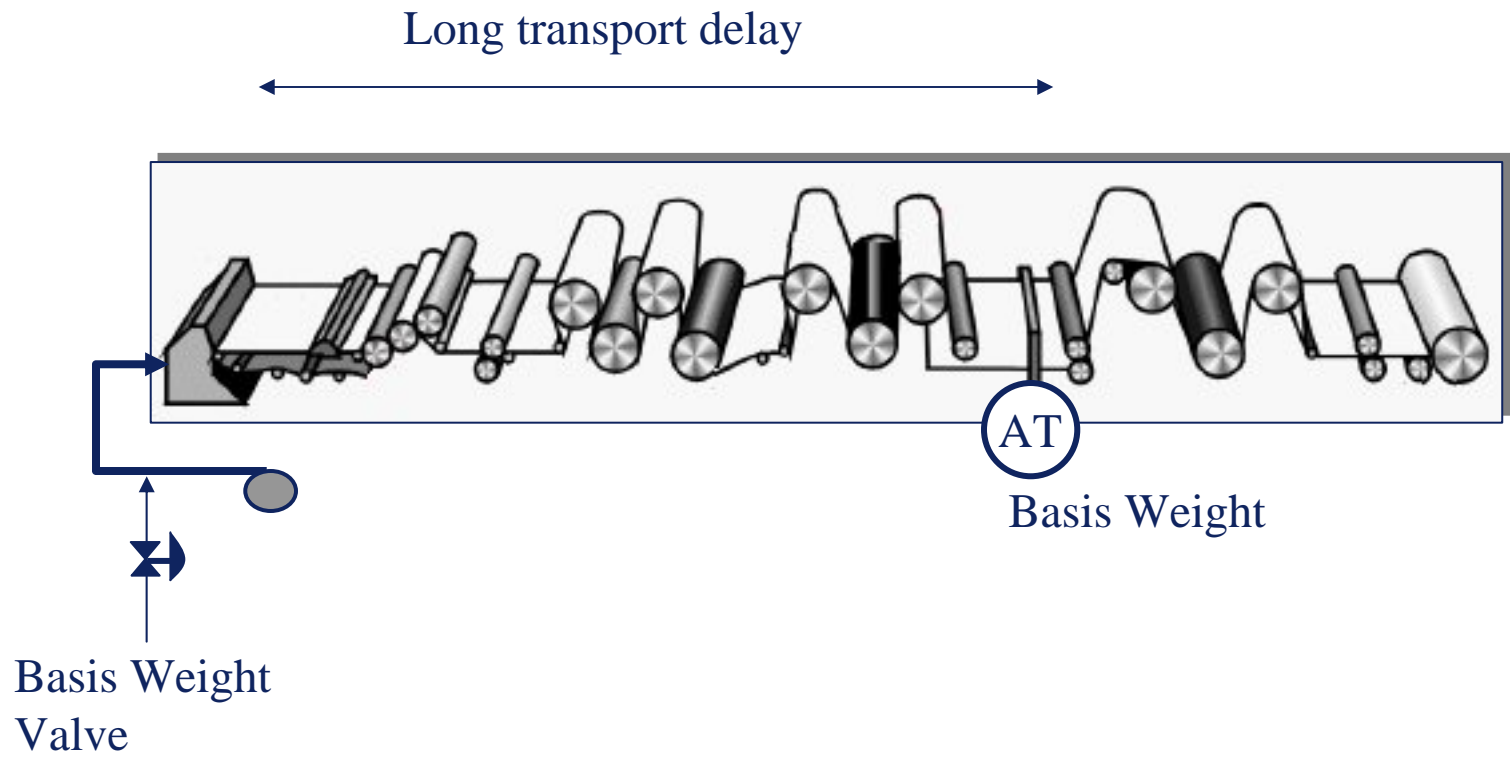


Scanner for Paper Properties



Final Product

Example - Paper Machine Basis Weight

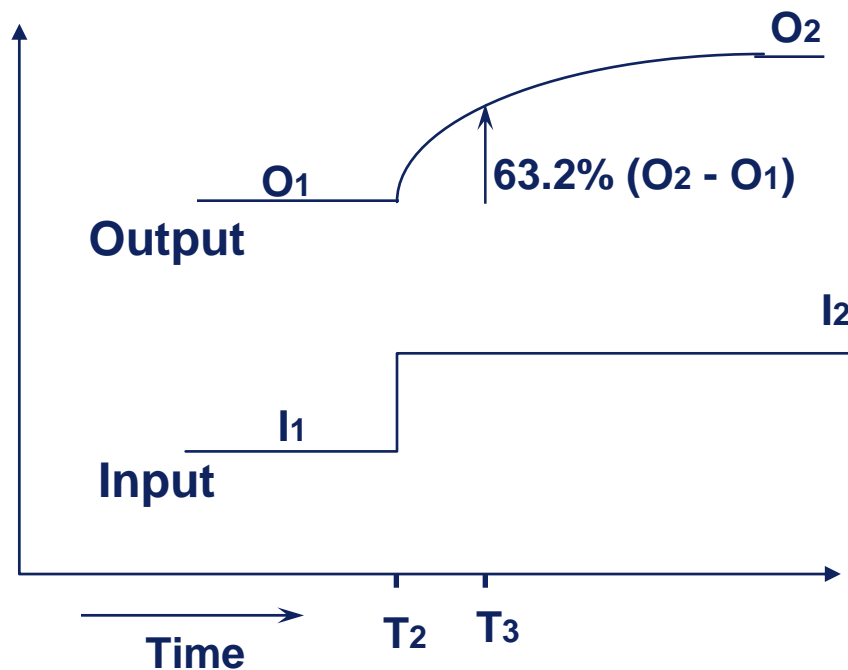


Pure Lag (First Order) Process

$$\text{Gain} = \frac{O_2 - O_1}{I_2 - I_1}$$

Note: Output and Input in % of scale

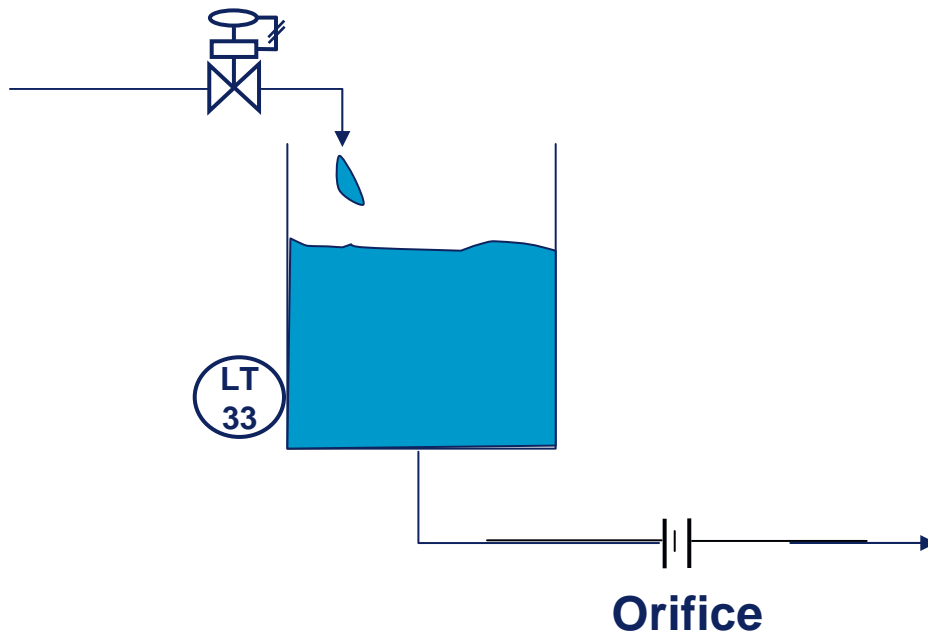
$$\text{Time Constant (T)} = T_3 - T_2$$



→ When the rate at which the process output changes is proportional to the difference between the current output and the final values associated with the current input, the process is known as pure lag (or first order) process.

→ For a step change in process input, the time required for the output to reach 63% of its final change in value is known as the process time constant.

Example – Pure Lag Process



- An example of a pure lag process is a tank with outlet flow determined by tank level and the outlet flow restriction caused by the orifice.
- The level will settle at a value which results in an outlet flow that matches the inlet flow.

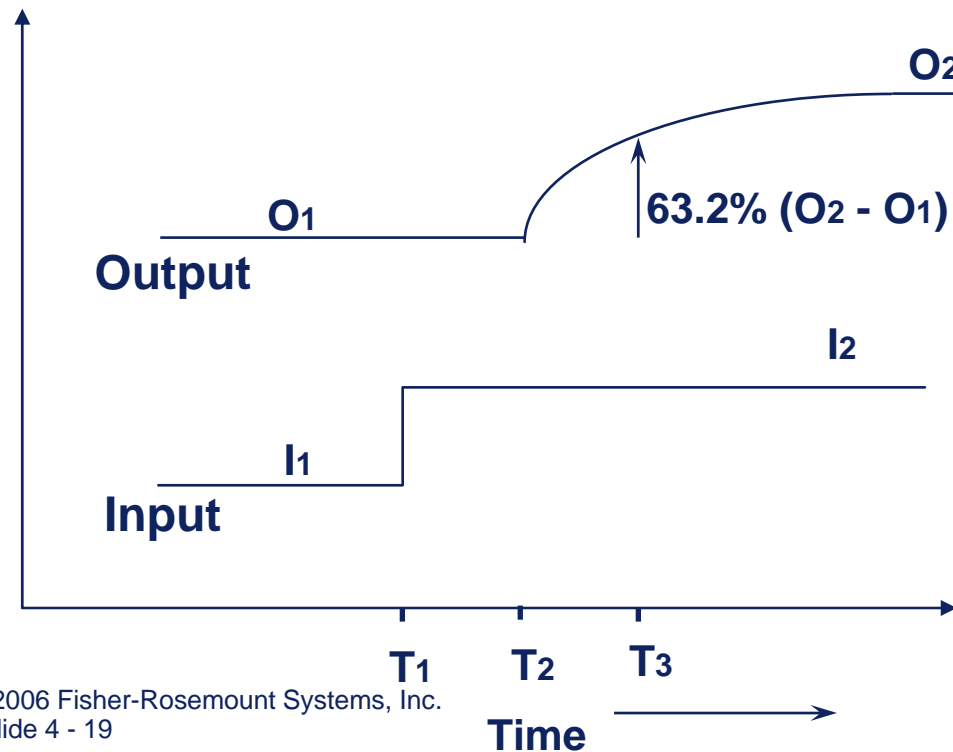
First Order Plus Deadtime Process

$$\text{Gain} = \frac{O_2 - O_1}{I_2 - I_1}$$

Note: Output and Input in % of scale

$$\text{Dead Time} = T_2 - T_1$$

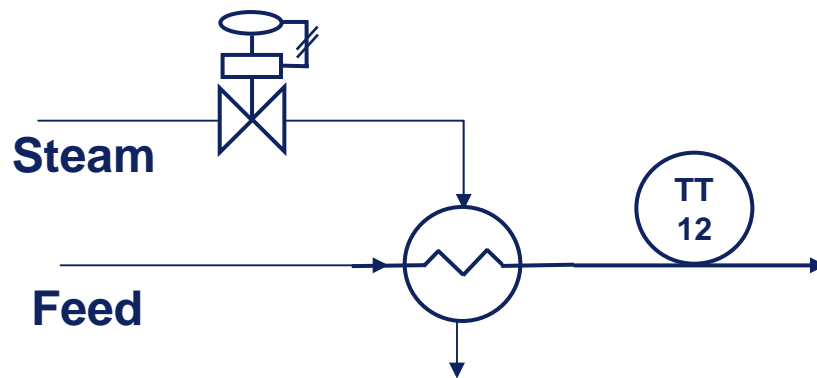
$$\text{Time Constant (T)} = T_3 - T_2$$



→ Most process in industry may be approximated as first order plus deadtime processes.

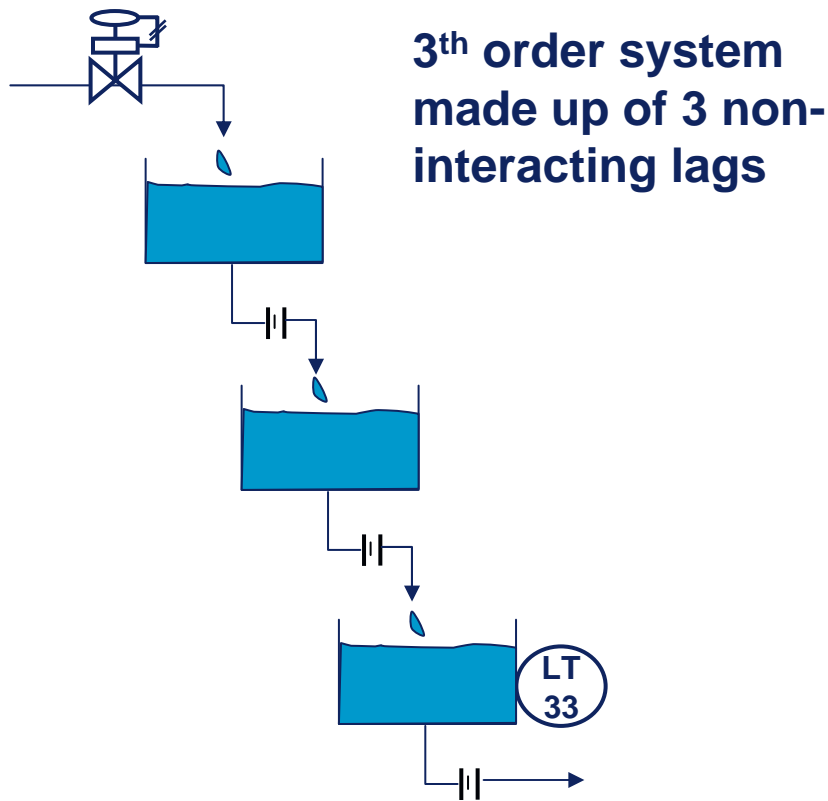
→ A first order plus deadtime process exhibits the combined characteristics of the lag and delay process.

Example - First Order Plus Deadtime Process



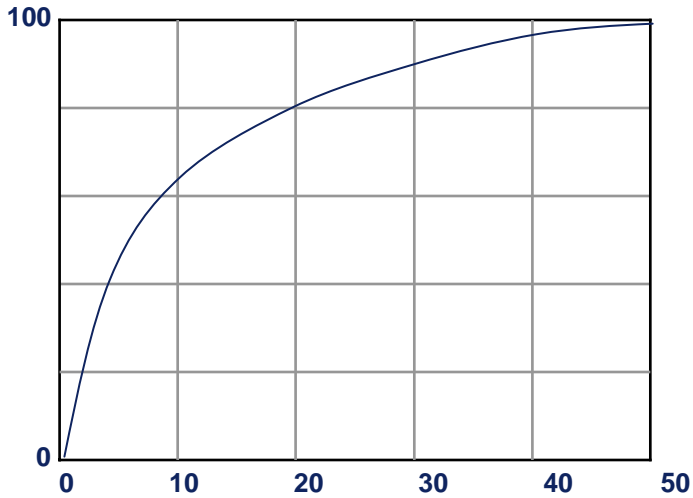
- An example of a first order plus deadtime process is a steam heater.
- The process lag is caused by the heating process
- The process deadtime is caused by transport delay

Addressing Higher Order Systems

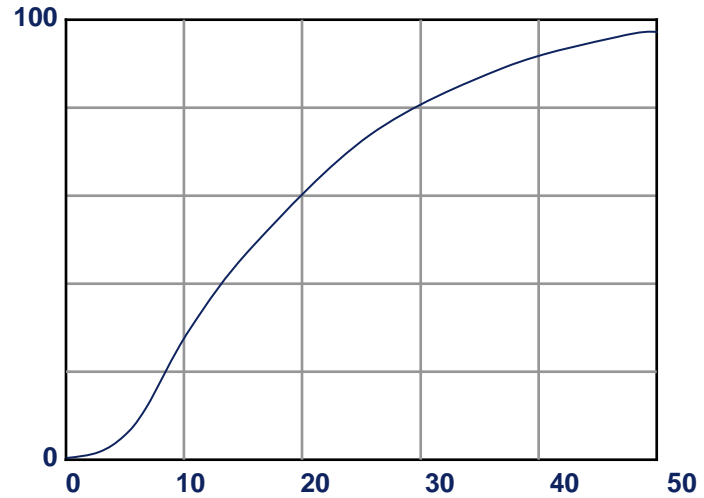


- The dynamic response of a process is the results of many components working together e.g. I/P, Valve actuator, heat or fluid/gas transport, etc.
- The net process response of these higher order systems can be approximated as first order plus deadtime.

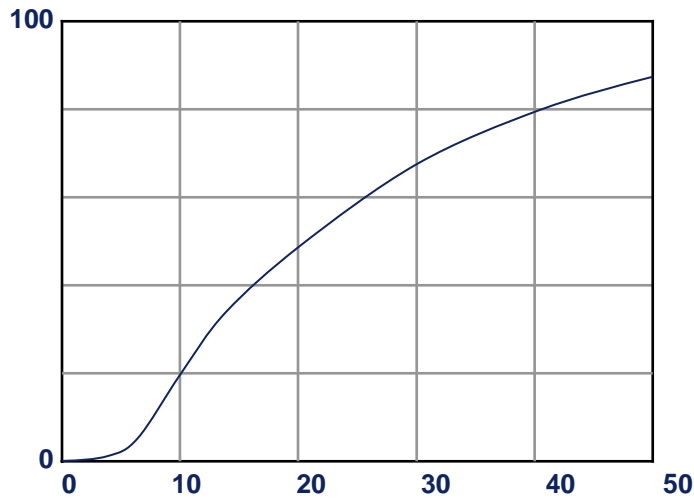
Higher Order Systems (Cont)



Number of Lags 1
Lag Time (Sec)10



Number of Lags 2
Lag Time (Sec)10



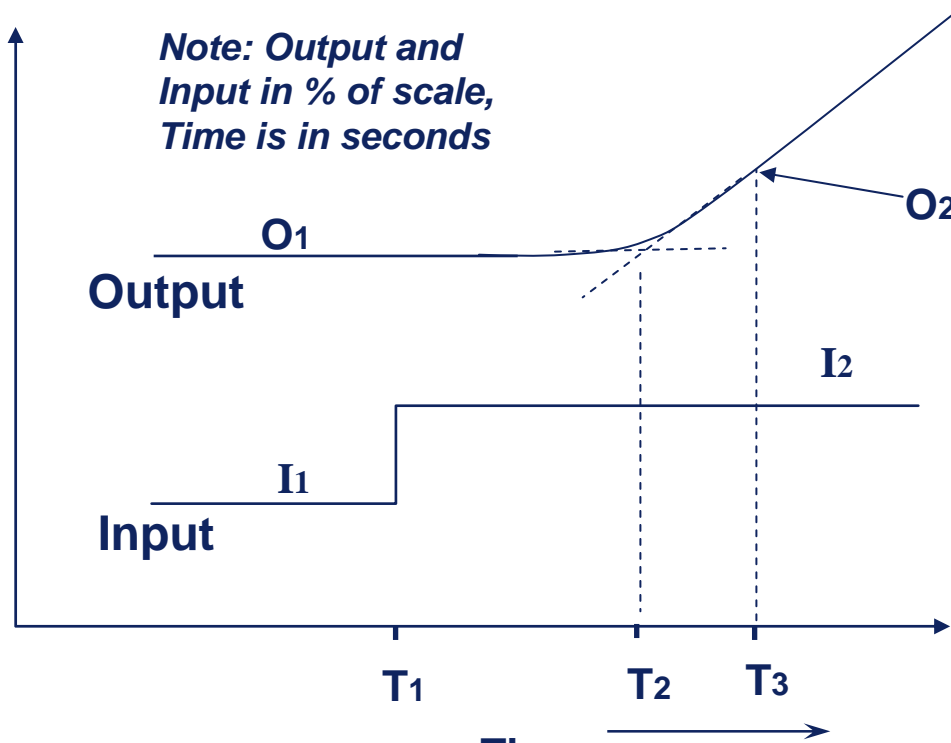
Number of Lags 3
Lag Time (Sec)10

Integrating (Non-Self-Regulating) Process

$$\text{Integrating Gain} = \frac{O_2 - O_1}{(I_2 - I_1) * (T_3 - T_2)}$$

$$\text{Dead Time} = T_2 - T_1$$

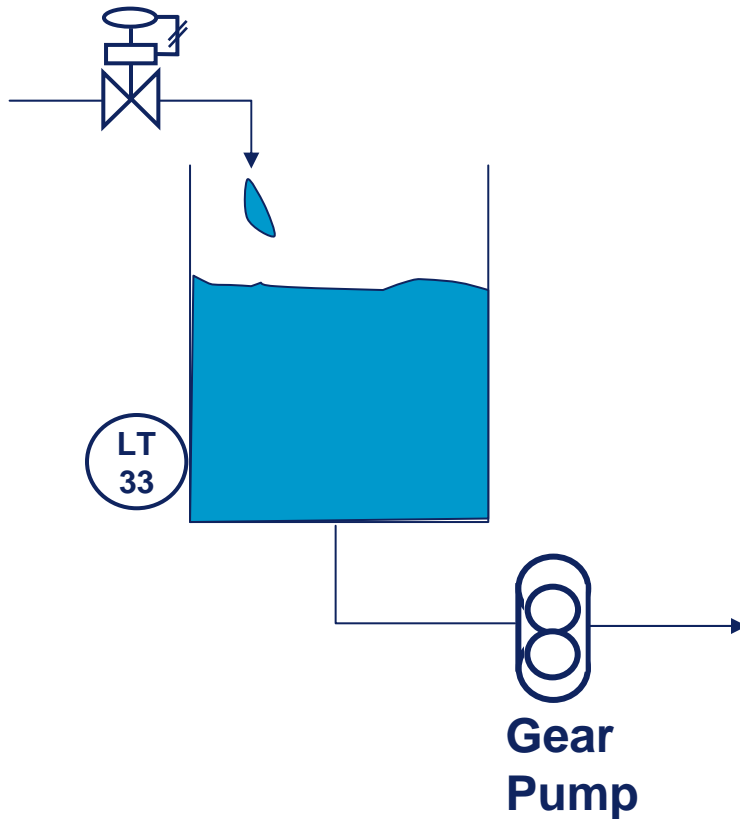
Note: Output and Input in % of scale, Time is in seconds



→ When a process output changes without bound when the process input is changed by a step, the process is known as a non-self-regulating process.

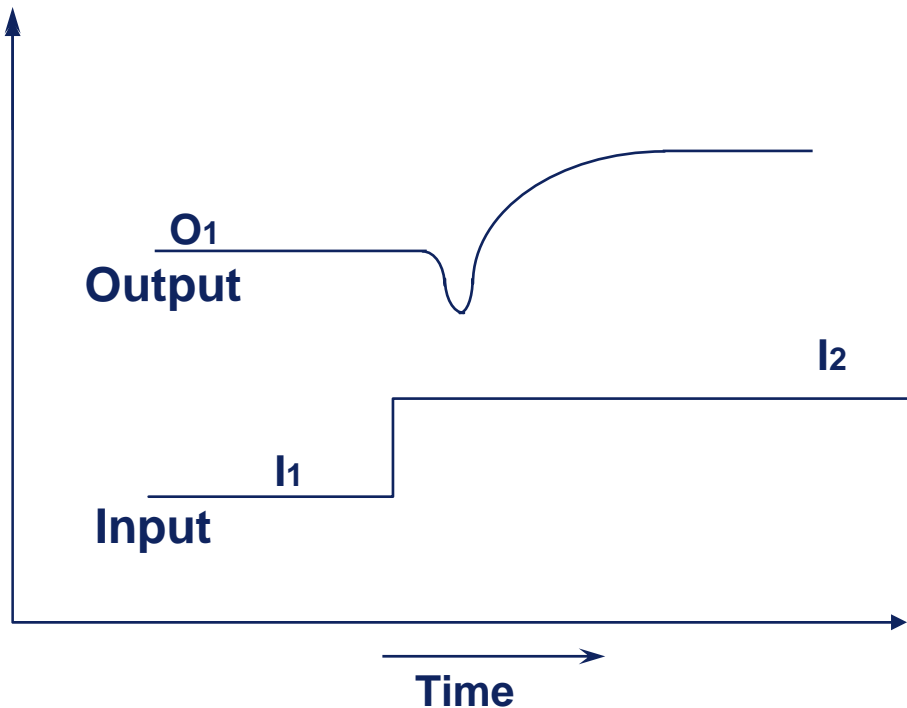
→ The rate of change (slope) of the process output is proportional to the change in the process input and is known as the integrating gain.

Example - Integrating (Non-Self Regulating) Process



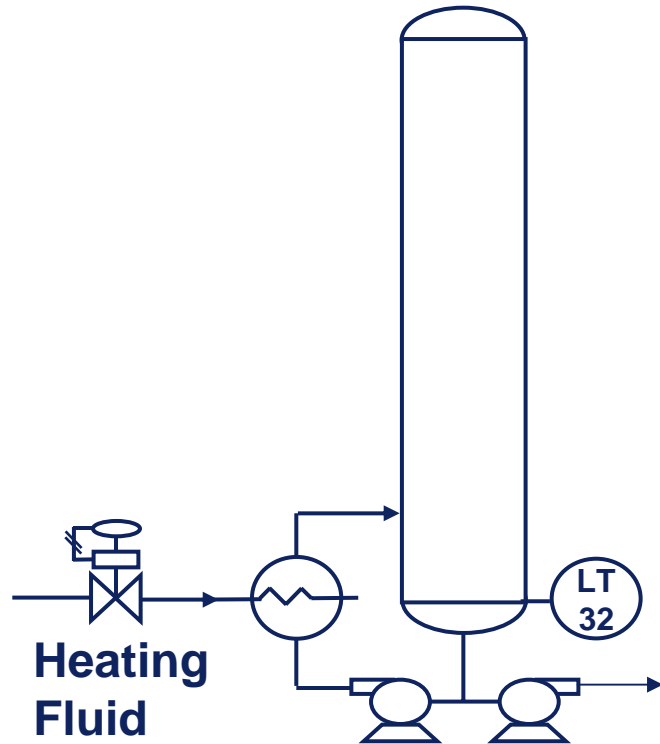
- An example of a non-self-regulating process is tank level where outlet flow is established by a gear pump.
- If the inlet flow does not match the outlet flow, then level will continue to change until the tank overflows or runs dry.

Inverse Response Process



- For a few processes, the initial change in the process output to a step change in a process input will be in the opposite direction of the final output change.
- Processes exhibiting this characteristic are said to have an inverse response.

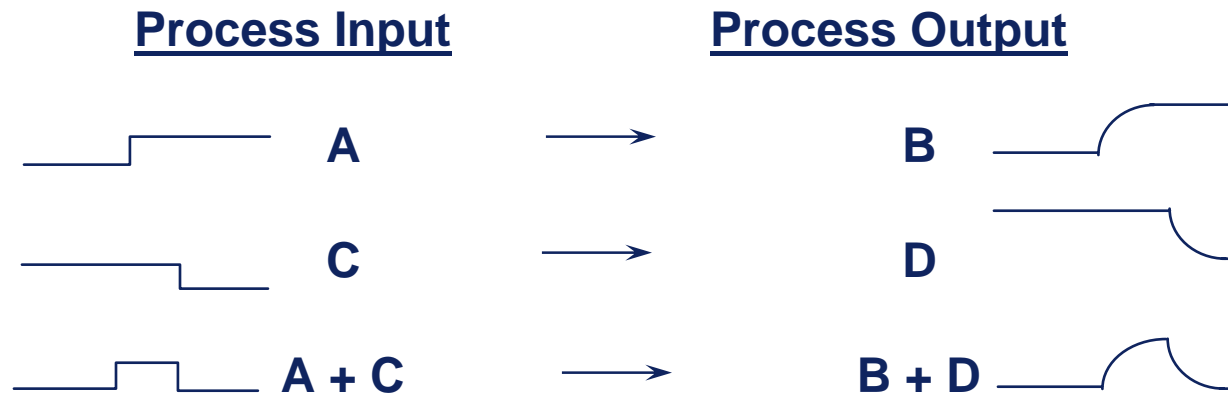
Example – Process with Inverse Response



- The level of a vertical thermosiphon reboiler in a distillation column may exhibit an inverse response to a rapid increase in heat input.
- The size or direction of the change in heat input may determine if an inverse response is obtained.

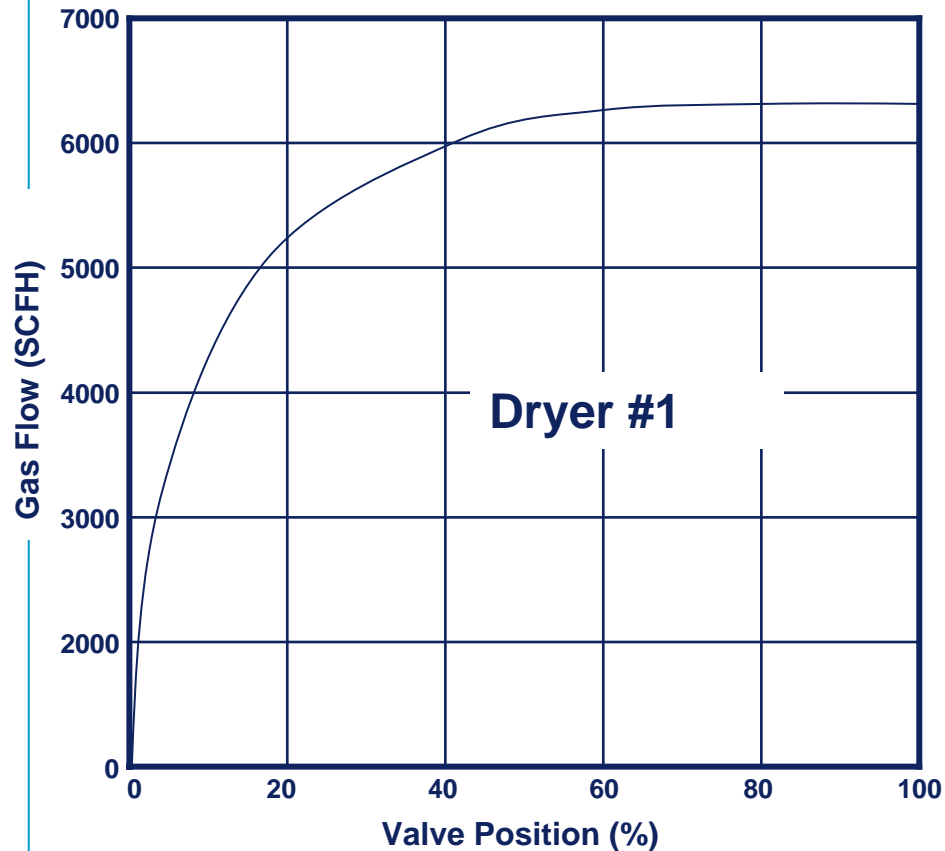
Linear /Non-Linear Response

- If the process output response depends on the amplitude of the process input then it is said to be non-linear. Thus, a process is said to be linear if it meets the following condition:



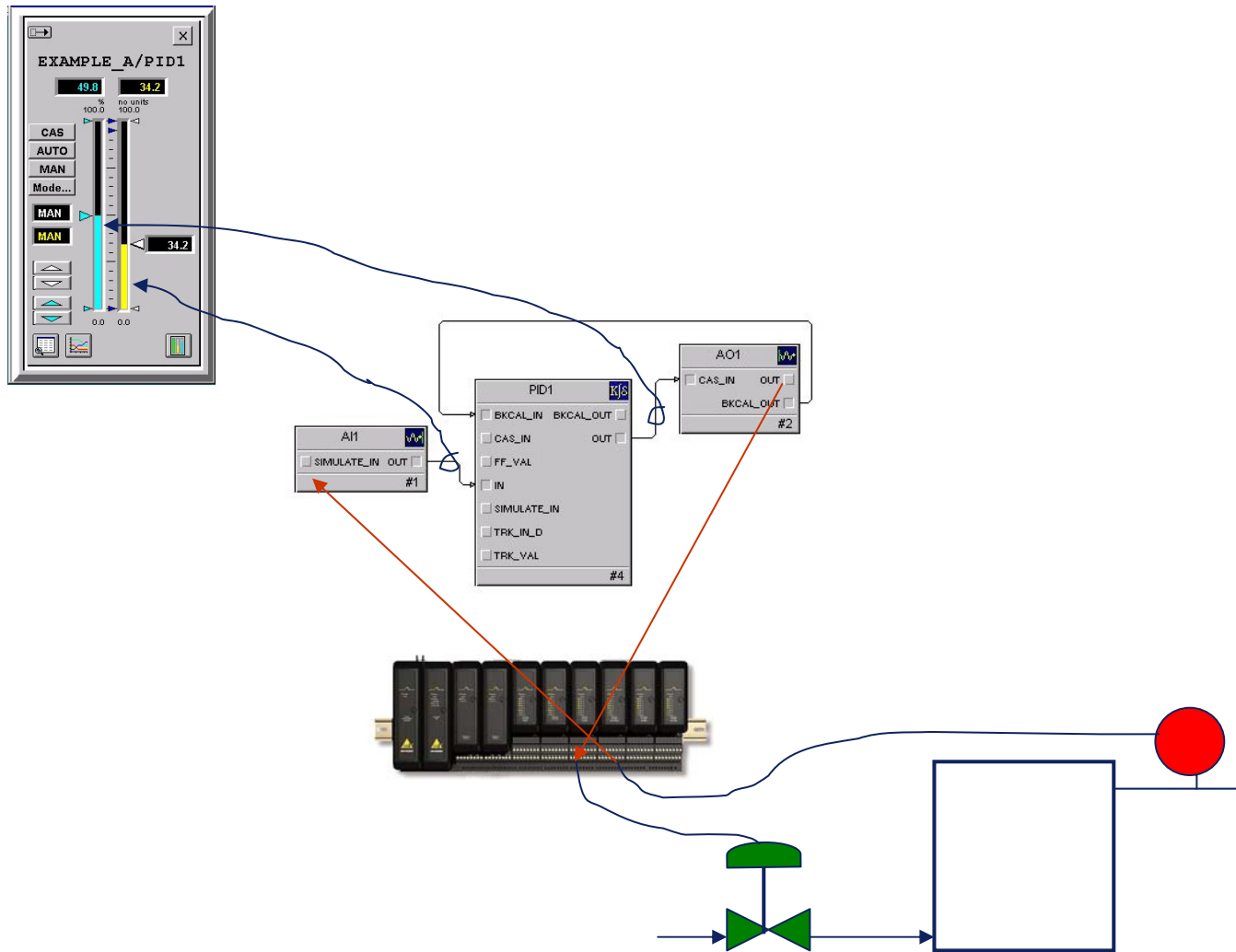
- Saturation of the final control element (valve fully open or closed) is one cause of process Non-linearity.

Process Non-linearity

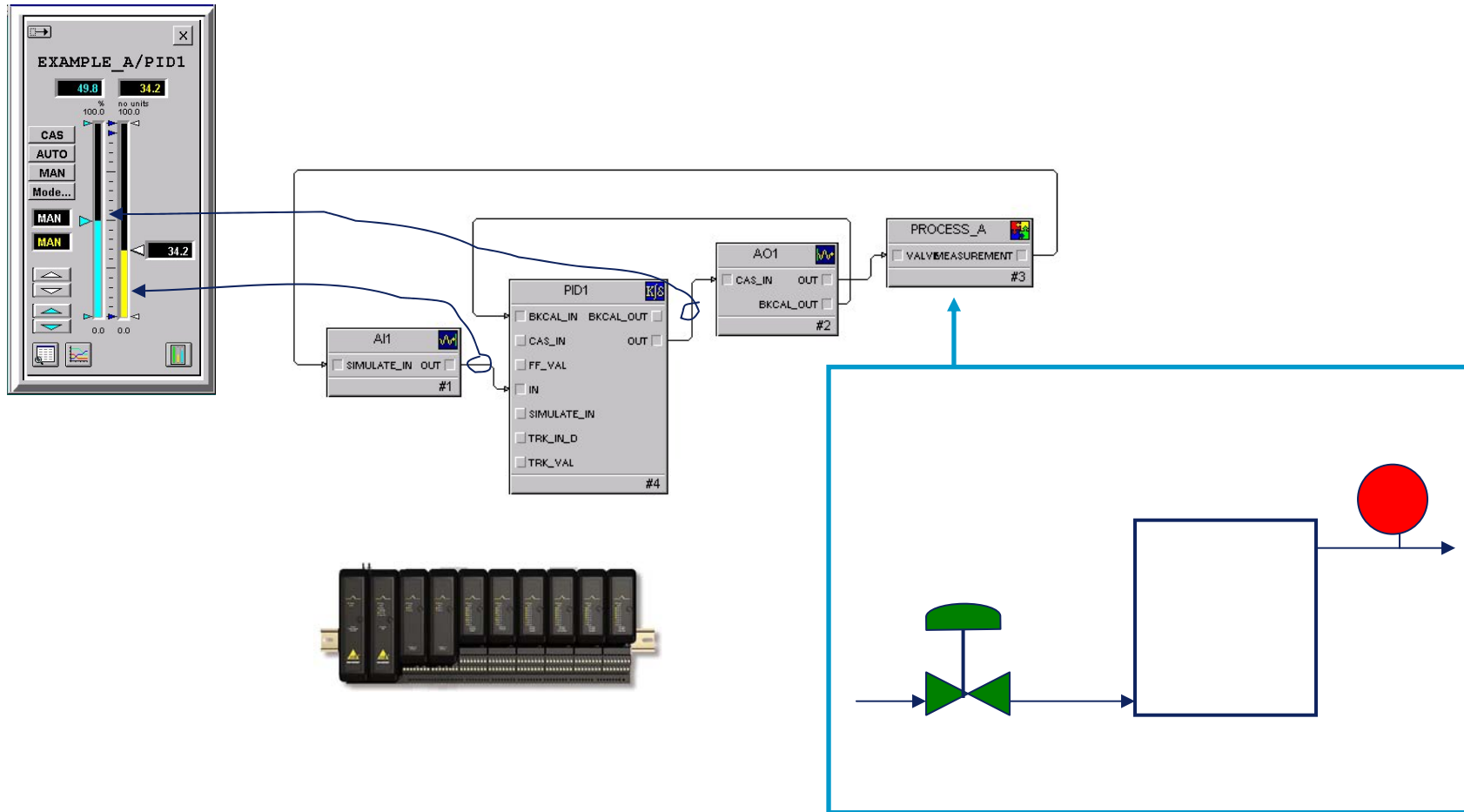


- Most processes may be approximated as linear over a small operating range. However, over a wide range of operation, processes may exhibit some non-linearity.
- A common cause of non-linearity is a change in process gain – reflecting the ***installed characteristics of the final control element*** i.e. valve acting with the other equipment making up the process, as illustrated in this example.

Typical Control Loop



Simulated Process for Workshop Exercises



Process Identification Workshop

This workshop you will perform the following:

Step 1. From Control Studio, open EXAMPLE_A module and go to on-line operation. Determine the process gain, deadtime and lag by making a step change; e.g., 40=>50 in the SP parameter of the AO block and observe response on trend. To change the SP parameter, the MODE parameter must be set to Auto. Repeat this test to see if you get the same results

Question: Based on your observation, how would you classify this process?

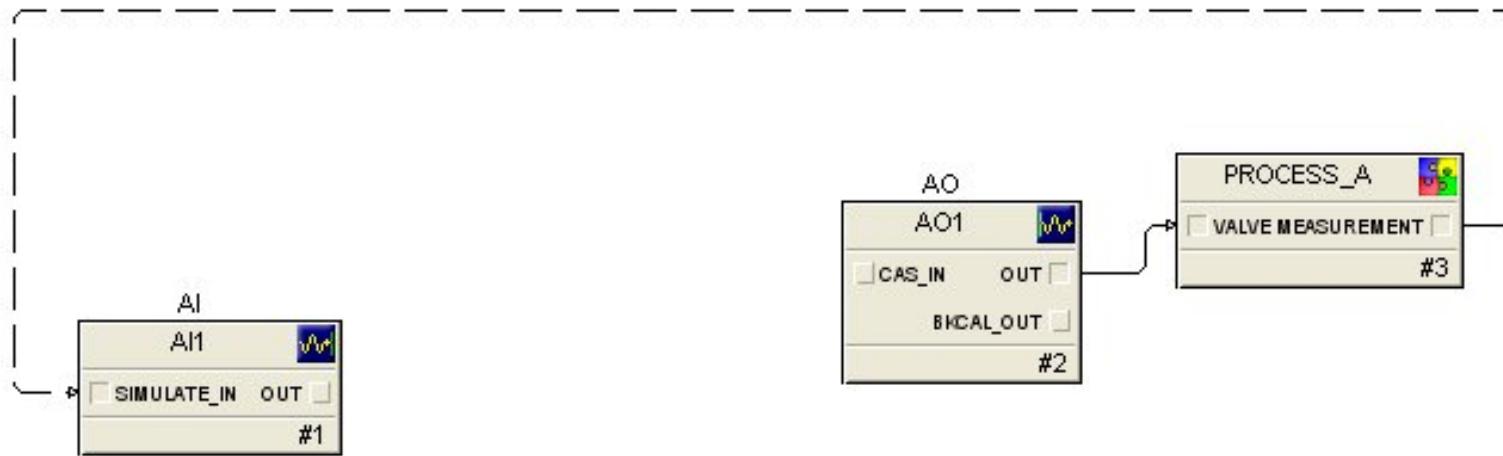
Step 2. Open EXAMPLE_B module and go to on-line operation. Make a step change in the SP of the AO block and observe the process response

Question: Based on your observation, how would you classify this process?

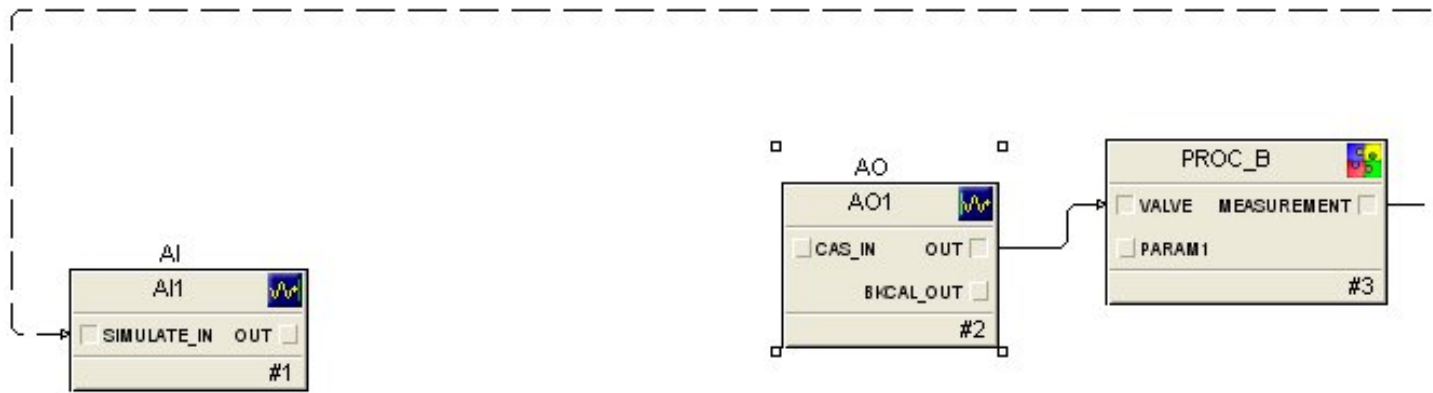
Step 3. Open EXAMPLE_C module and go to on-line operation. With the disturbance set to 40, adjust the valve to 50 and record your observation. Once the process output (LEVEL_MEAS) is above 60%, change the AO Setpoint to 40 and observe the process output. Change the process disturbance from a value of 40 and observe the process response.

Question: Based on your observations, how would you classify this process?

EXAMPLE_A



EXAMPLE_B



EXAMPLE_C

