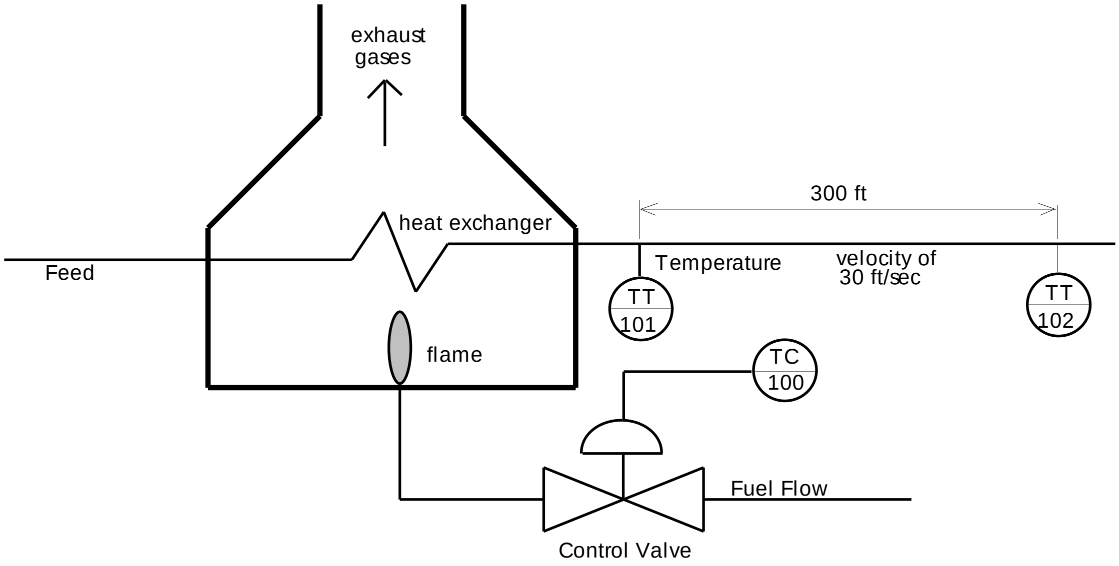
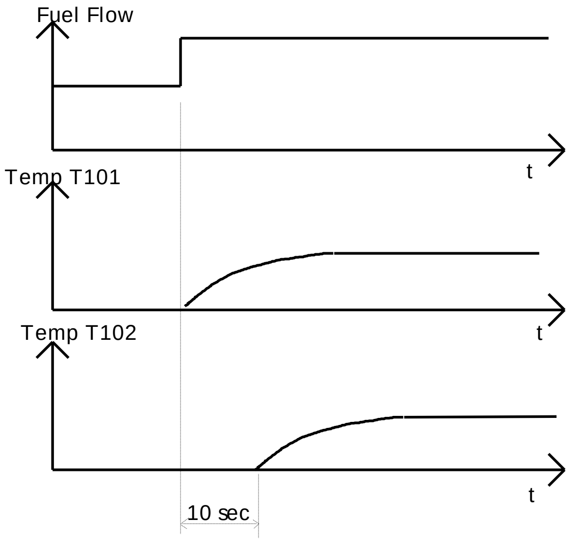
Dead Time and **Process Gain** will be discussed using the furnace as the process, but these 2 characteristics can be found in all processes including electromechanical. thermodynamic, chemical, mechanical and electronic.

Dead Time





This is called the "Dead Time" or "Velocity Lag" or "Transportation Lag."
LaPlace transform for a function delayed by a seconds is:

$$f(t-a) \Leftrightarrow e^{-as}$$

Where "a" in this equation is equal to the dead time.

Process Gain

- Process Gain ***is not*** the same as controller gain.
- Process gain is not adjustable while controller gain is adjustable.
- Process gain is a function of the physical, chemical, mechanical and thermodynamic characteristics of the process

Example:

For TT1:
Range = 100 to 1000 deg C (An absolute value)
In %, 0% = 100 deg C, 100% = 1000 deg C
Span = 900 deg C

For FT1:
Range $= 0.5 \times 10^6$ to 5.5×10^6 J/sec
In %, 0% = $0.5\text{x}10^6$ J/sec to 100% = $5.5\text{x}10^6$ J/sec
Span = $5\text{x}10^6$ J/sec

Process Gain refers to sensitivity: For a given change in heat flow, how much will the outlet temperature change by?

- Suppose a change of 10^6 J/sec in fuel flow produces a change of 500 C^O. Find the process gain.

$$\text{Process Gain } = \frac{\Delta C^o}{\Delta J/\sec} = K_P$$

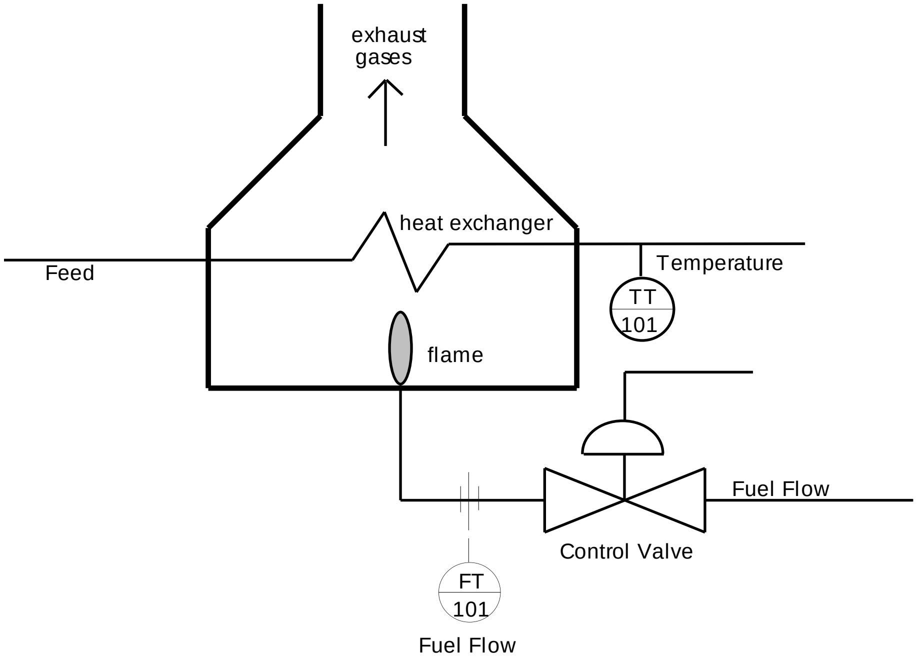
$$K_P = \frac{500^o C}{10^6 J/\sec} = 500 \times 10^{-6} \ {}^oC/J/\sec$$

K_P represents a sensitivity

For unitless gain, we must use the span of the measurement instruments

$$K_P = \frac{\%\ \text{Temp Span}}{\%\ \text{Fuel Flow Span}} = \frac{\frac{500}{900}}{\frac{10^6}{5 \times 10^6}} = .277$$

How Process Gain Can Be Affected By Changing the Calibration of a Measuring Instrument Such as a Temperature Sensor:



Suppose ranges are TT101 200 to 700 deg C ---->0 to 10V
FT101 2 to 12 J/sec --->0 to 10V

We find that a fuel flow change of 6 to 6.5 J/sec produces a temperature change of 500 to 550 deg F.

The process gain will be $\frac{550-500}{6.5-6}=100\ \frac{C^{\circ}}{\frac{J}{sec}}$ in engineering units.

The unitless process gain will be $\frac{\frac{50}{500}}{\frac{0.5}{10}}=2$.

An instrumentation technician was measuring the actual signal voltages from each of the transmitters. Suppose FT101 was outputting 5 volts and TT101 was outputting 3 volts.

Then the actual fuel flow would be $2+(\frac{5}{10})10=7\ \frac{J}{sec}$

and the actual temperature would be $200+\frac{3}{10}(500)=450\ {}^{\circ}C$.

Suppose the fuel flow was suddenly increased from 7 J/sec to 8 J/sec.

The temperature would increase by $100\frac{C^\circ}{\frac{J}{sec}}\times 1\frac{J}{sec}=100\ C^\circ$ to 550 C deg

The voltage change at the output of FT101 would be $\frac{1}{10}\times 10=1\,\text{volt}$ or the voltage would rise to 5+1=6 volts. Similarly the voltage change at the output of TT101 would be $\frac{100}{500}\times 10=2\ \text{volts}$ or the voltage would rise to 3+2=5 volts.

You could have arrived at the voltage change at the output from TT101 by using the unitless value of process gain. That is a 1 volt change of FT101 would have resulted in 2X1 or a 2 volt change in the TT101 output.

Now suppose the instrument technician recalibrates TT101 so that the range is 400 deg C to 600 deg C which corresponds to 0 to 10 volts.

Find the new unitless process gain and find out how much the TT101 output voltage changes.

The unitless process gain will be: $\frac{\frac{50}{200}}{\frac{0.5}{10}}=5$

That is the same 1 volt change from FT101 will result in a 5 volt change from TT101. In the furnace, the temperature change is the same but the controller sees a much larger change in voltage. It is in this way that recalibrating the measurement can effectively be seen as a change in the unitless process gain to the controller.