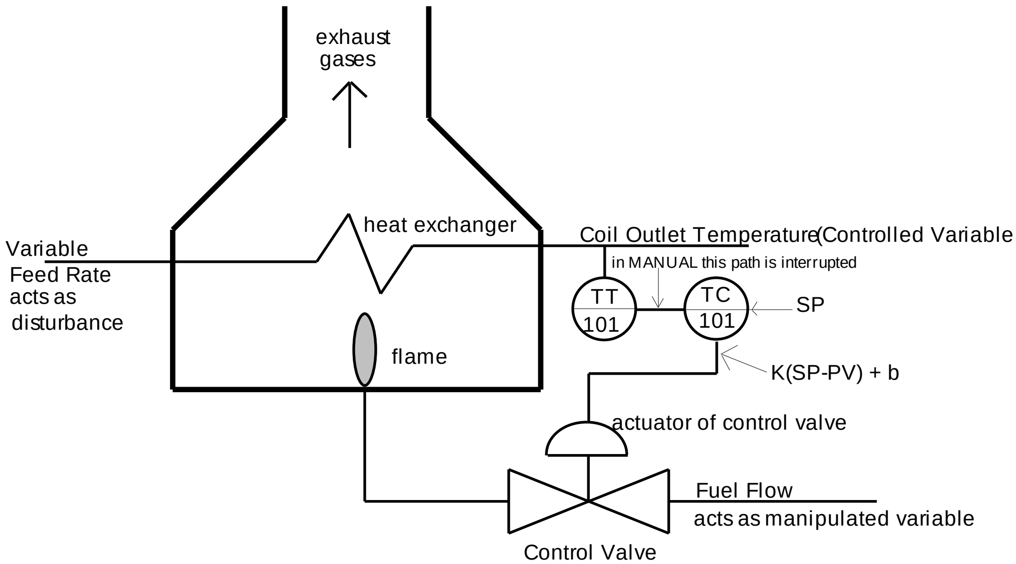
Proportional Control of Thermal Process



T_{out} Range and Setpoint range are always the same.

(SP-PV)=0

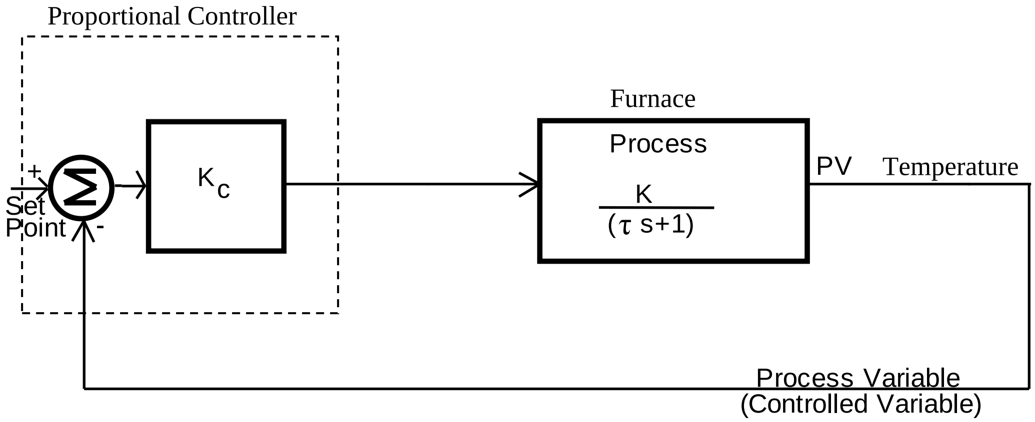
Suppose

Desired output temp T_{out} (PV)=500^0F

T_{in} =300^0F

To start up the furnace, you would:

- Set controller to manual
- Adjust bias b to set T_{out} =500^0F
- Adjust the set point to 500^0F
- Put controller into automatic
- if Tin rises, SP-PV will become negative (PV >SP)
- K(SP-PV)+b will decrease and close the fuel valve to reduce the temperature.
- PV wiil not however, go back and equal SP (if it did, the output of the controller would go back to its original setting before the disturbance that caused PV to rise. That is the setting of the valve that resulted in the PV greater than SP)
- The proportional controller reduces the error caused by the disturbance to PV, but it does not eliminate it.
- To get rid of this error (often referred to as ***offset***) the "b"value or bias could be adjusted manually (sometimes referred to as ***manual reset***)
- For a higher gain K, the (SP-PV) term of the expression K(SP-PV) can be smaller to result in the same change to the controller output. That is a ***higher controller gain will result in a smaller error or offset.***
- Steady state error can be eliminated by manually adjusting "b" (manual reset)
- Integral action looks at (SP-PV) and automatically adjusts or resets "b". That is, integral action performs automatic reset replacing the manual reset.



Find $\dfrac{PV}{SP}$

$$\frac{K_C \cdot K.SP}{\tau s+1} - \frac{K_C \cdot K.PV}{\tau s+1} = PV$$

$$\frac{K_C \cdot K.SP}{\tau s+1} = \frac{K_C \cdot K.PV}{\tau s+1} + PV$$

$$\frac{K_C \cdot K.SP}{\tau s+1} = PV[\frac{K_C \cdot K}{\tau s+1} + 1]$$

$$\frac{\frac{K_C \cdot K}{\tau s+1}}{\frac{K_C \cdot K}{\tau s+1} + 1} = \frac{PV}{SP}$$

$$\frac{K_C \cdot K}{K_s \cdot K + \tau s + 1} = \frac{PV}{SP} \qquad \text{LET } \frac{K_C \cdot K}{K_C \cdot K + 1} = K^I$$

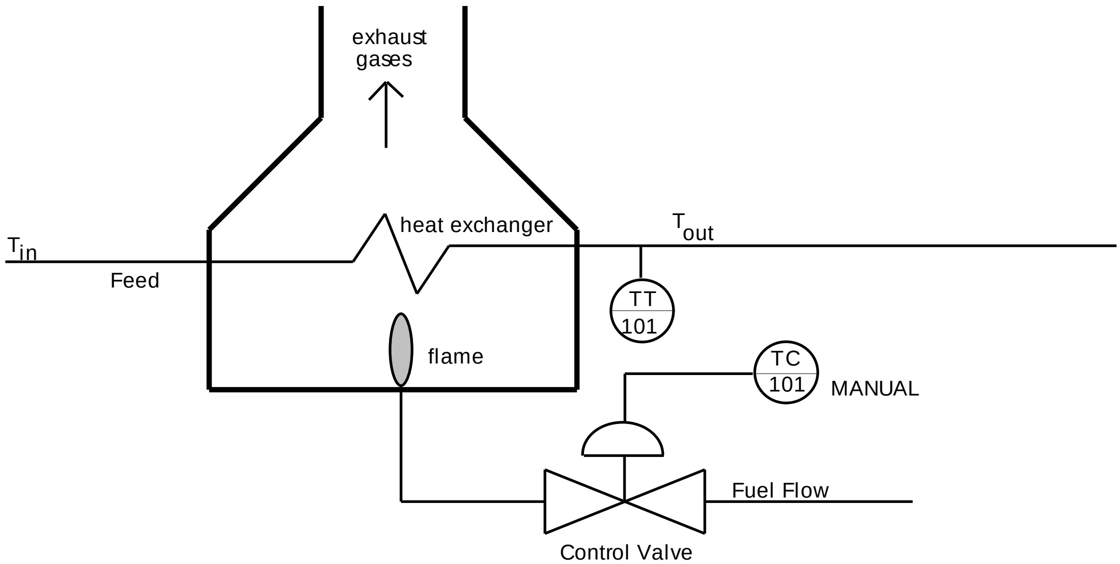
$$\frac{K^I}{\tau^I s + 1} = \frac{PV}{SP} \qquad \text{LET } \frac{\tau}{K_C \cdot K + 1} = \tau^I$$

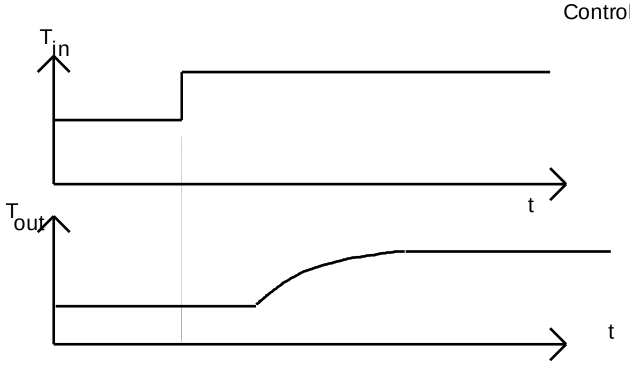
Closed Loop Control of a first order process using proportional only control is relatively simple to analyze. The resulting transfer function relating PV (T_{out}) to SP is surprisingly first order. In practice there is almost no closed loop system that is truly first order as there is always an element of the control system that contributes an additional lag.

With proportional control a steady state error or offset occurs that is the difference between the set point or desired value and the PV, the actual value of the controlled variable. The larger the gain, the smaller is the steady state offset.

Process Disturbance

Process disturbances are the reason we need feedback control. A process disturbance is an external event that causes the controlled variable to change. For the furnace below, one of many process disturbances would be a change in inlet temperature of the feed.





The response above is an illustration of the change of outlet temperature when inlet temperature suddenly rises. Outlet temperature rises in a first order manner after a delay (dead time). The change in inlet temperature is a disturbance. The above graph assumes that the fuel flow and feed rate is fixed. That is , no closed feedback control is employed. Below is a block diagram for the process disturbance.