CONTROL SYSTEM

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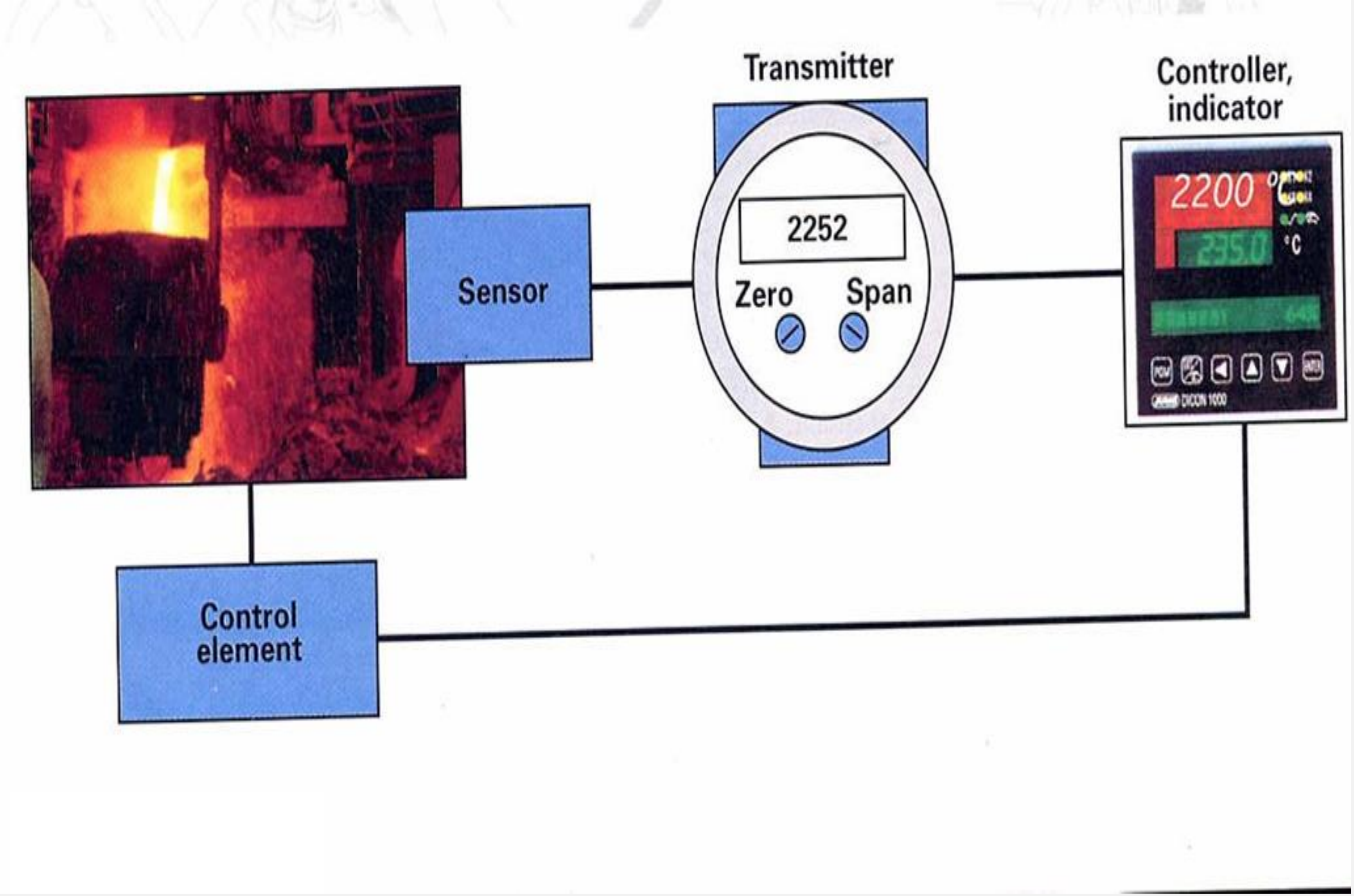
TYPICAL PROCESS LOOP



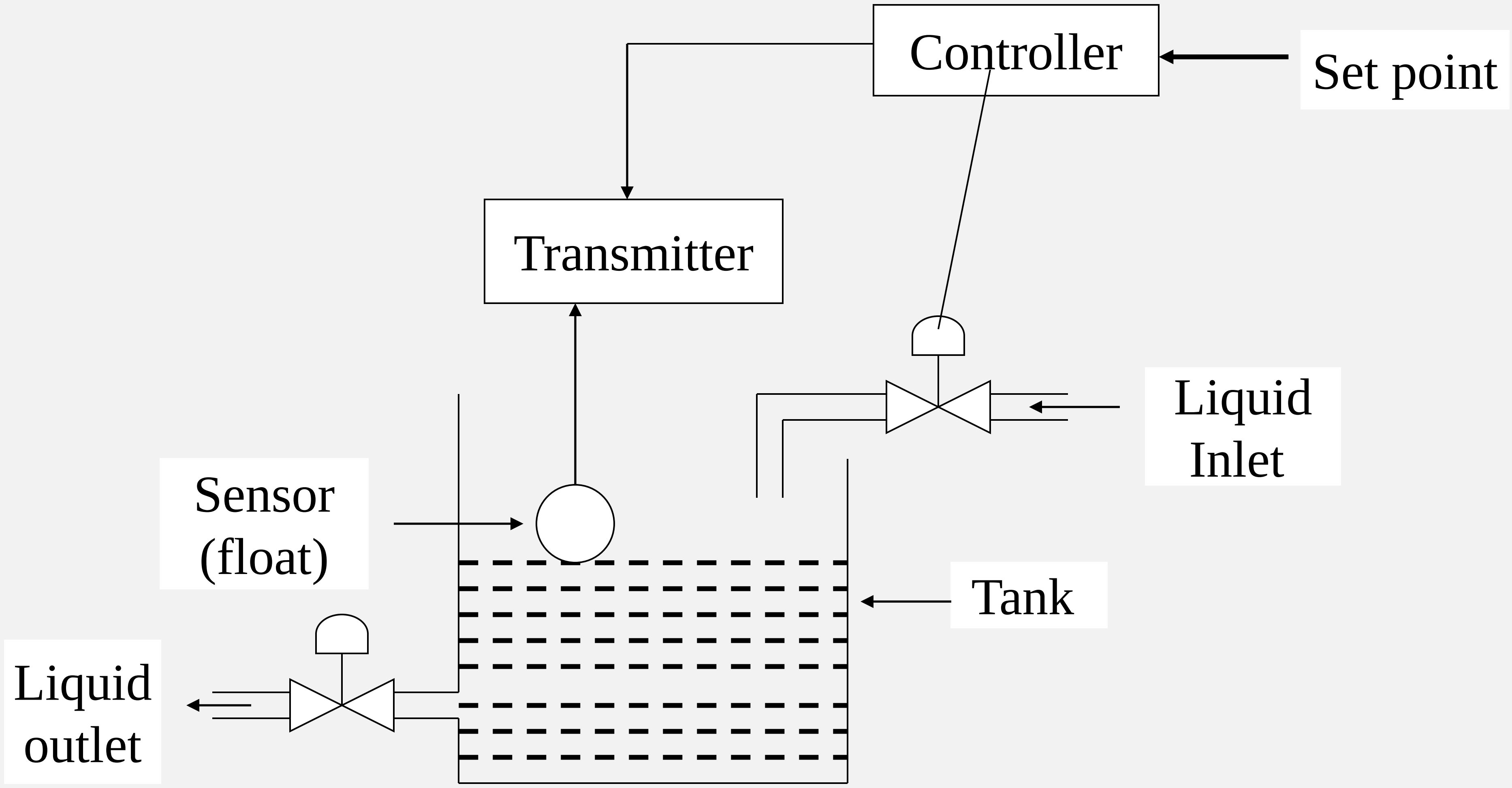
WHAT IS FEEDBACK CONTROL SYSTEM?

- Feedback in a control loop is information about the status of the controlled variable which is compared with that which is desired (set point), in the interest of making them coincide.

WHAT IS CASCADE CONTROL SYSTEM?

- Cascade control system is a control system in which the output of one controller is the input for another .The relationship that exits between controller is referred to as a master-slave or primary-secondary relationship.

LEVEL CONTROL SYSTEM



Controller

Set point

Transmitter

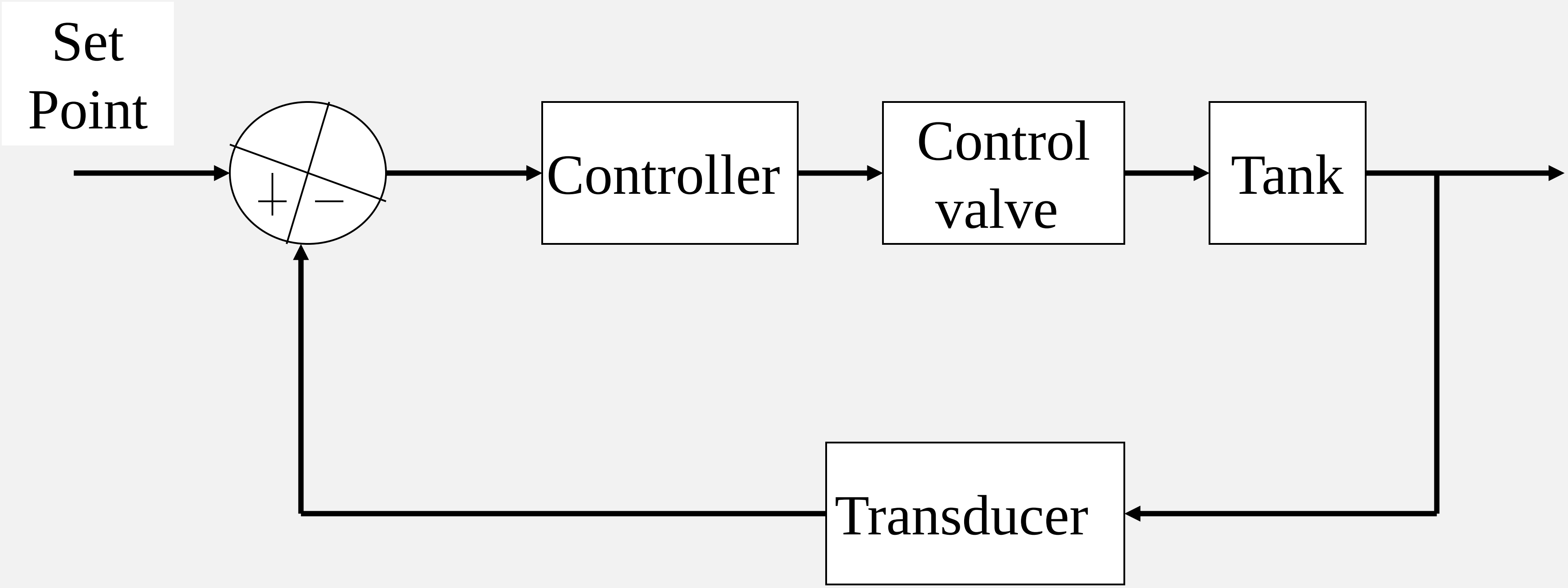
Liquid Inlet

Sensor (float)

Tank

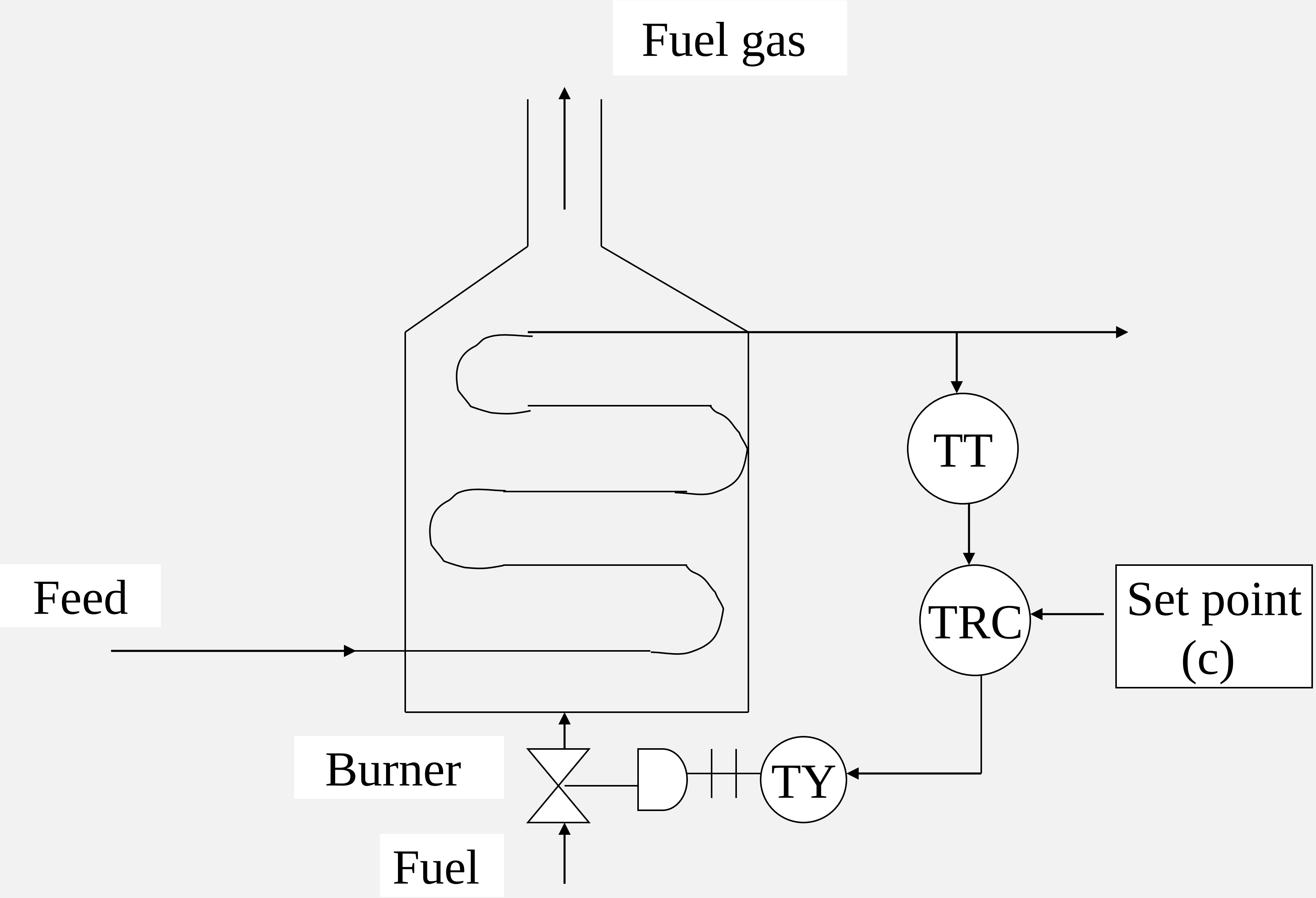
Liquid outlet

LEVEL CONTROL SYSTEM



BLOCK DIAGRAM

FURNACE CONTROL



FURNACE CONTROL

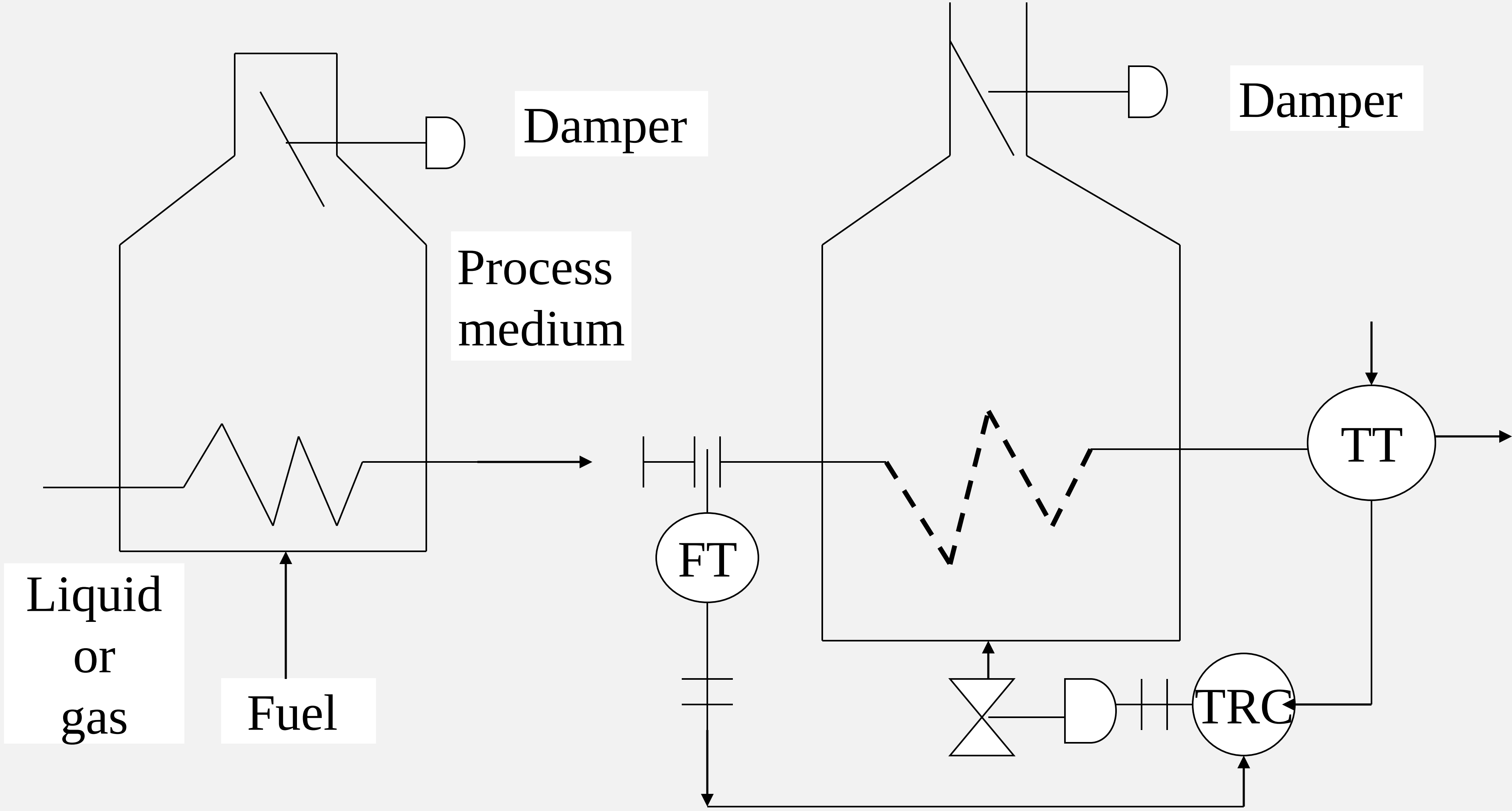
-Process is used to heat process gas by burning fuel in the fire box outside the tube.

-The temparature of fire box is uniform.

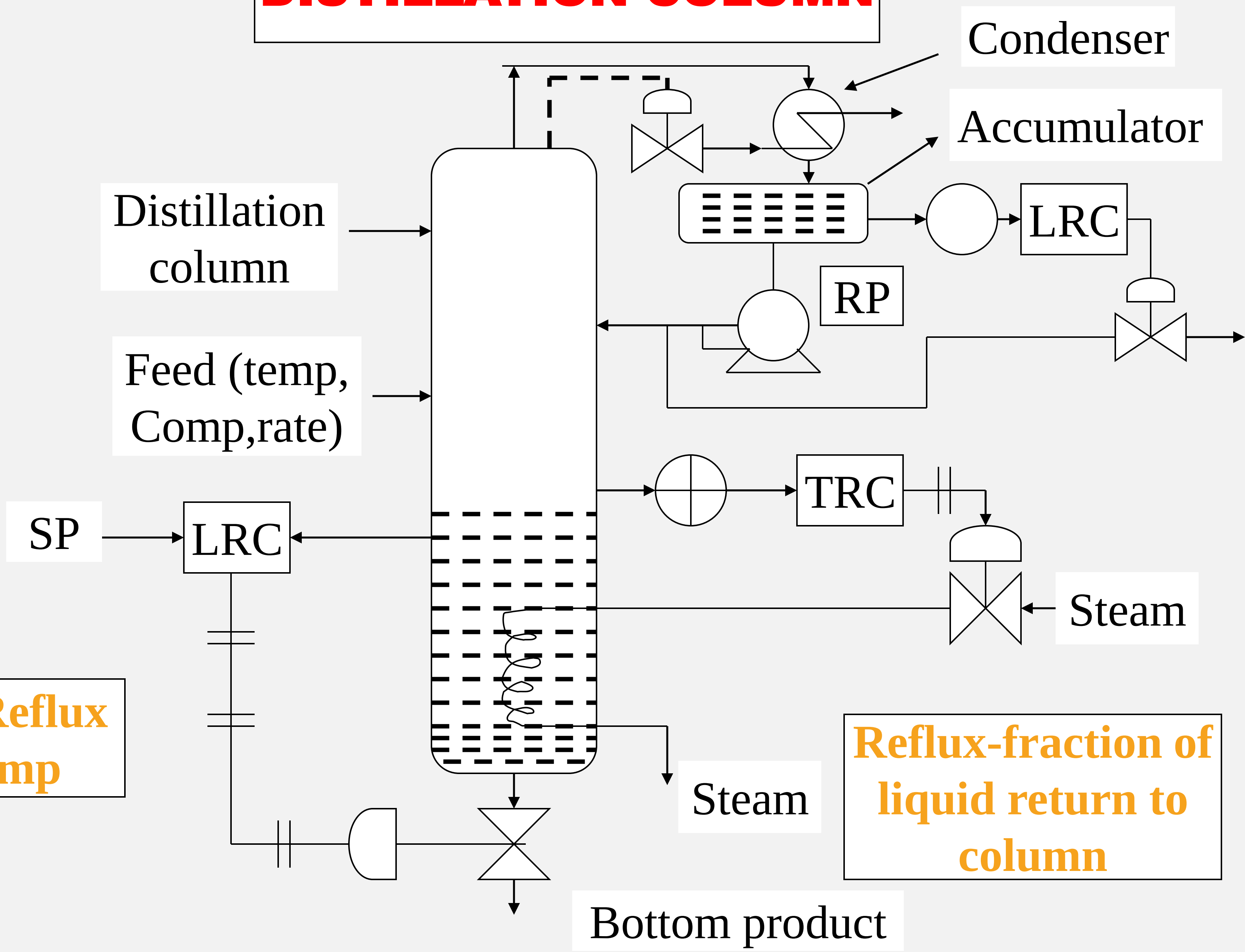
- Outlet process temparature is controlled by f/b system that manipulates flow of fuel to the burners.

-Disturbances : 1] inlet temparature to fluid.
2] flow rate.

FURNACE CONTROL



DISTILLATION COLUMN



Rp--Reflux Pump

Reflux-fraction of liquid return to column

DISTILLATION COLUMN

- Process of seperation by boiling.

-Method to separate mixtures of two or more miscible liquids in to their components.

- Liquid heated to its boiling point.

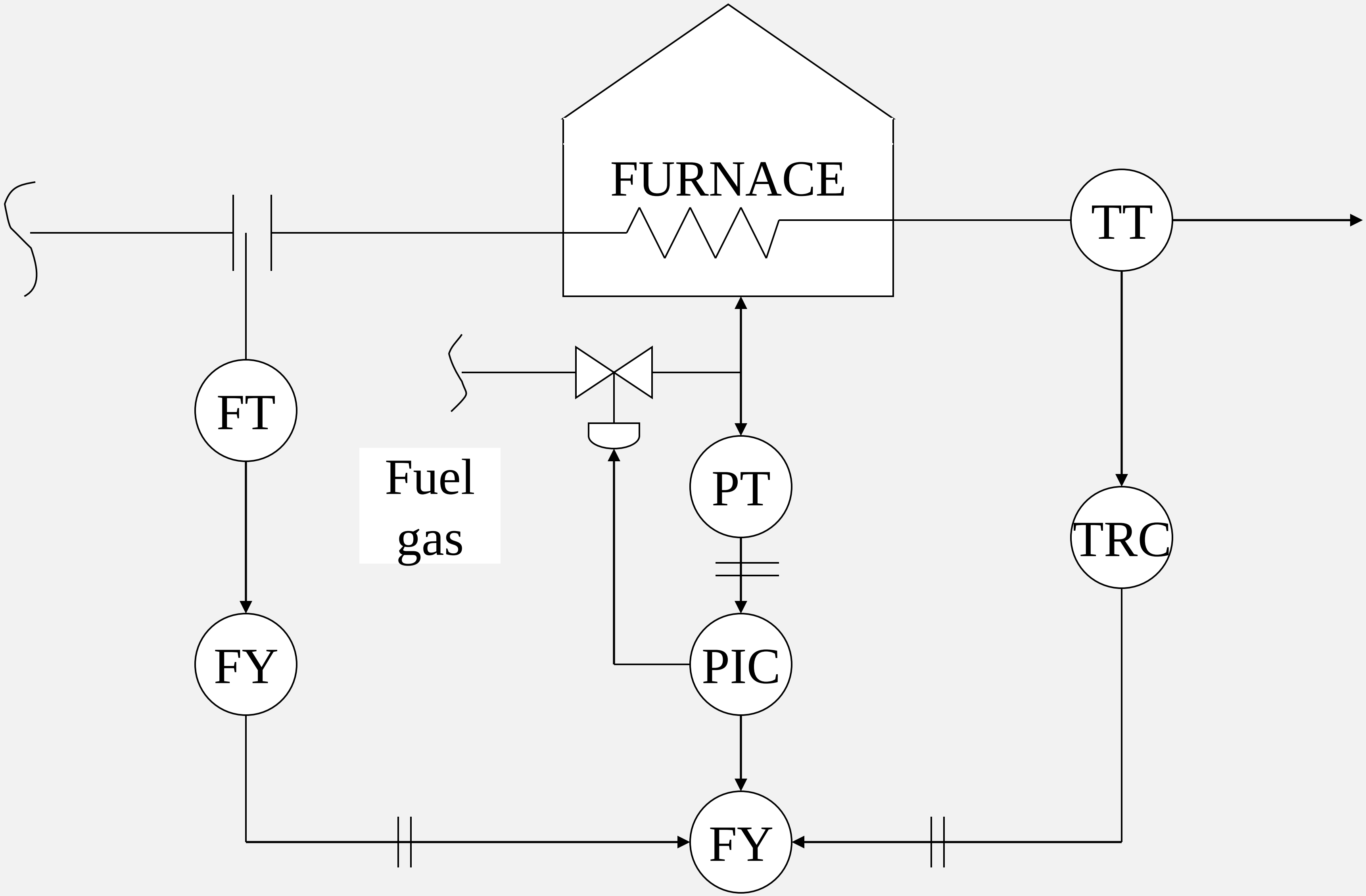
- Vapours are condensed & connected.

Two stream Vapour
Liquid

-Interactive Process

-Parameters- 1) Temp (through steam rate)
2) Bottom level (Bottom rate product)
3) Pressure (by manufacture of coolant rate)
4) Top accumulations level (by overhead product rate)

FEED FORWARD CONTROL SYSTEM



FEED FORWARD CONTROL SYSTEM

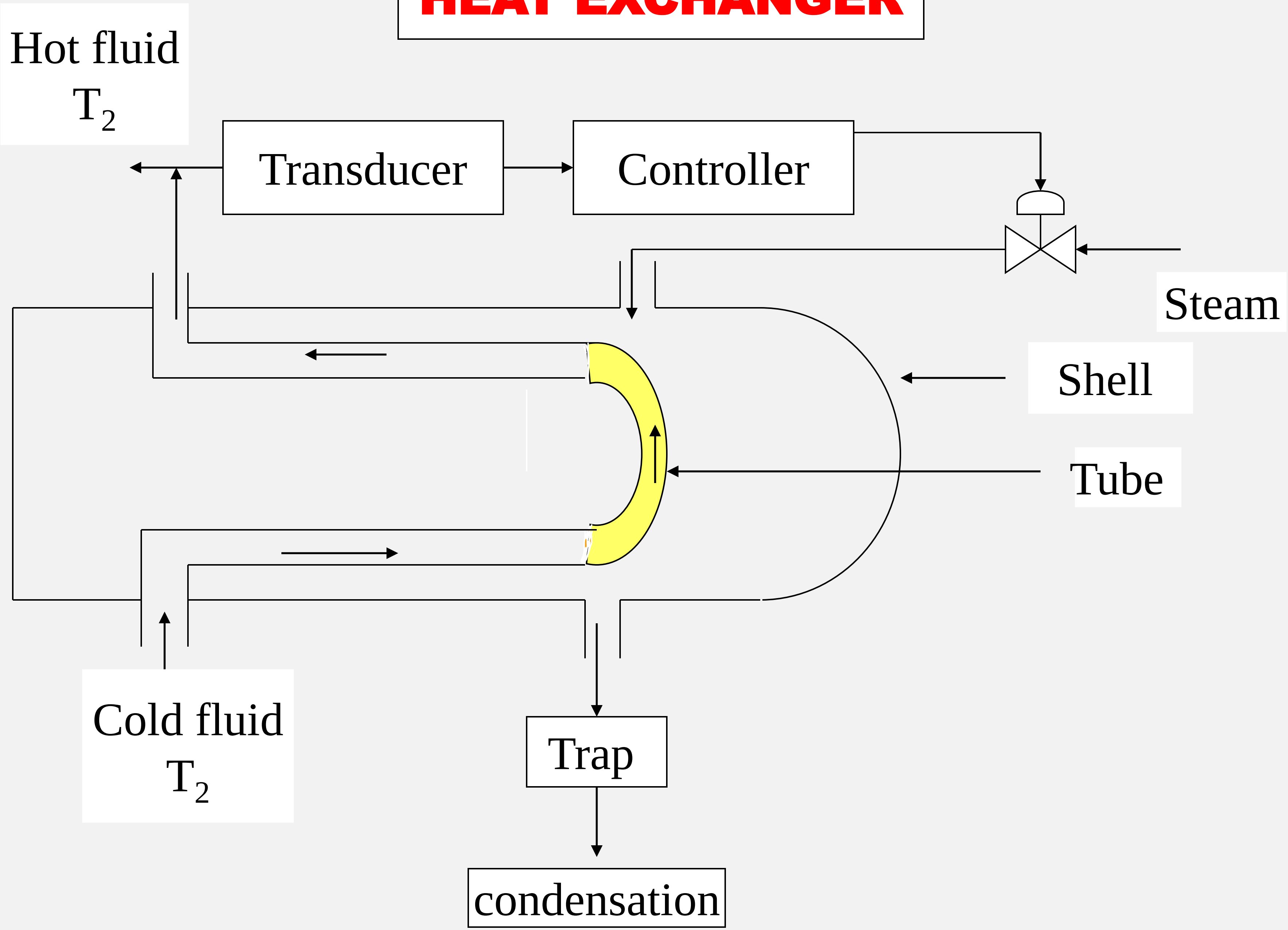
FUNCTIONS :

1] To maintain the desired rate of energy transfer.

2] To maintain,controlled & efficient combustion of fuel.

3] To maintain safe condition of phase.

HEAT EXCHANGER



Hot fluid
T_2

Transducer

Controller

Steam

Shell

Tube

Cold fluid
T_2

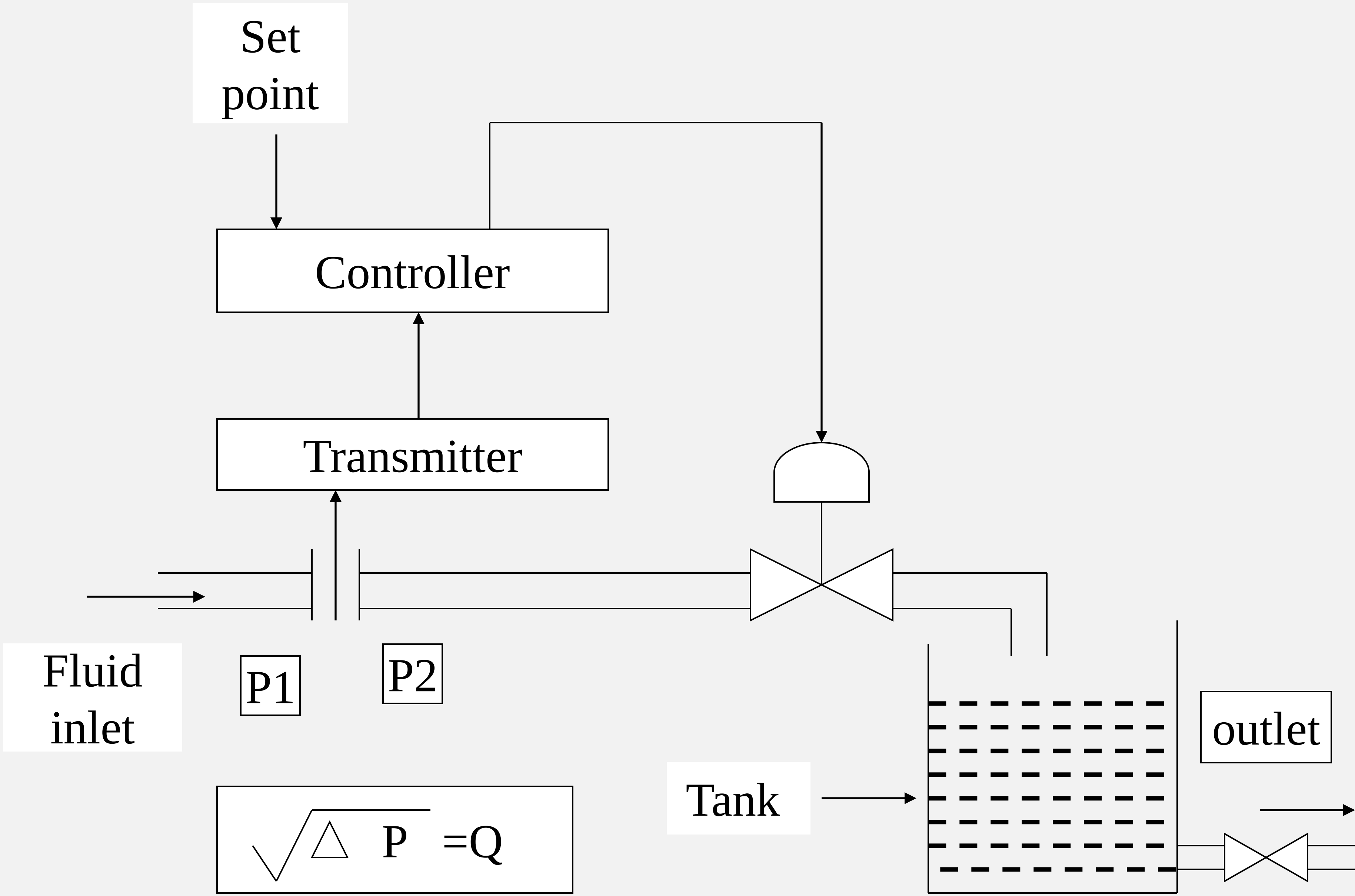
Trap

condensation

HEAT EXCHANGER

- Hot fluid (steam) flows through shell.
- Cold fluid flows through tube (6mm-50mm)
- As cold fluid travels in the tubes it recieves heat from hot fluid.
- Disturbance steam flow rate .
- Cascade by steam flow rate.

FLOW CONTROL



Set point

Controller

Transmitter

Fluid inlet

P1

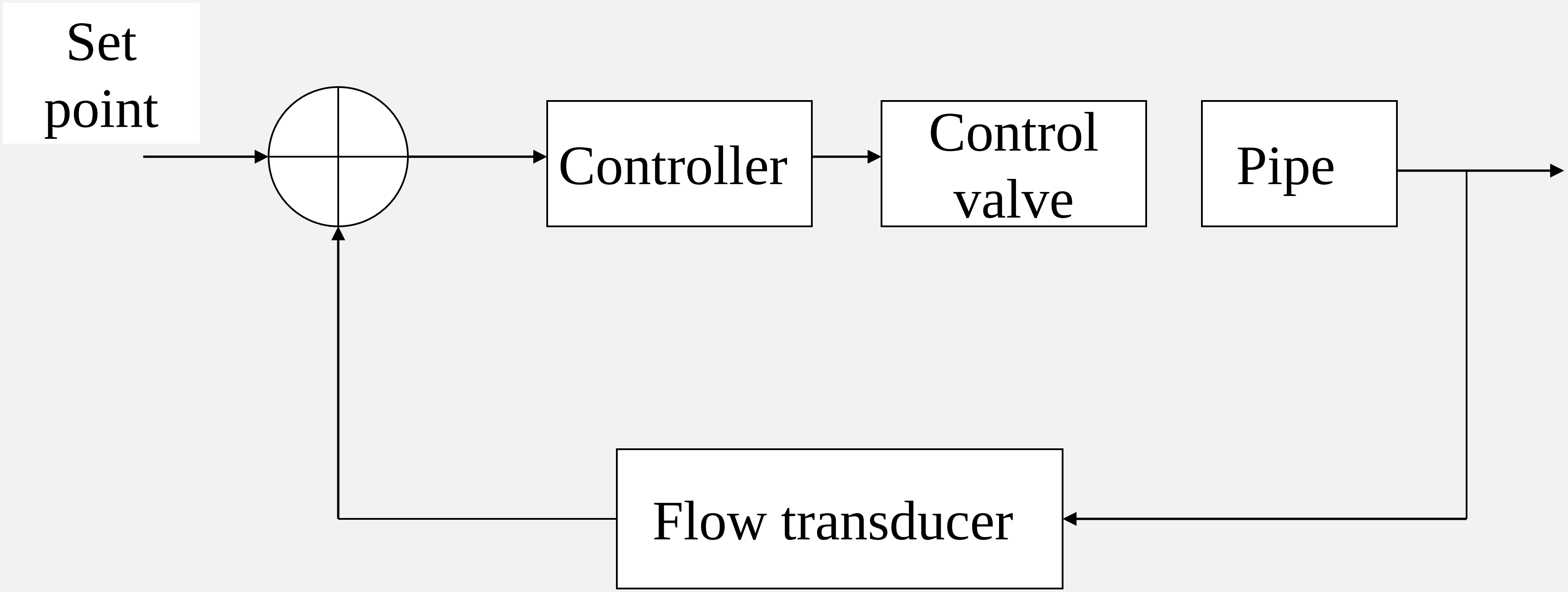
P2

$\sqrt{\Delta P} = Q$

Tank

outlet

FLOW CONTROL



Set point

Controller

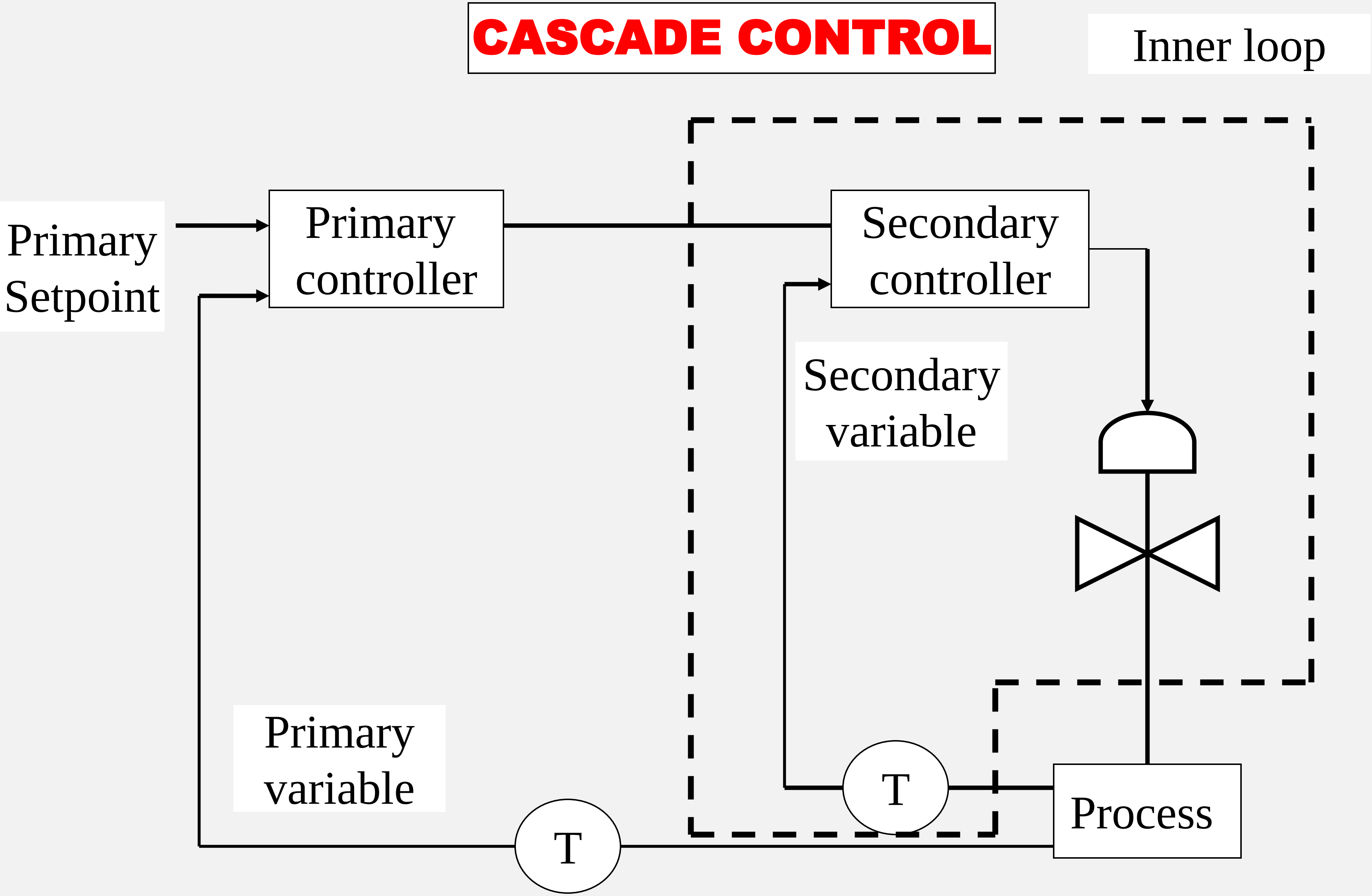
Control valve

Pipe

Flow transducer

BLOCK DIAGRAM

CASCADE CONTROL



Inner loop

Primary Setpoint

Primary controller

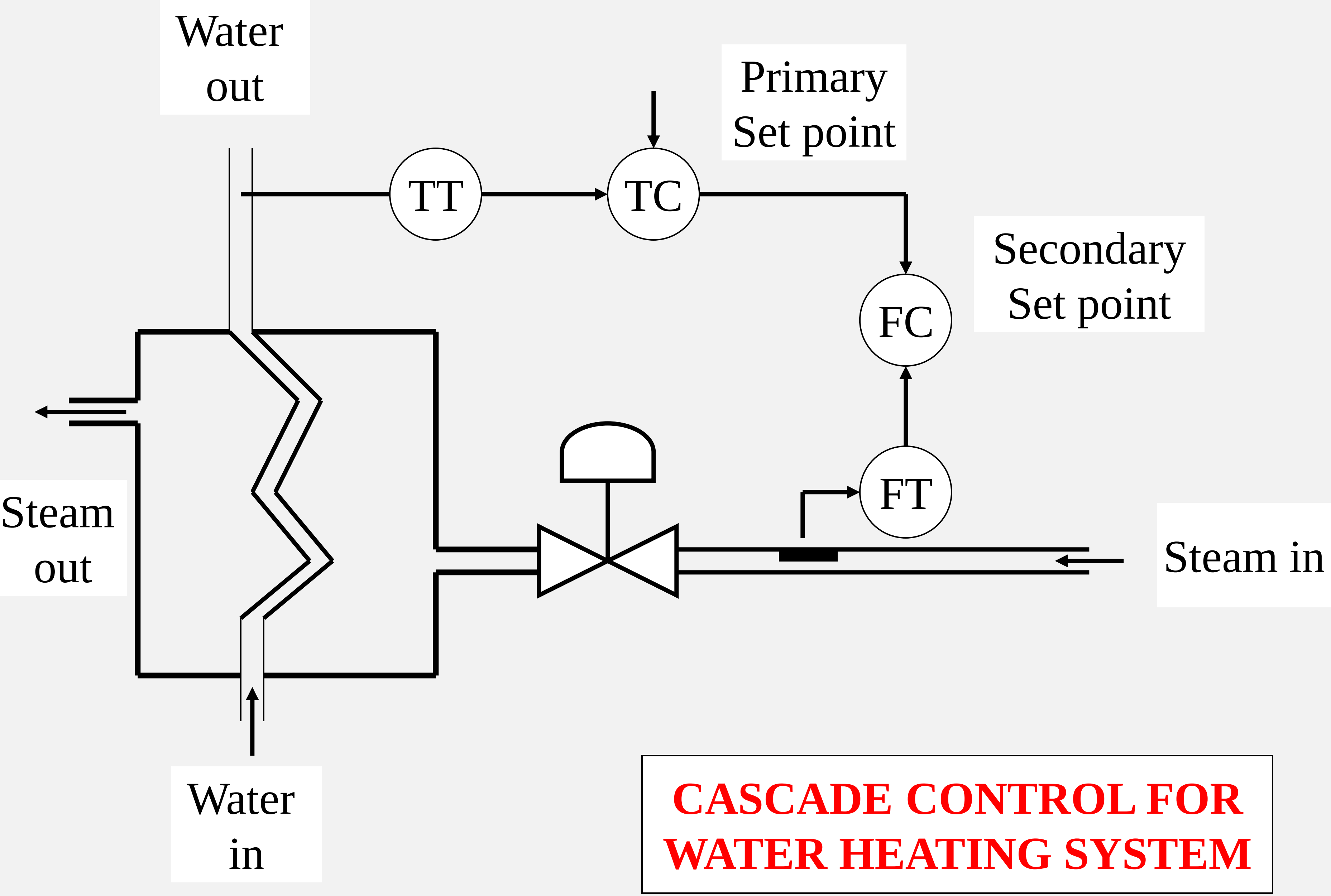
Secondary controller

Secondary variable

Primary variable

Process

CASCADE CONTROL



Water out

Primary Set point

Secondary Set point

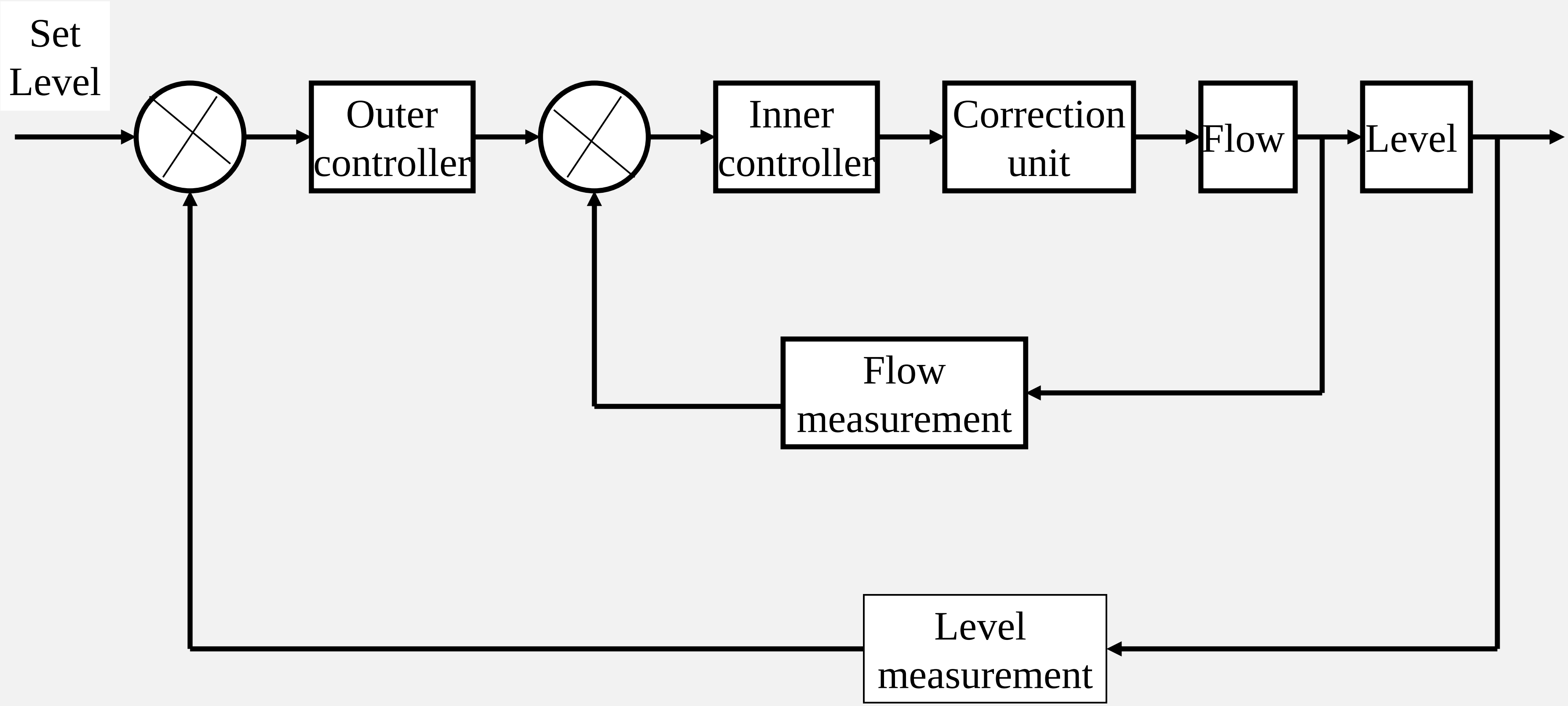
Steam out

Steam in

Water in

CASCADE CONTROL FOR WATER HEATING SYSTEM

CASCADE CONTROL



Set Level

Outer controller

Inner controller

Correction unit

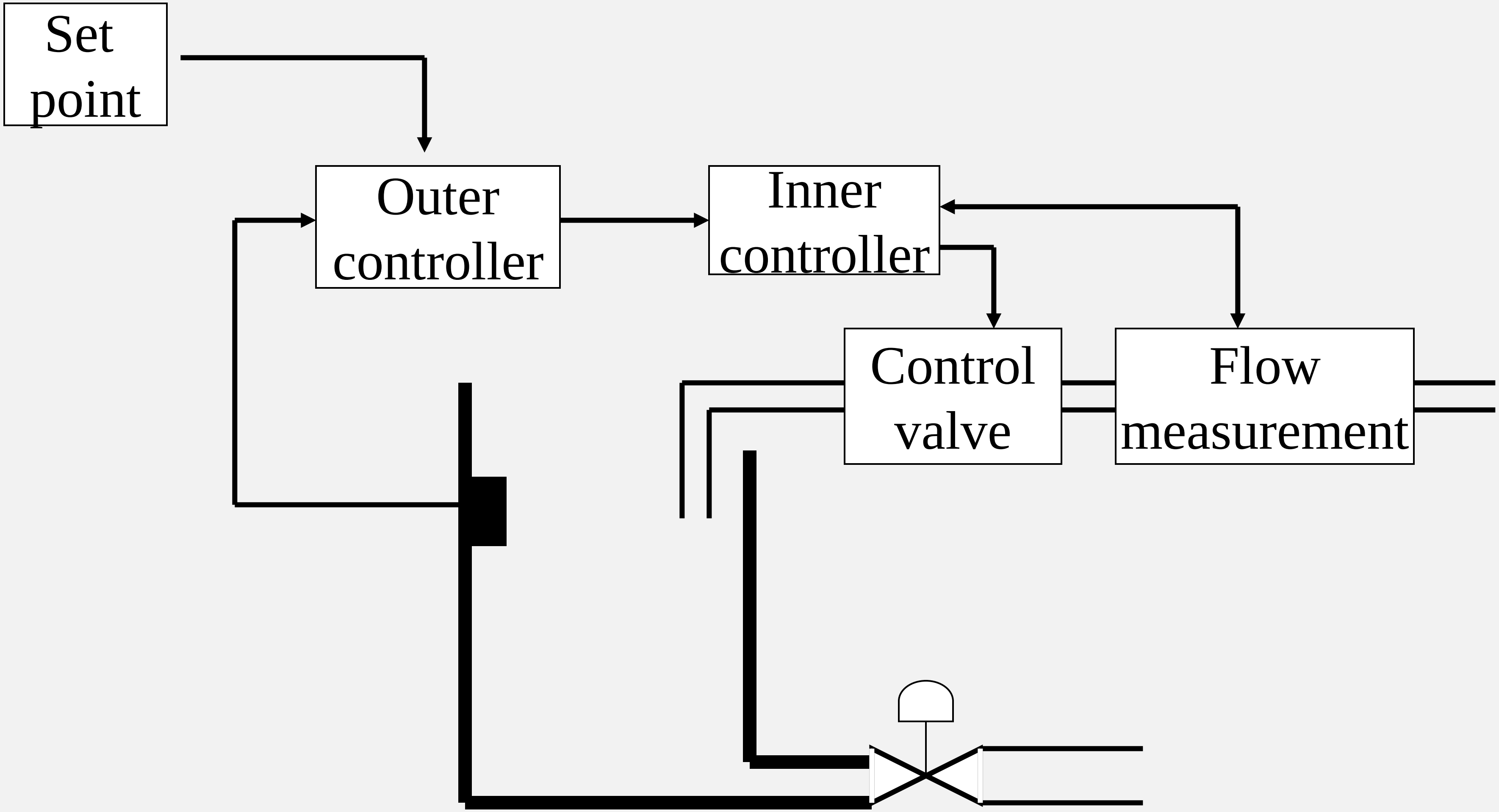
Flow

Level

Flow measurement

Level measurement

CASCADE CONTROL



Set point

Outer controller

Inner controller

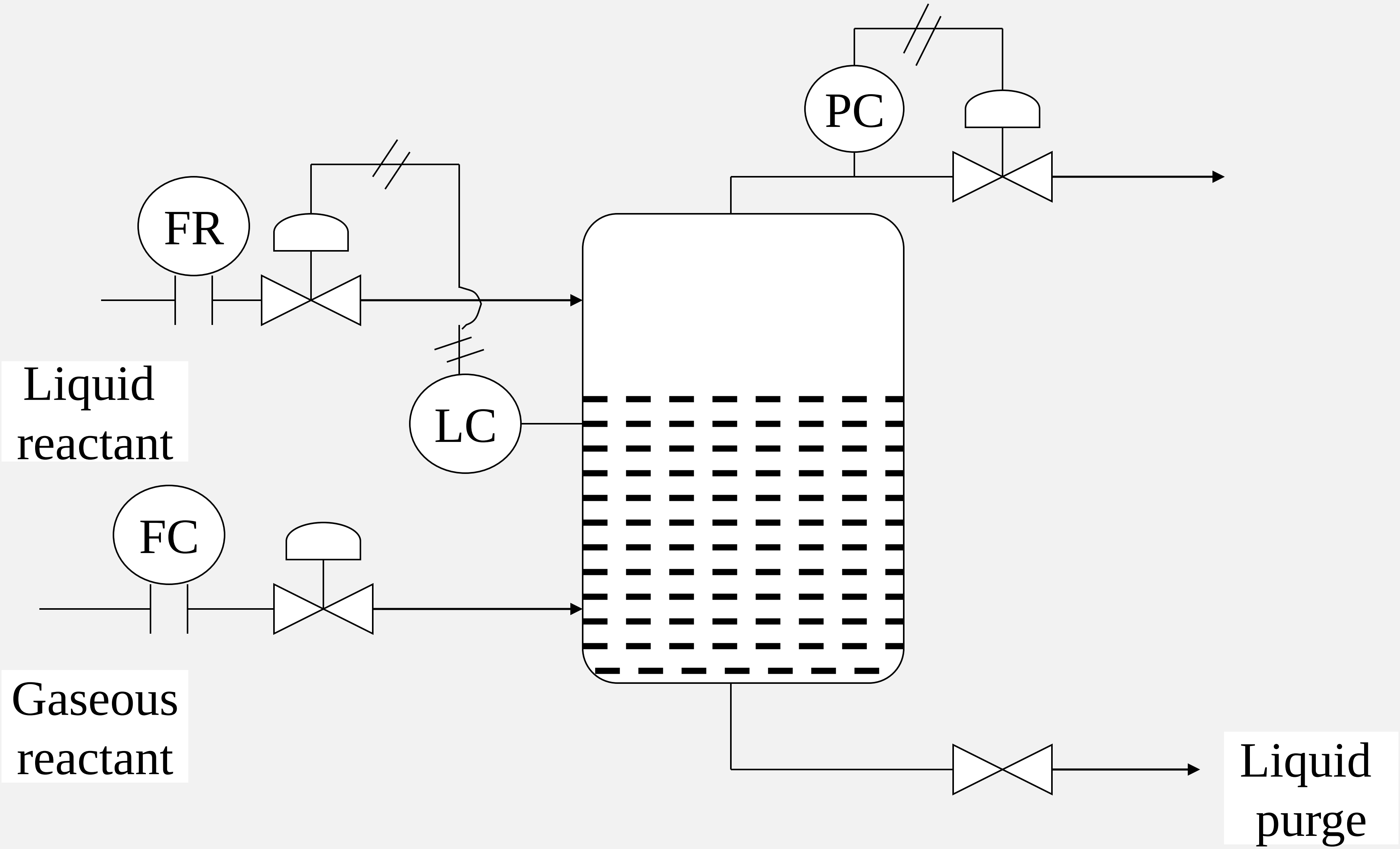
Control valve

Flow measurement

CASCADE CONTROL

-Involves use of two controller,two feedbackloops.
- Outer loop concerned with main variable (level).
- Inner loop (minor) concerned with intermediate variable (flow rate).
- Set point for inner loop is determined by the outer loop controller.
- Reduces the time lags,effect of load changes disturbances.
- Better control system.

REACTOR CONTROL

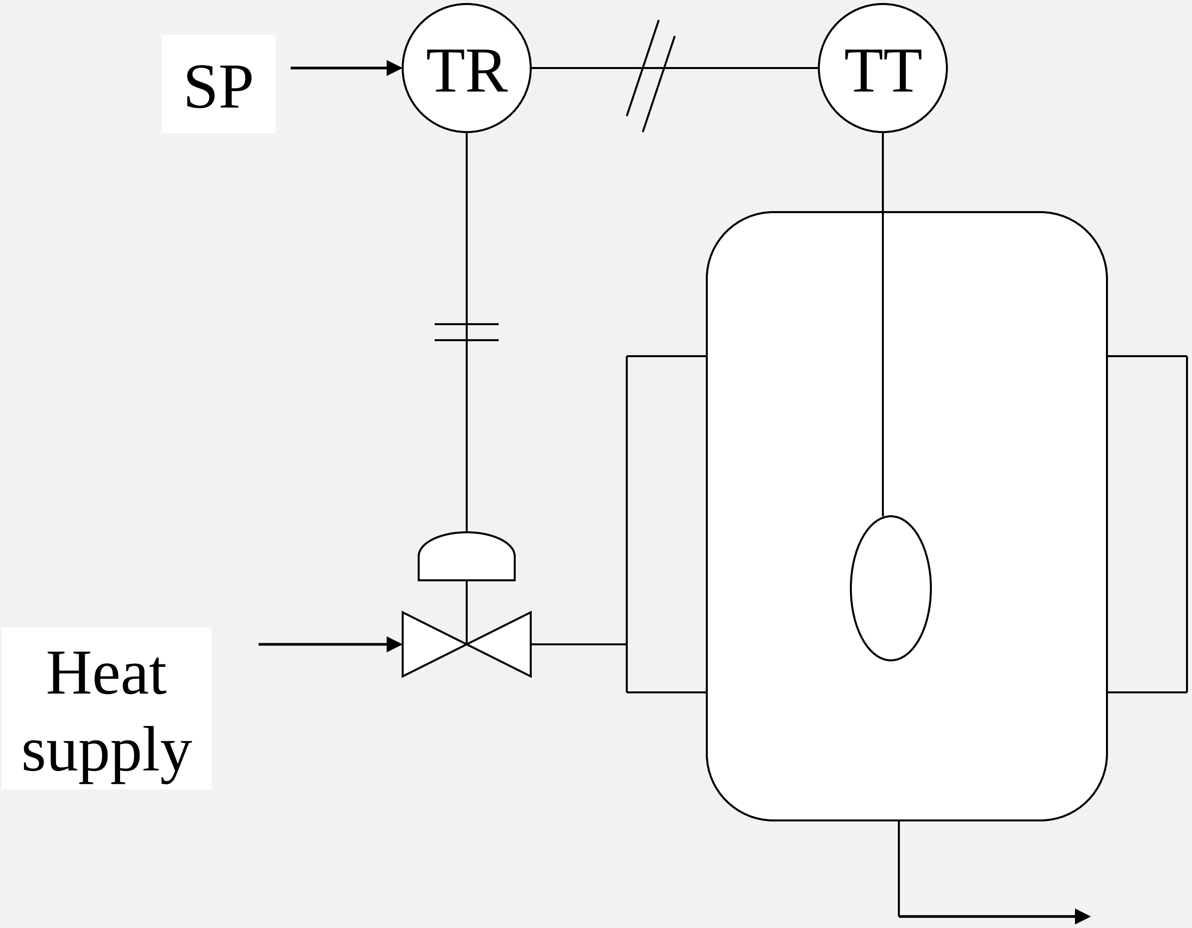


Liquid reactant

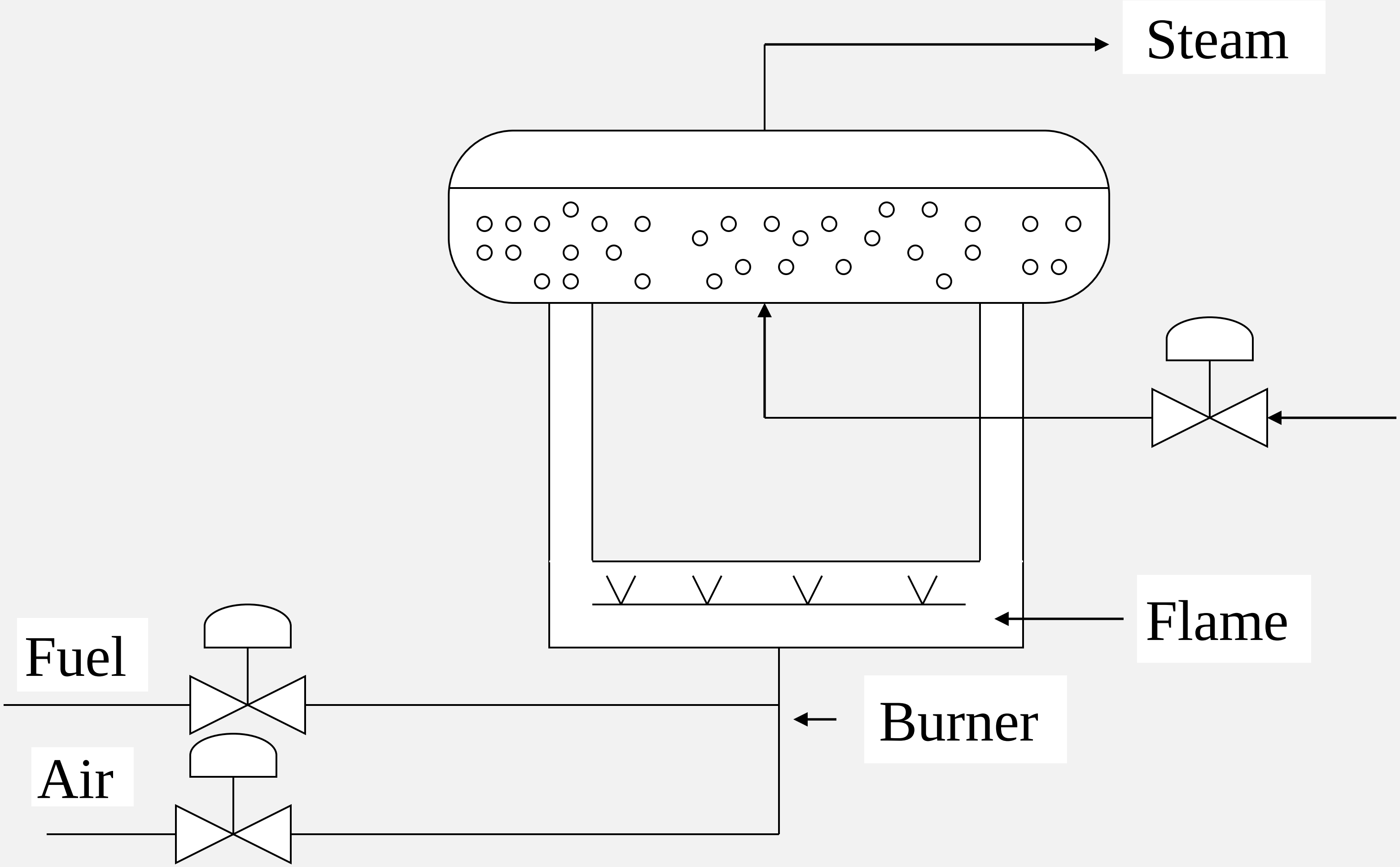
Gaseous reactant

Liquid purge

TEMPARATURE CONTROL



BOILER CONTROL



Steam

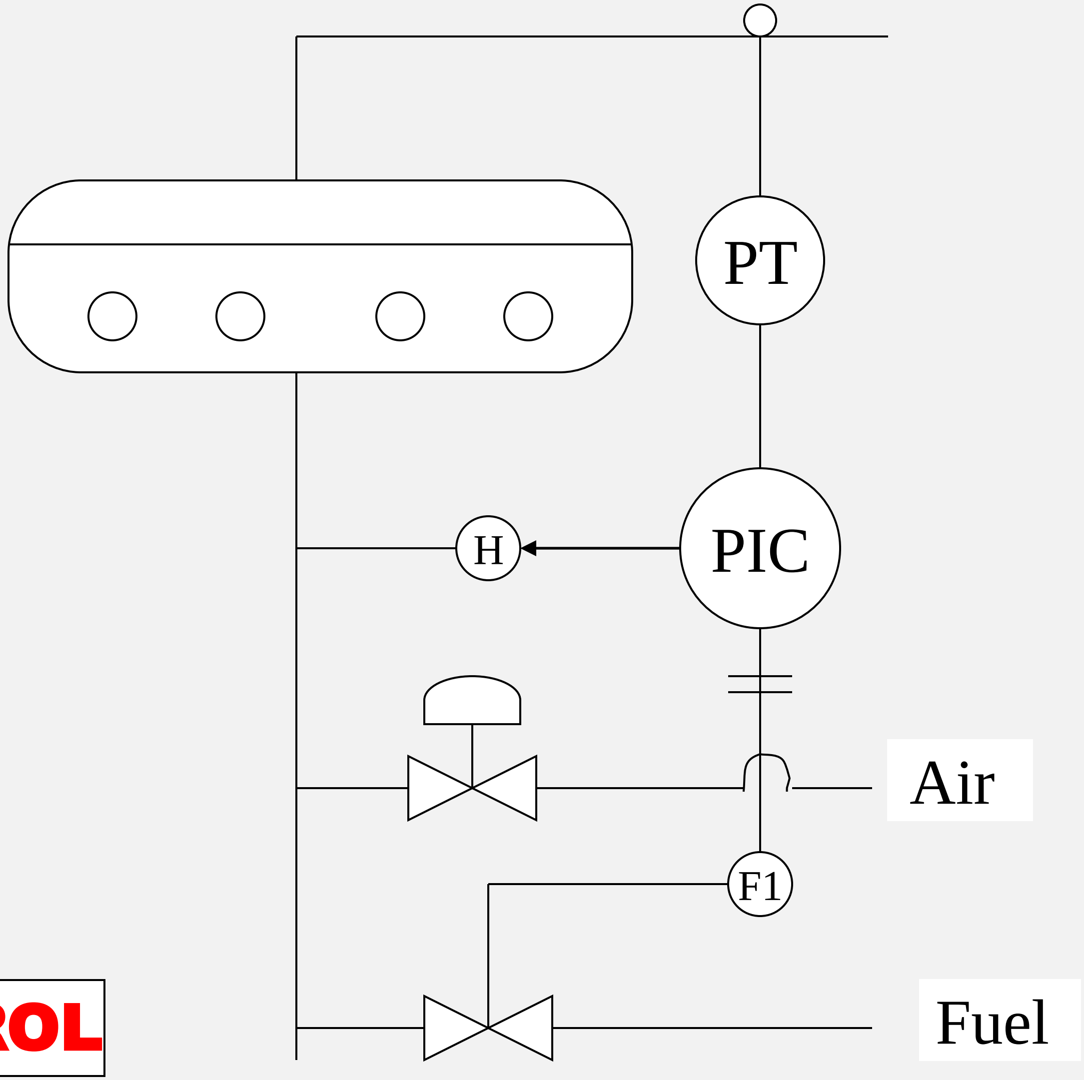
Flame

Burner

Fuel

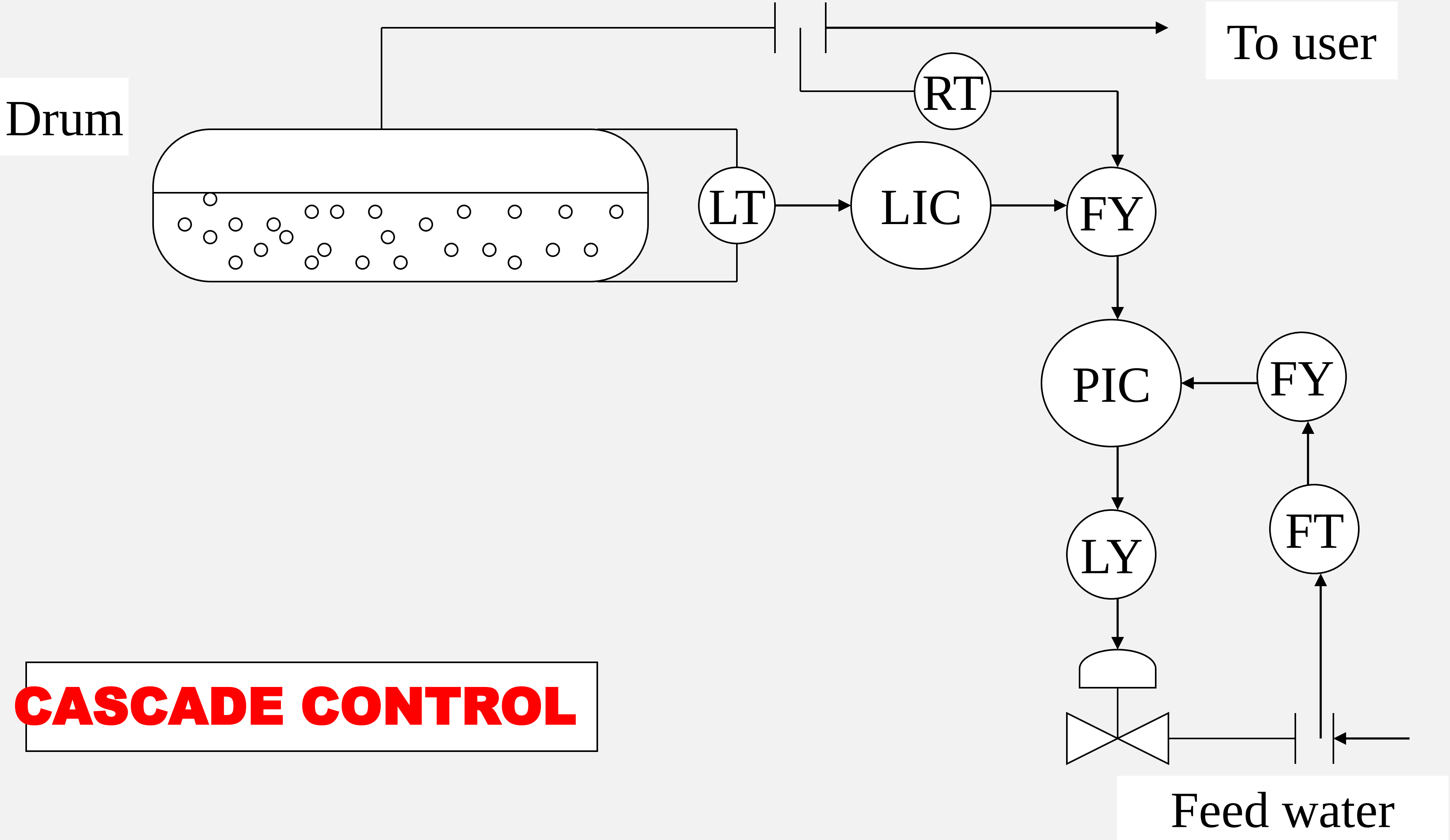
Air

BOILER CONTROL



RATIO CONTROL

BOILER CONTROL



CASCADE CONTROL

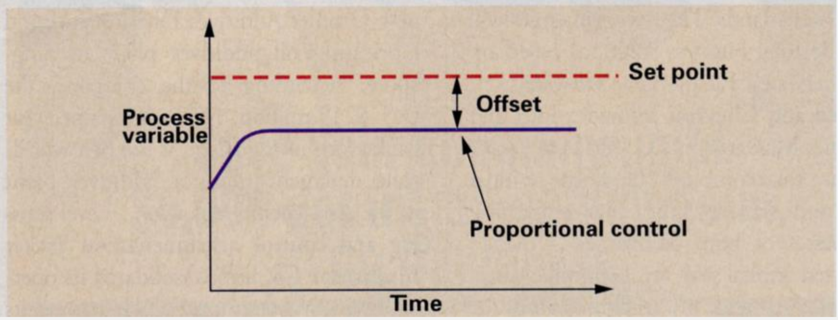
PROCESS CONTROLLERS

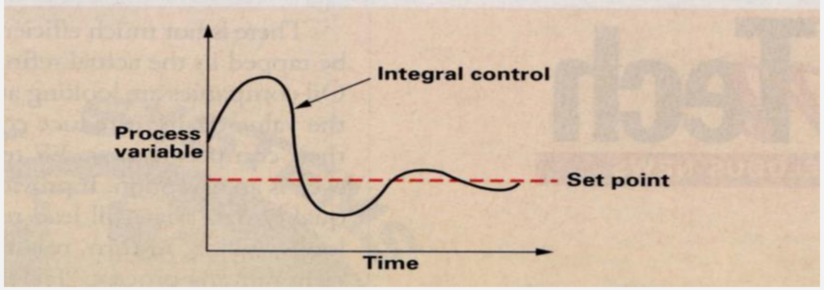
A number of controllers are available for controlling a process. These are

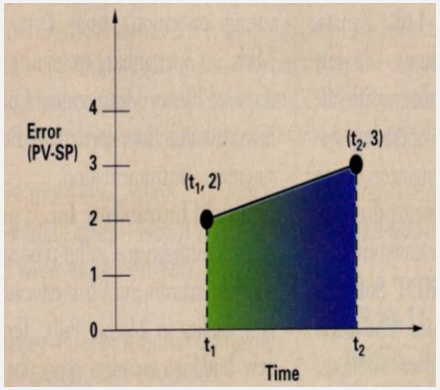
- On/Off Controllers
- Proportional Controllers
- Derivative Controllers
- Proportional-Integral Controllers
- Proportional- Integral-Derivative Controllers

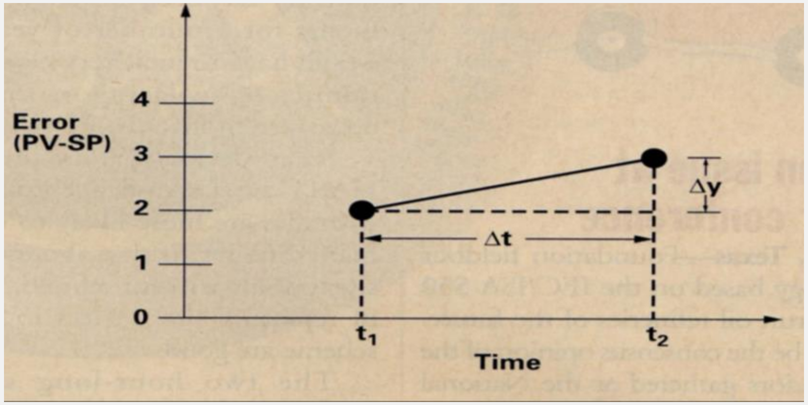
WHAT IS PID CONTROL MEANS?

- This is the three mode control-proportional plus reset plus rate.When proportional only action is used, a load change produces an offset from the set point.Rate action has the effect of reducing the overshoot that occures when reset is added to proportional action. Rate action also counteracts the log characterstics introduced by reset action.

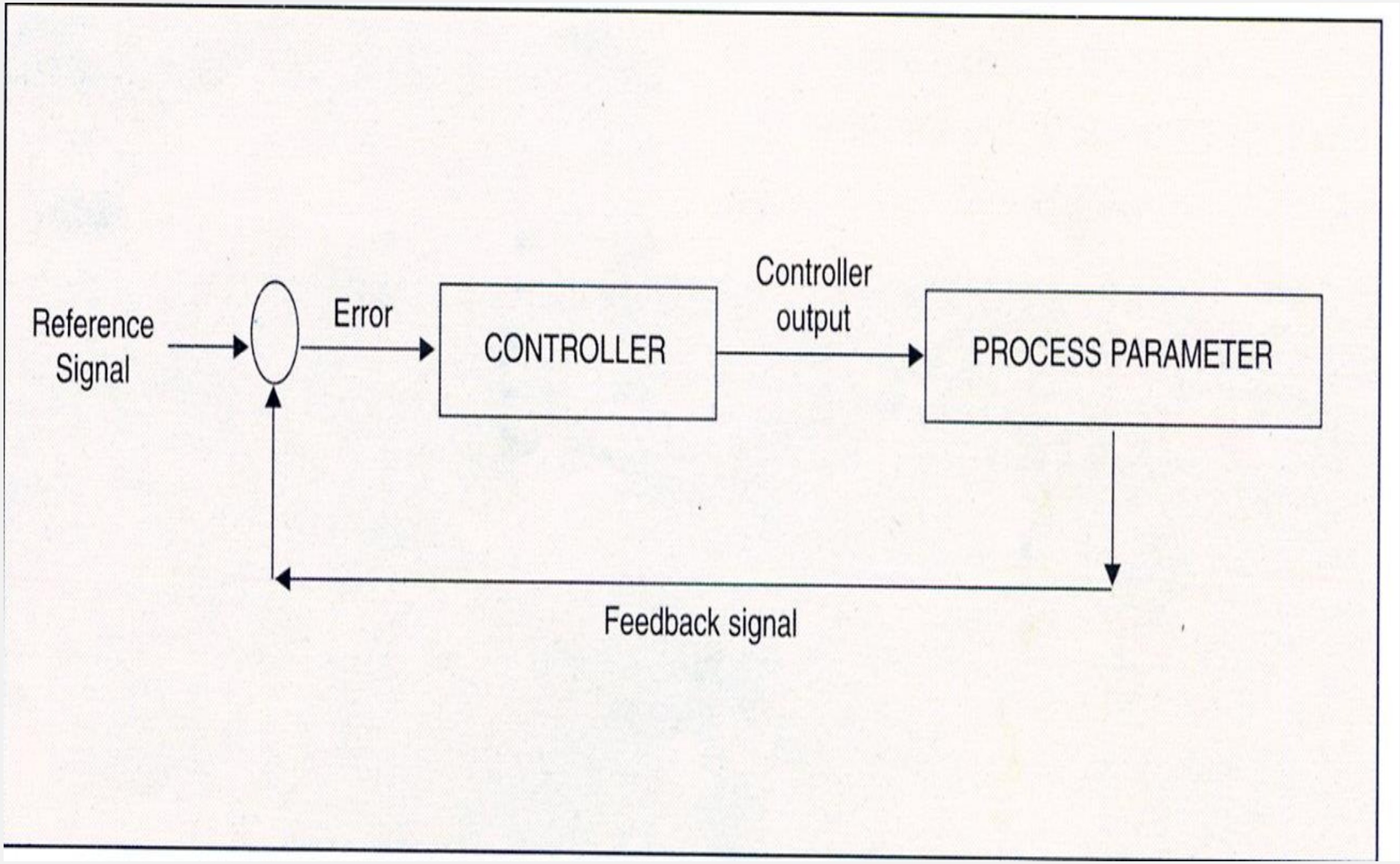




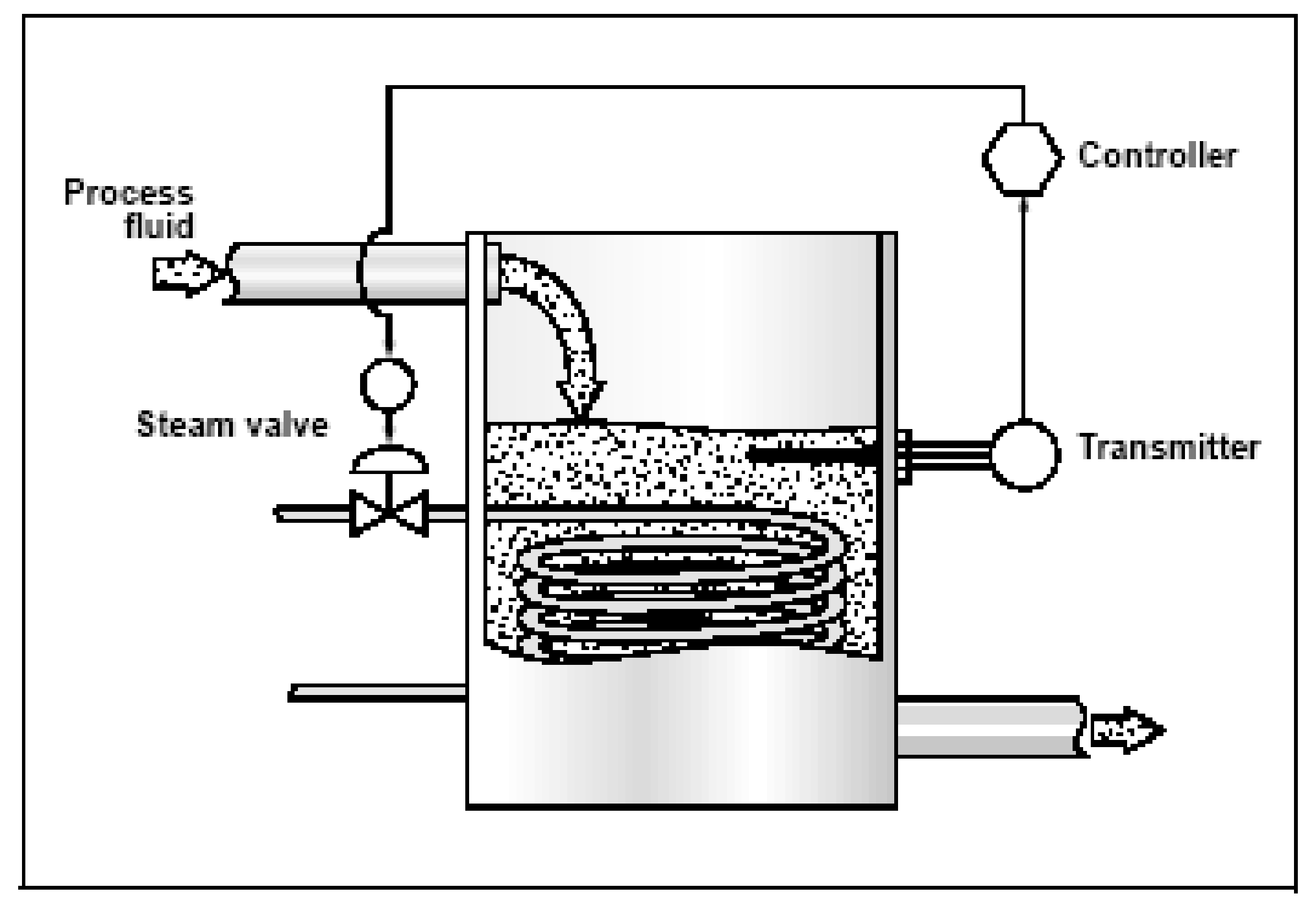




AUTOMATIC FEEDBACK CONTROL



SINGLE FEEDBACK CONTROL LOOPS



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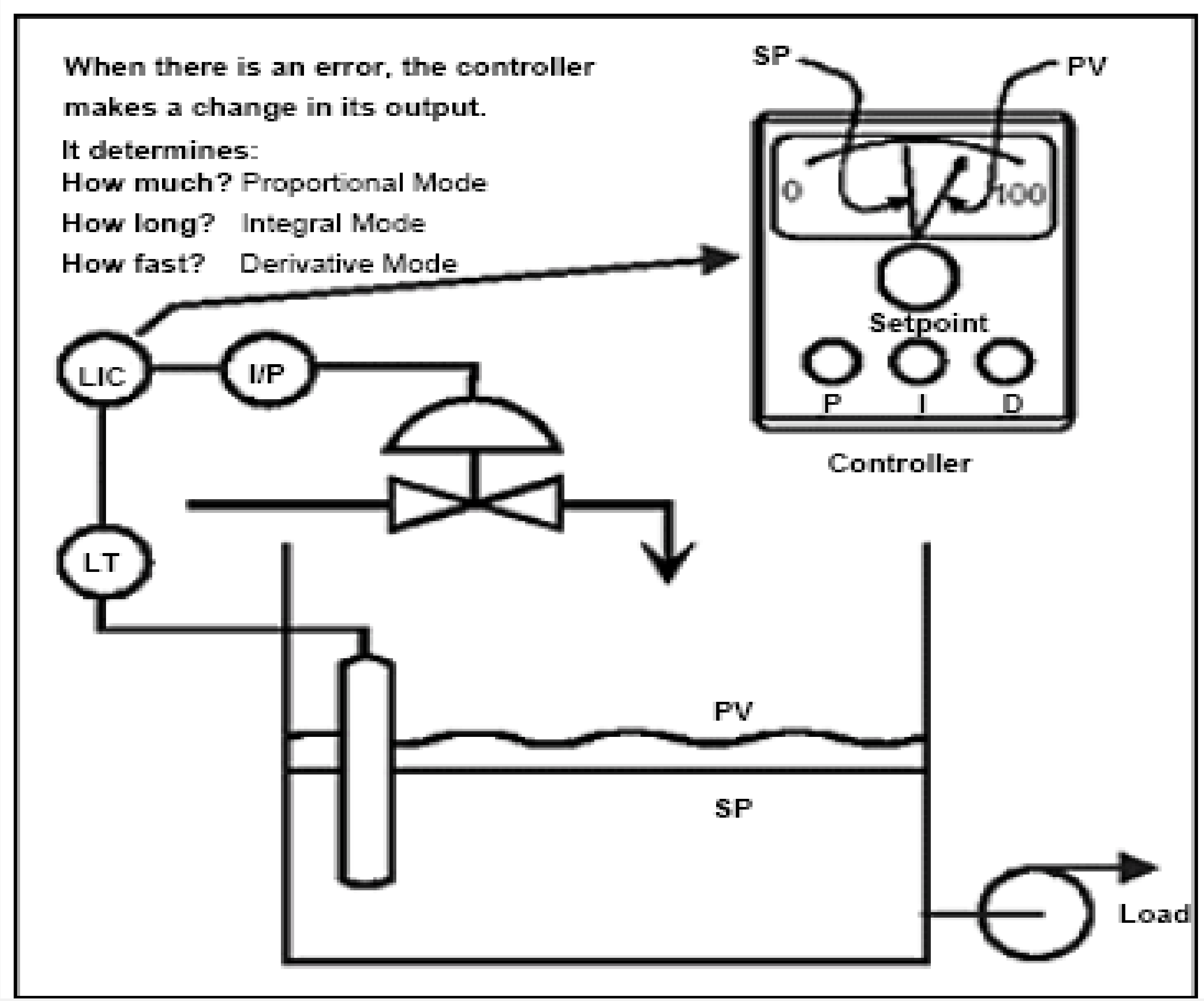
AUTOMATIC FEEDBACK CONTROL



When there is an error, the controller makes a change in its output.

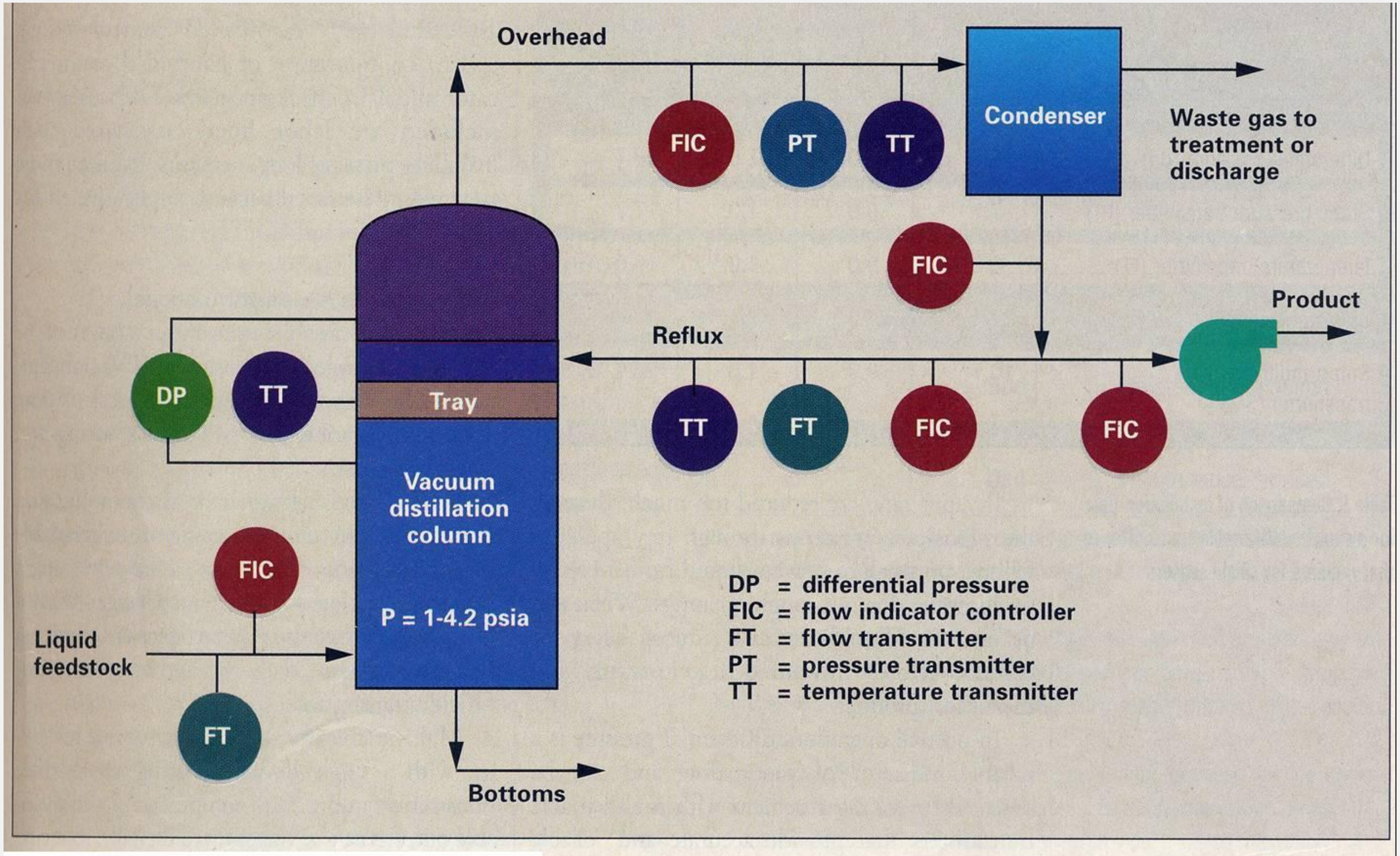
It determines:

How much? Proportional Mode

How long? Integral Mode

How fast? Derivative Mode

DISTILLATION COLUMN CONTROL



DP = differential pressure
FIC = flow indicator controller
FT = flow transmitter
PT = pressure transmitter
TT = temperature transmitter

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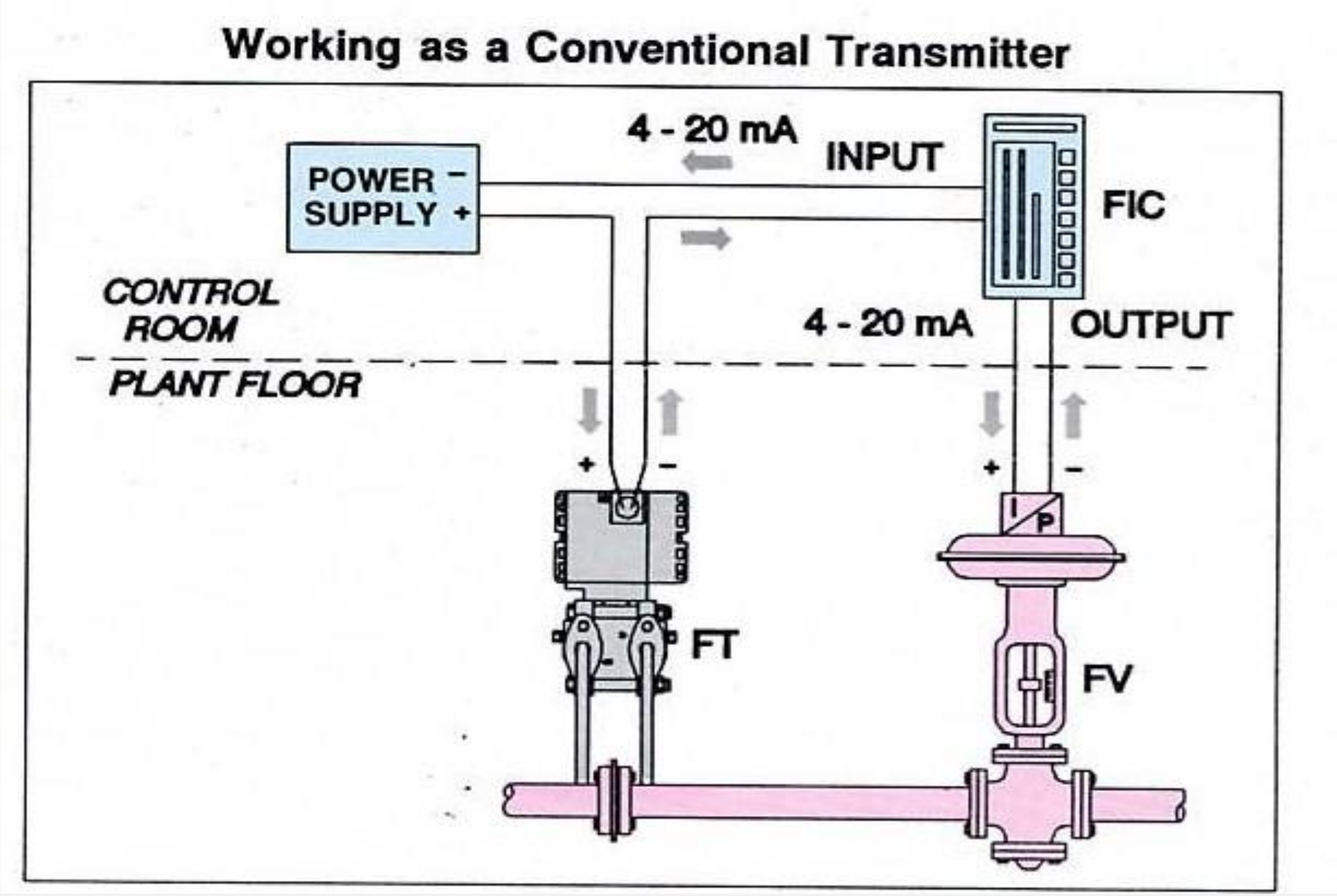
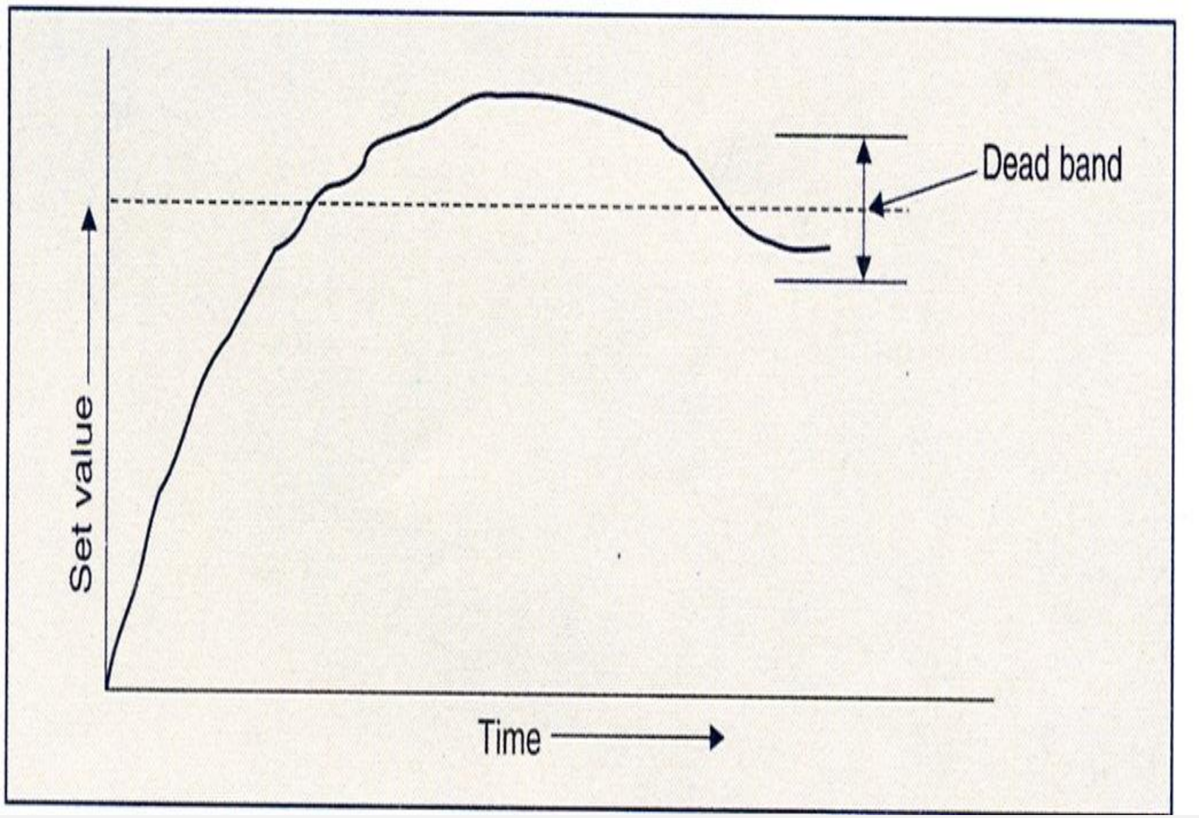
TYPICAL CONTROL LOOP



ON-OFF CONTROLLER



WHAT IS PID CONTROL?

- Modern process control is a relatively new field. Controllers are widely used in all of the process industries. Continuous feedback process controllers using the ubiquitous proportional-integral-derivative (PID) algorithm have been around only since the 1940s.

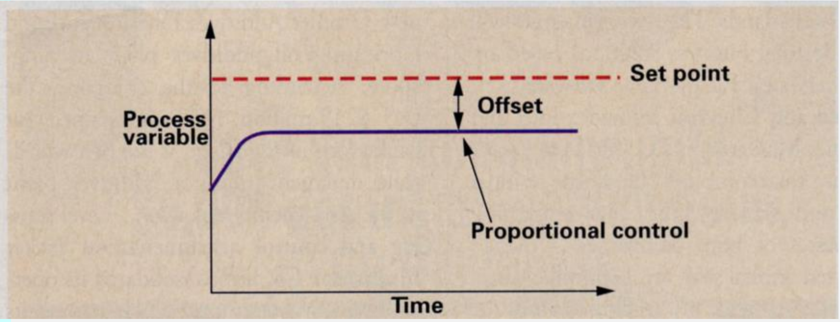
- Fourier, Laplace, Kirchoff, Kelvin, and others had laid out the mathematical basics for this control theory by the end of the 1800s. All of the terms, *proportional*, *integral*, and *derivative*, . The latter two are the heart of calculus. The mathematical complexities need not be explored to understand PID control theory. Graphical insight and lowtech interpretation is more than adequate.

TAKE ANY SYSTEM

- To begin, consider a parameter that needs to be controlled. Take the temperature of water in a tank that is continuously fed with cold water and is continuously pumping 100°C water. If the temperature of the water coming out of the tank is less than 100°C, a variable gas flame is applied until the temperature goes back up. This is the process.
- The controlled parameter in this process is temperature. The set point (SP) is 100°C. The set point minus the actual temperature (PV) of the water is the error, or offset. When there's an error, the controller sends a message (CO) to crank up the heat.

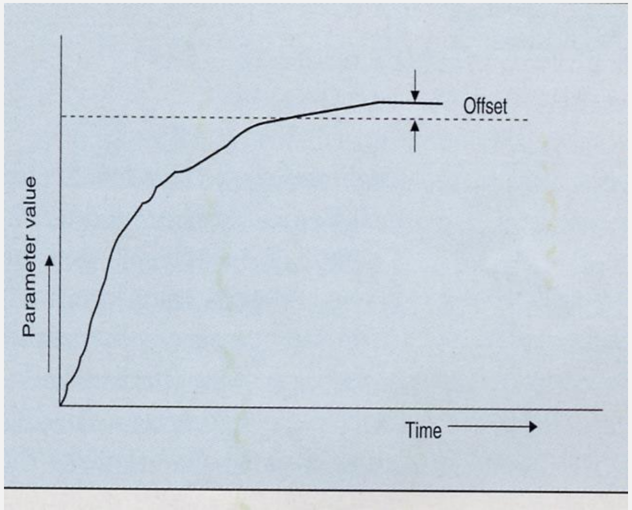
PROPORTIONAL CONTROL

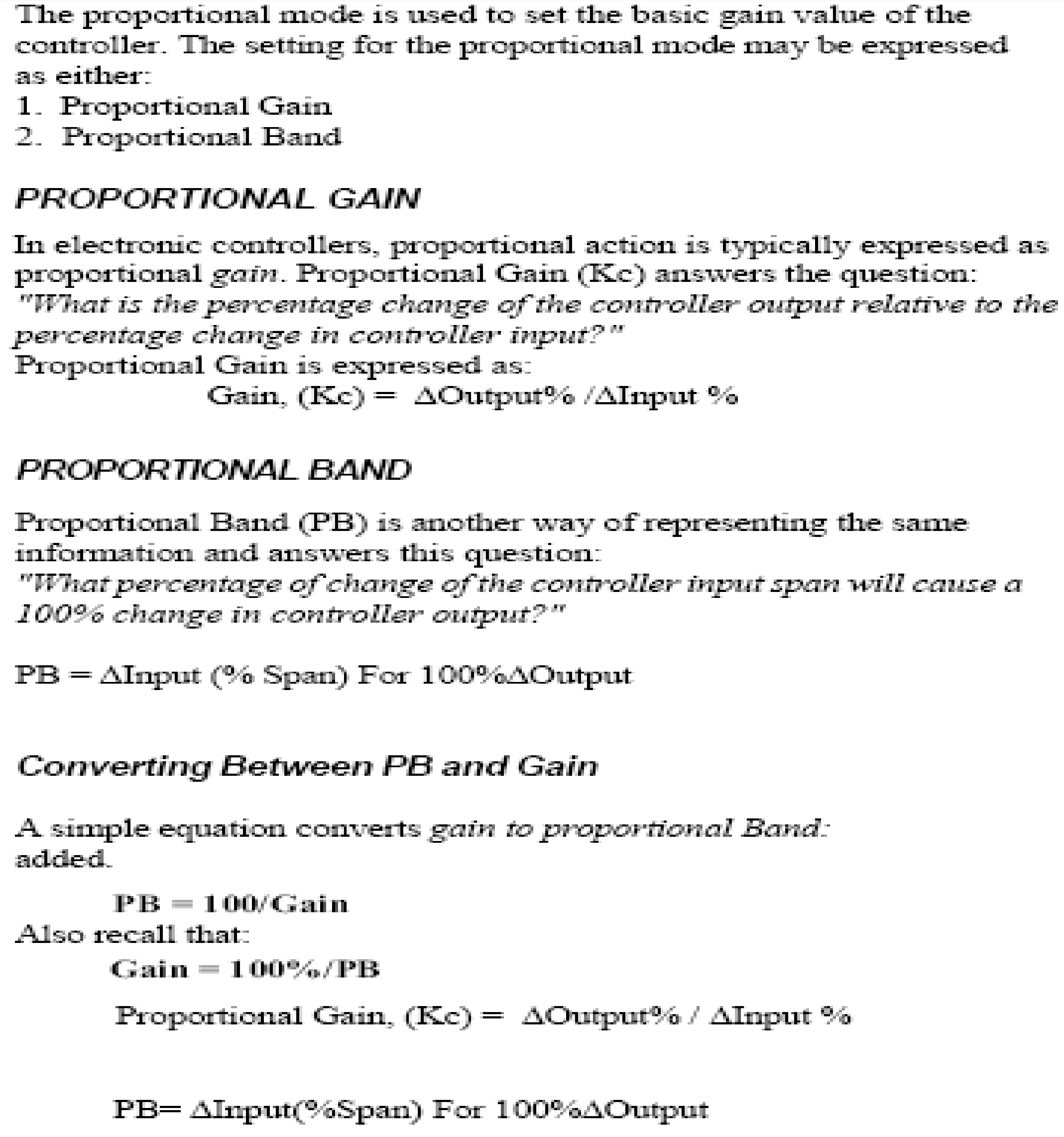
- The *proportional* mode (P) is the least complicated of the three. The mathematical expression is: **CO = Kp(PV-SP)**
- The Kp is called the constant of proportionality. That's a fancy term for the number on a dial of the controller apparatus that is adjustable and that can be used by the operator to tweak the process.
- If the Kp is negative .5 (- .5), the PV is 98°C, and the SP is 100°C, then the CO would be 1. This 1, then, has a calibrated meaning to the gas burner underneath the tank that will adjust the flame to a certain intensity.



PROPORTIONAL CONTROL….

- As well, if the water coming out of the tank is 100°C, (PV-SP) would equal zero, the CO would be zero, and this number would be associated with a setting for the flame under the tank, possibly zero or no flame.
- Because the P mode has only one adjustment, Kp, it is the easiest to operate. Used by itself (see Figure), the mode never is able to completely eliminate the difference between the set point and the actual value (PV). The P mode does, however, provide rapid response and it is stable.





The proportional mode is used to set the basic gain value of the controller. The setting for the proportional mode may be expressed as either:

1. Proportional Gain
2. Proportional Band

PROPORTIONAL GAIN

In electronic controllers, proportional action is typically expressed as proportional *gain*. Proportional Gain (Kc) answers the question:
"What is the percentage change of the controller output relative to the percentage change in controller input?"
Proportional Gain is expressed as:

$$\text{Gain, (Kc)} = \Delta\text{Output\%} / \Delta\text{Input \%}$$

PROPORTIONAL BAND

Proportional Band (PB) is another way of representing the same information and answers this question:
"What percentage of change of the controller input span will cause a 100% change in controller output?"

$$\text{PB} = \Delta\text{Input (\% Span) For } 100\%\Delta\text{Output}$$

Converting Between PB and Gain

A simple equation converts *gain to proportional Band:*
added.

$$\textbf{PB} = \textbf{100/Gain}$$

Also recall that:

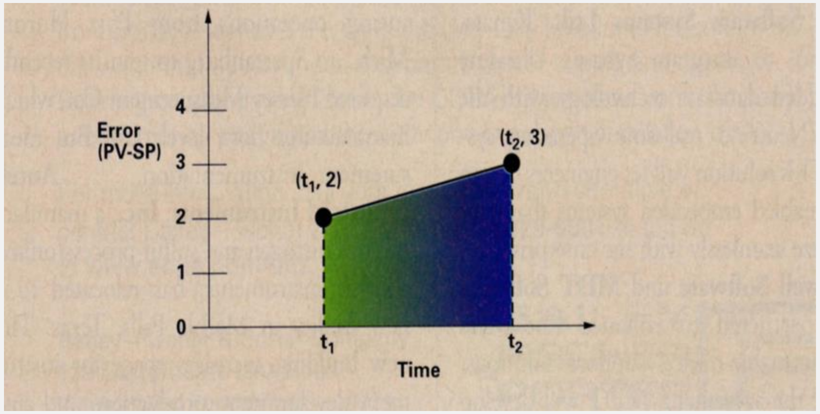
$$\textbf{Gain} = \textbf{100\%/PB}$$

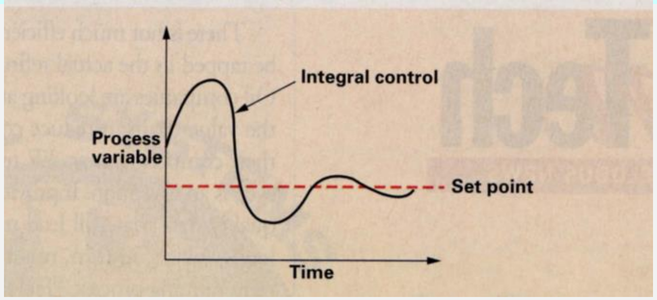
$$\text{Proportional Gain, (Kc)} = \Delta\text{Output\%} / \Delta\text{Input \%}$$

$$\text{PB} = \Delta\text{Input(\%Span) For } 100\%\Delta\text{Output}$$

INTEGRAL CONTROL

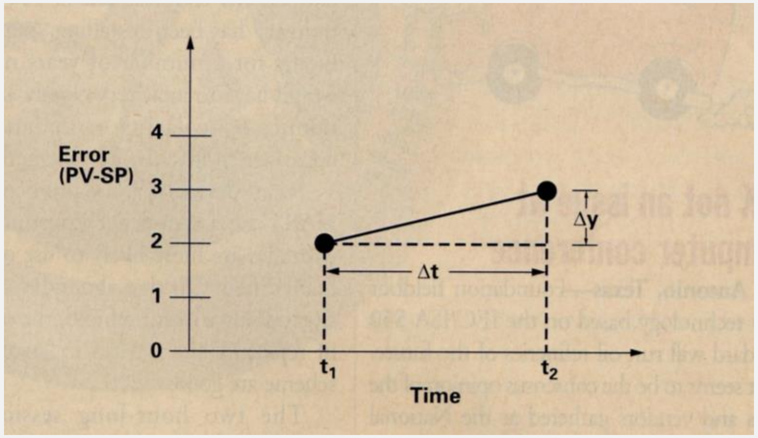
- The expression for the *integral Kim* of a PID algorithm stems from calculus, a kind of mathematics invented by Isaac Newton. $\mathbf{CO = Ki\Sigma(PV\text{-}SP)dt}$
- This expression says we're integrating (Σ) the error (PV-SP) with respect to time (dt), multiplying it by a tweaking factor (K;), and getting a number that is the controller output signal (CO). Never mind that.
- In calculus, when we integrate, we are finding the area of a space underneath a line. Plotting the error versus time, in this case, forms that line (see Figure). Thus, if at time one *(t1)* tlie error is 2 and at time two (t2j the error is 3, the number arrived at by integrating is the shaded area in Figure.
- Likewise, if the error is zero at time one and zero at time two, then there is no area under the line and the above expression for CO equals zero.
- As with die proportional mode, adjustments are made using a constant. In addition, the time period over which the line is plotted can be manipulated.
- Unlike the proportional mode, integral action can eliminate error on its own (see Figure). Because of its dependence on a long time interval to average out the error, the correction is slow and suitable only to smaller systems.
- The expressions for P mode and I mode are often added together to take advantage of both types of action. The integral component eliminates error, and the proportional component provides response speed and stability.





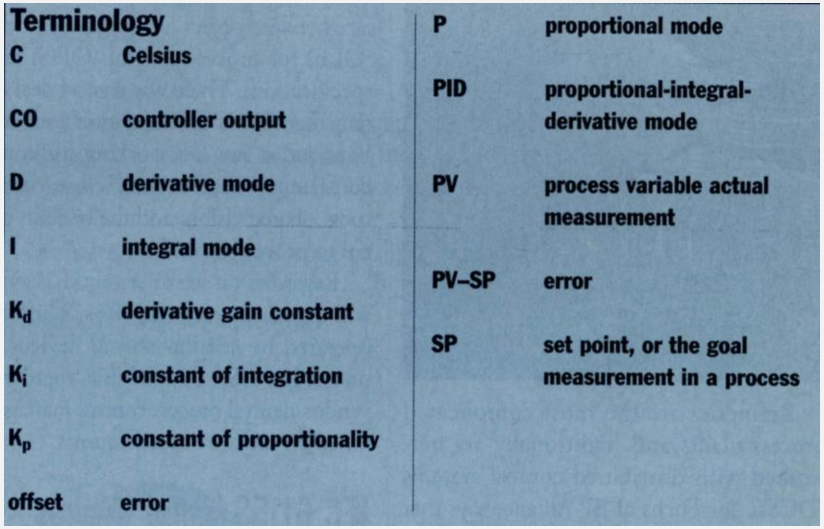
DERIVATIVE CONTROL

- The D term of the PID control expression stands for the word *derivative* and also comes from calculus.
- **CO = Kd[d(PV-SP)/dt]**
- The derivative control mode provides a controller output that is proportional to the rate of change of the difference between the actual value of the parameter (temperature) and the set point (PV-SP).
- The visual interpretation of this is clearer. Using the same data used to construct the line in Figure, an identical line is shown in Figure. The [d(PV-SP)/dt] component of the derivative expression merely says divide the change in the error by the change in time. In this example, that means divide one (Ay) by the elapsed time (At). If the elapsed time is 10 seconds, our result would be VIO. This number is then multiplied by a tweaking factor (Kj), resulting in a CO.
- The derivative mode cannot, by itself, control a process. One reason for this is that a constant deviation from the set point makes the above expression equal to zero. As well, if a sudden change in the process variable occurs, an infinite signal is sent to the controller, which causes the relevant mechanical apparatus to fully open or close. This leads to an unending instability.
- Derivative action adds lead time in the controller, compensating for the time delays present in nearly all process control loops. When correctly applied, it stabilizes the process.



PID CONTROL

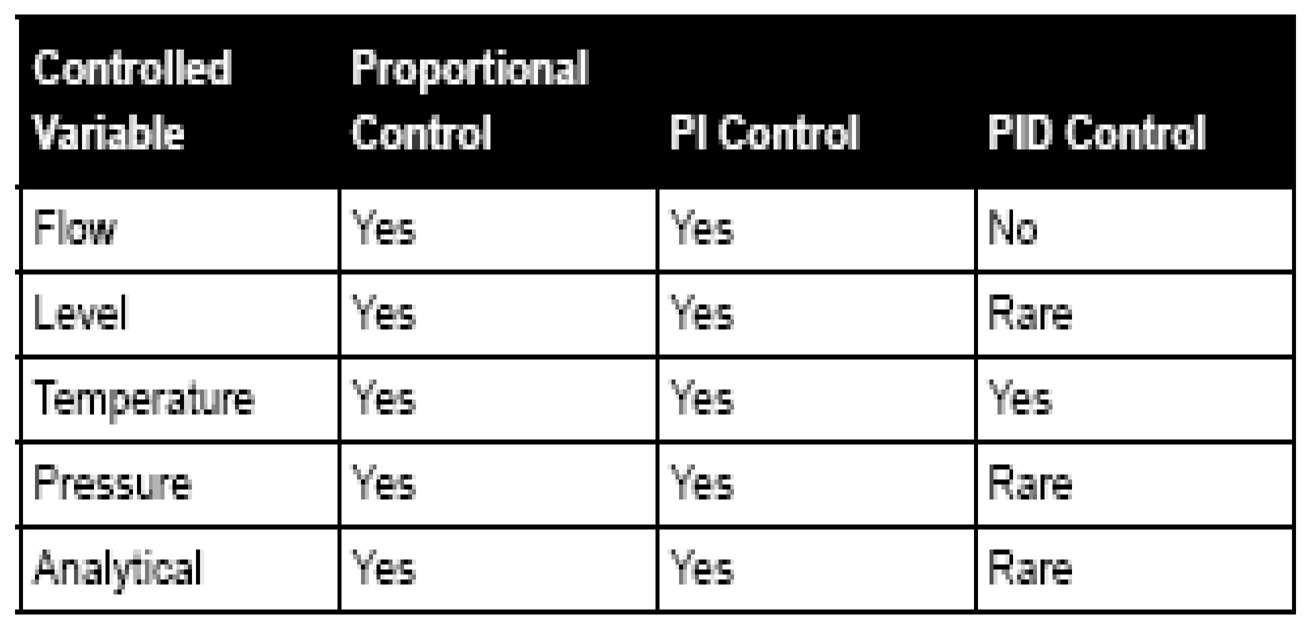
- The crux of each of these three modes is they each produce a number (CO) from the same input data (Kx, SP, and PV). That number is different for each mode. The interplay of these numbers as data is input is the magic of the PID relationship.
- When the three modes' individual numbers are combined, a PID controller controls the system. The proportional mode is the basic control. The integral mode deals with the long-term errors that the proportional is unsuited to handle. The derivative mode takes care of the more pronounced disturbances occurring in the ongoing process.
- The PID algorithm is used when the system is large, when there are rapid changes in some process variables, and when these changes are big. It's a complex system and necessitates tinkering at start-up to justify the various proportionality constants (K.,, Kj, Kj) of each individual mode to efficiently reach and maintain the set point.



Terminology

C	**Celsius**
CO	**controller output**
D	**derivative mode**
I	**integral mode**
K_d	**derivative gain constant**
K_i	**constant of integration**
K_p	**constant of proportionality**
offset	**error**
P	**proportional mode**
PID	**proportional-integral-derivative mode**
PV	**process variable actual measurement**
PV–SP	**error**
SP	**set point, or the goal measurement in a process**

CONTROL LOOPS AND CONTROL ALGORITHMS



Controlled Variable	Proportional Control	PI Control	PID Control
Flow	Yes	Yes	No
Level	Yes	Yes	Rare
Temperature	Yes	Yes	Yes
Pressure	Yes	Yes	Rare
Analytical	Yes	Yes	Rare

By using all three control algorithms together, process operators can:

- Achieve rapid response to major disturbances with derivative Control.
- Hold the process near setpoint without major fluctuations with proportional control.
- Eliminate offset with integral control.

CONTROL LOOPS AND CONTROL ALGORITHMS

Not every process requires a full PID control strategy. If a small offset has no impact on the process, then proportional control alone may be sufficient.

PI control is used where no offset can be tolerated, where *noise* (temporary error readings that do not reflect the true process variable condition) may be present, and where excessive *dead time* (time after a disturbance before control action takes place) is not a problem.

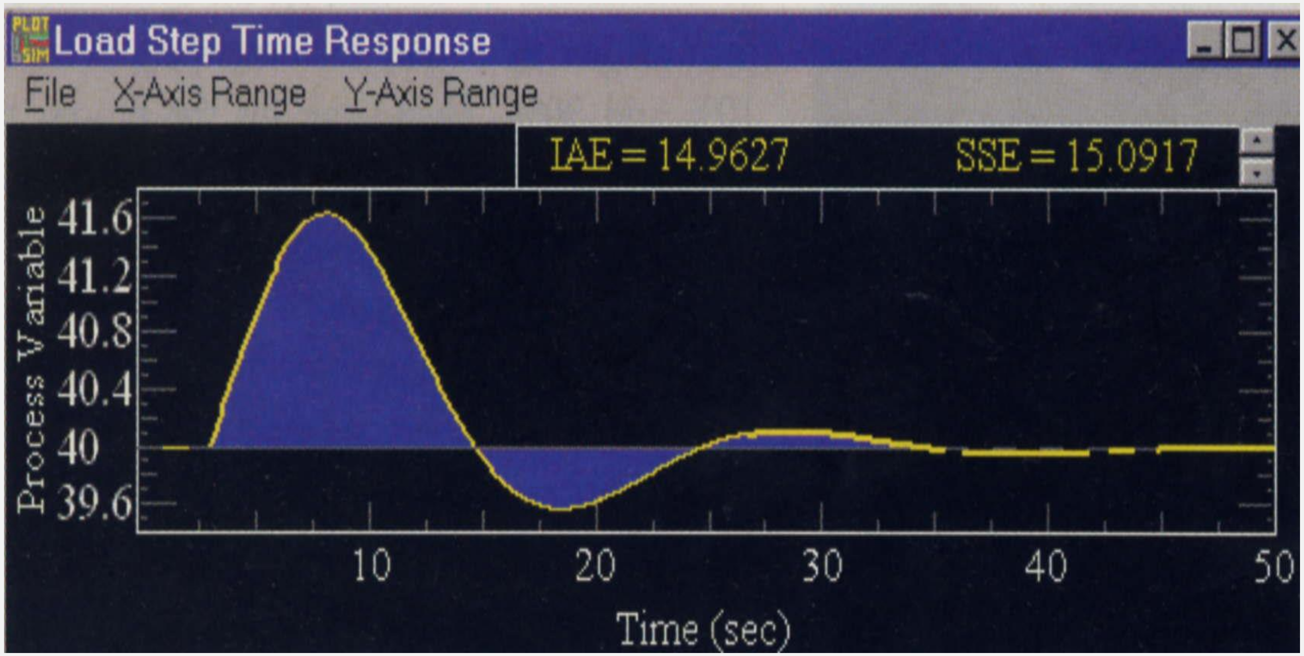
In processes where no offset can be tolerated, no noise is present, and where dead time is an issue, customers can use full PID control.

TUNING PROCESS CONTROLLERS STARTS IN MANUAL

- PID controllers are designed to automatically control a process variable like flow, temperature, or pressure. A controller does this by changing process input so that a process output agrees with a desired result: the set point.
- An example would be changing the heat around a tank so that water coming out of that tank always measures 1OO Degree C.
- Usually adjusting a valve controls the process variable. How the controller adjusts the valve to keep the process variable at the set point depends on process parameters entered into three mathematical functions: proportional (P), integral (I), and derivative (D).

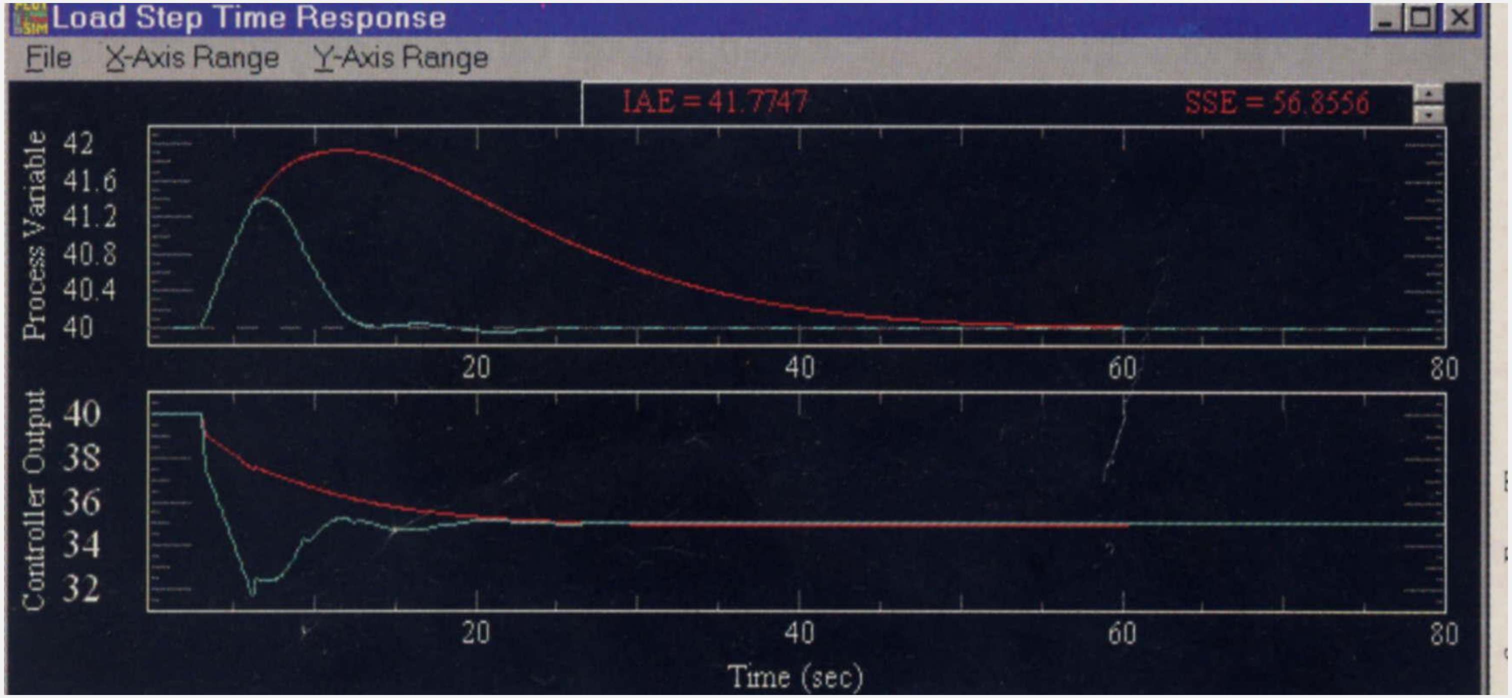
HOW DOES ONE SET THE PARAMETERS SO THAT THE CONTROLLER DOES ITS JOB?

- First, know that there is more to tuning a PID loop than just setting the tuning parameters. The process has to be controllable. You won't be able to get good temperature in a hot shower if there is no hot water or if the adjusting valve is too small or too large.
- Assuming the process can be conquered, then you can begin tuning it. The goal for good tuning is to have the fastest response possible without causing instability. One of the best tools for measuring response is integrated absolute error (IAE).



ADVANCED TUNNING METHOD

- A poorly tuned process results in sending a richer product than necessary out the door and with it, profits. Or, it causes oft-specification product, which requires rework and increased cost. With better tuning one can give away less while staying on spec.



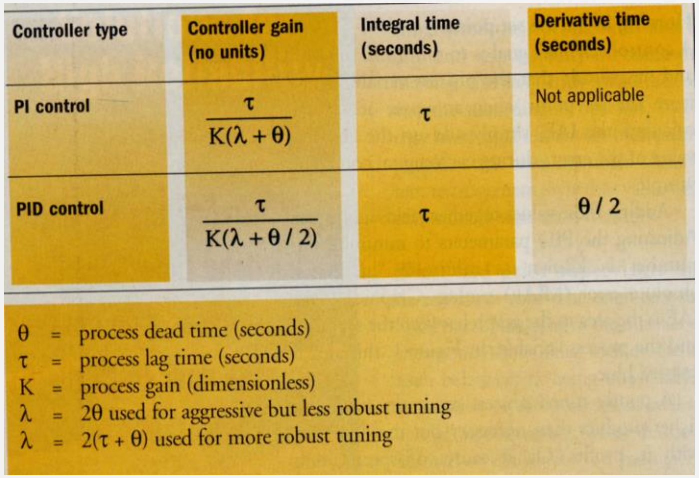
PID-BASE LINE PARAMETERS

- To perform the tuning chore, certain fundamental measurements must be taken. Specifically, the processes lag time, dead time, and gain must the determined. To do this, set the controller on manual. Set it's output to somewhere between 10% and 90%. Then, wait for the process to reach steady state.
- Next, change the controller output quickly in a stepwise fashion. The process variable will begin to change, too, after a period of time. This period of time is called the process dead time.
- The process lag time is how, long it takes for the process variable (PV) to go 63% of the way to where it eventually ends up. This would mean that if the temperature increased from 100° to 200°, the lag time would be the time it took to go from 100° to 163°.
- The process gain, or merely the gain, is found by dividing the total change in the PV divided by the change in the controller output.

DEAD TIME

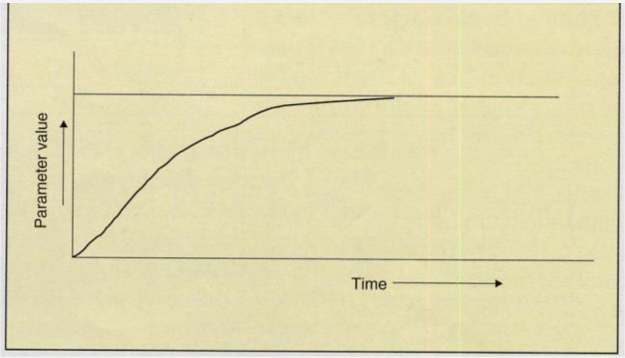
- A process that consists only of lag is easy to control. Simply use a P-only controller with lots of gain. It will be stable and fast. Unfortunately these processes are rare because of another dynamic element of most real processes: dead j time.
- Sometimes overlooked, dead time is the real limiting factor in process control. Dead time is j the time it takes for the PV to just start to move after a change in the controller's output. During dead time, nothing happens to the P .
- So, you wait. A control loop simply cannot respond raster than the dead time. Hopefully, the process is designed to make dead time as small as possible.
- With dead time in the process, gain can be increased to get a faster response, but this will cause loop oscillation. If gain is increased even more, the process will become unstable.

INTERNAL MODEL CONTROL METHOD FOR PID TUNNING



Controller type	Controller gain (no units)	Integral time (seconds)	Derivative time (seconds)
PI control	$\frac{\tau}{K(\lambda + \theta)}$	τ	Not applicable
PID control	$\frac{\tau}{K(\lambda + \theta / 2)}$	τ	$\theta / 2$

θ = process dead time (seconds)
τ = process lag time (seconds)
K = process gain (dimensionless)
λ = 2θ used for aggressive but less robust tuning
λ = $2(\tau + \theta)$ used for more robust tuning



CONTROLLER TUNING

TUNING :

The correct determination of gain, integral & derivative time to give optmimal control

$m = K_c * e$, where K_c = gain

$m = 1 / T_i \int e \, dt$ T_i = integral time

$m = T_d * de / dt$ T_d = derivative time