

VARIOUS TYPES OF CONTROLLERS



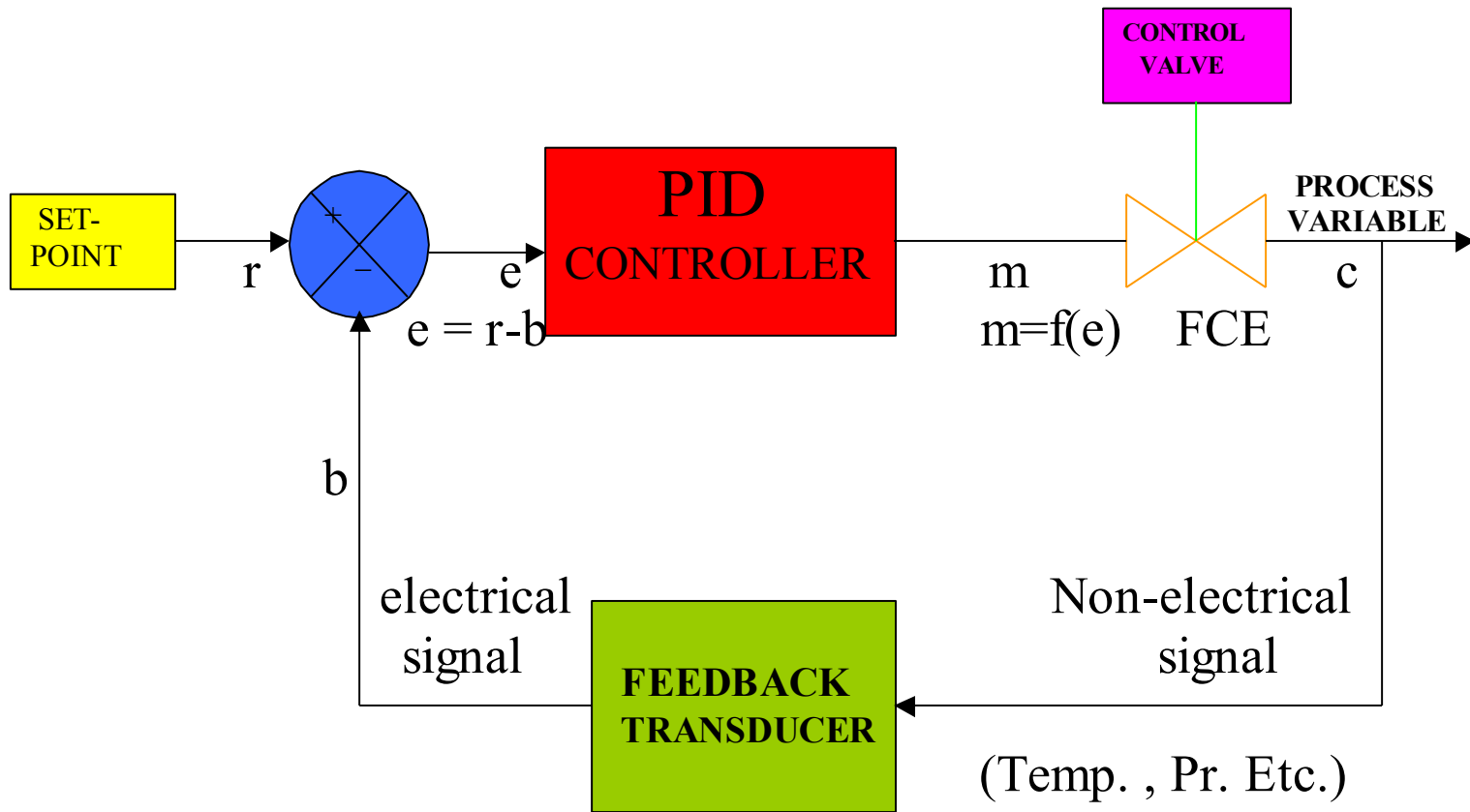
Presented by:
Deepesh gupta

INTRODUCTION

Most industrial processes require that certain variables such as flow, temperature, level or pressure should remain at or near some reference value, called **SET POINT**. The device that serves to maintain a process variable value at the set point is called a **CONTROLLER**.

A Controller is a device that receives data from a measurement instrument, compares that data to a programmed set point, and, if necessary, signals a control element to take corrective action.

Controllers may perform complex mathematical functions to compare Activities a set of data to setpoint or they may perform simple addition or subtraction functions to make comparisons. Controllers always have an ability to receive input, to perform a mathematical function with the input, and to produce an output signal.



r = ref. Point / Set-point
 b = feedback variable
 e = error(actuating) signal
 m = manipulated variable
 c = controlled variable / Process variable
 FCE= Final Control Element

CONTROLLER ALGORITHM

The Actions of Controllers can be divided into groups based upon the functions of their control mechanism.

Grouped by control mechanism function, the three types of controllers are:

- Discrete controllers

- Multistep controllers

- Continuous controllers

DISCRETE CONTROLLERS

Discrete controllers are controllers that have only two modes or positions: on and off. A common example of a discrete controller is a home hot water heater. When the temperature of the water in the tank falls below setpoint, the burner turns on. When the water in the tank reaches setpoint, the burner turns off.

MULTISTEP CONTROLLERS

Multistep controllers are controllers that have at least one other possible position in addition to on and off.

CONTINUOUS CONTROLLERS

Controllers automatically compare the value of the PV to the SP to determine if an error exists. If there is an error, the controller adjusts its output according to the parameters that have been set in the controller.

But this needs a tuning and tuning parameters essentially determine:

How much correction should be made? The magnitude of the correction(change in controller output) is determined by the proportional mode of the controller.

How long should the correction be applied? The duration of the adjustment to the controller output is determined by the integral mode of the controller

How fast should the correction be applied? The speed at which a correction is made is determined by the derivative mode of the controller.

SINGLE-LOOP CONTROL

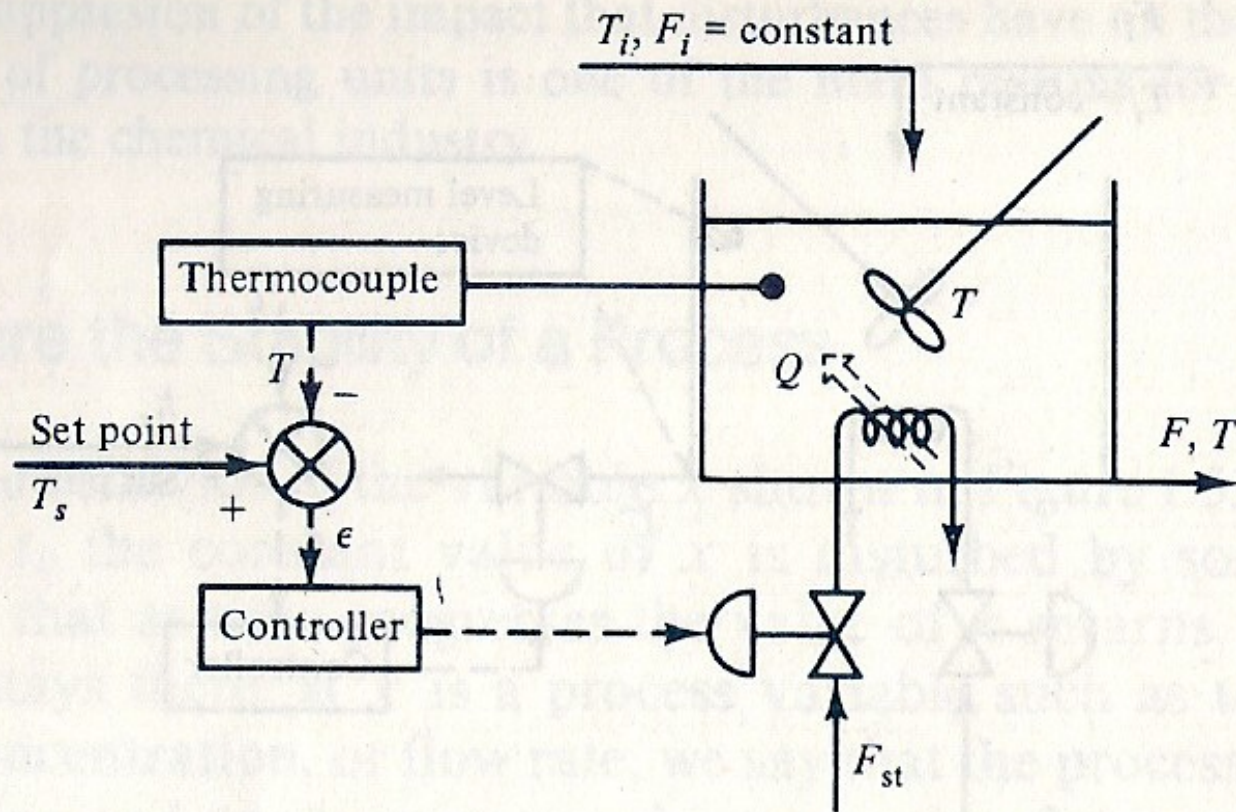


Figure 1.2 Feedback temperature control for a tank heater.

Why Controller need tuning

Controllers are tuned in an effort to match the characteristics of the control equipment to the process so that two goals are achieved:

- The system responds quickly to errors.
- The system remains stable (PV does not oscillate around the SP).

CLASSIFICATION OF INDUSTRIAL CONTROLLERS

- Two position or ON-OFF controllers
- Proportional (P) controllers
- Proportional (P) + Integral (I) i.e. PI controllers
- Proportional (P) + Derivative(D) i.e. PD controllers
- Proportional (P) + Integral (I) + Derivative (D) i.e. PID controllers

PROPORTIONAL CONTROLLER



m is proportional to e

$$m = K_c * e + M$$

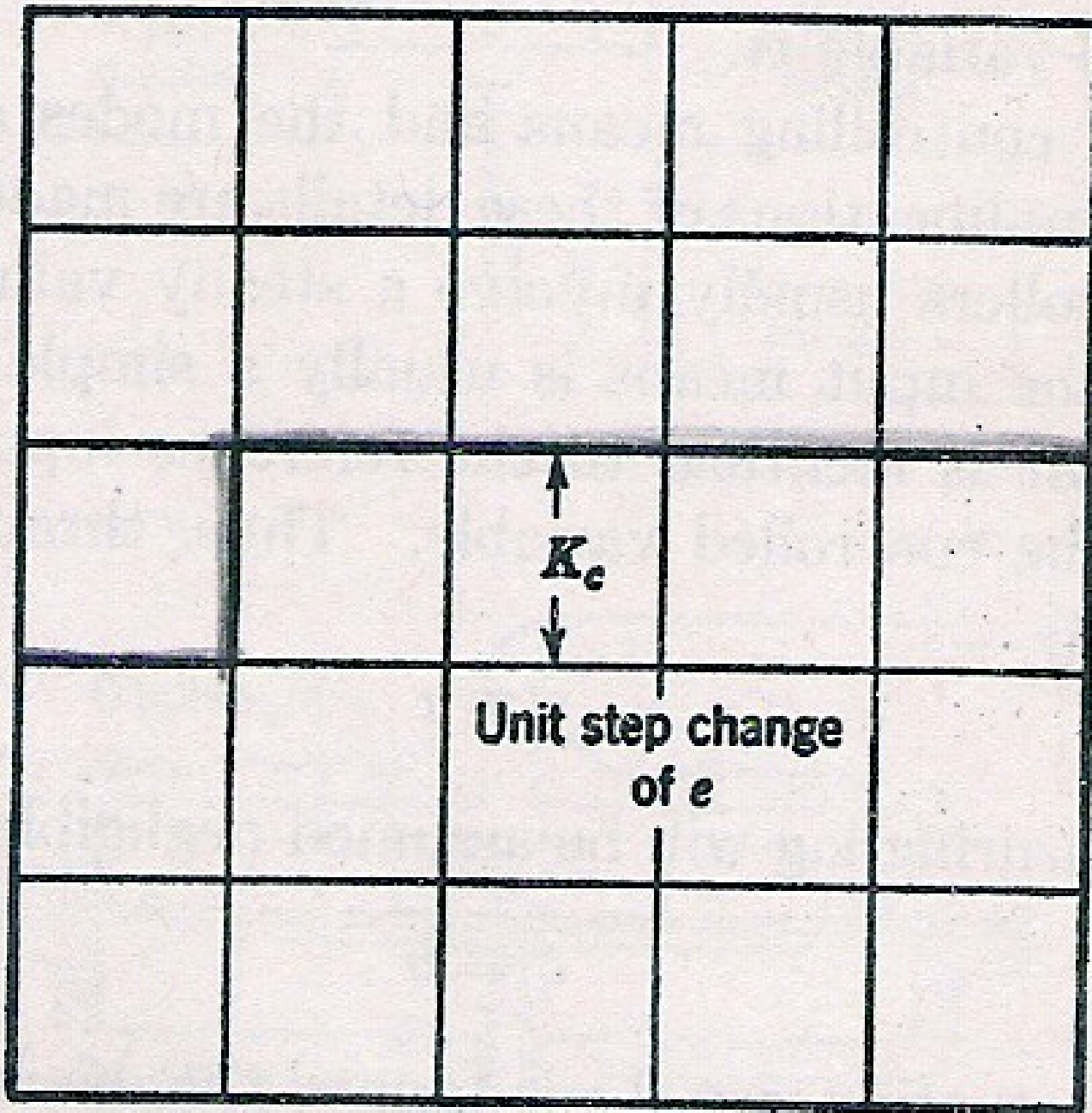
Where **K_c** = Proportional Sensitivity or **Prop. Gain**

And is defined as the unit change in manipulated variable (m) caused by unit change in deviation (e)

$$\text{P.B.} = (1/K_c) * 100 \%$$

Prop. Band (P.B.) is the %age change in error that causes 100 % age change in manipulated variable

Manipulated variable, m \uparrow



Time, t \rightarrow

INTEGRAL-CONTROL



Rate of change of manipulated variable(m)
is proportional to error.

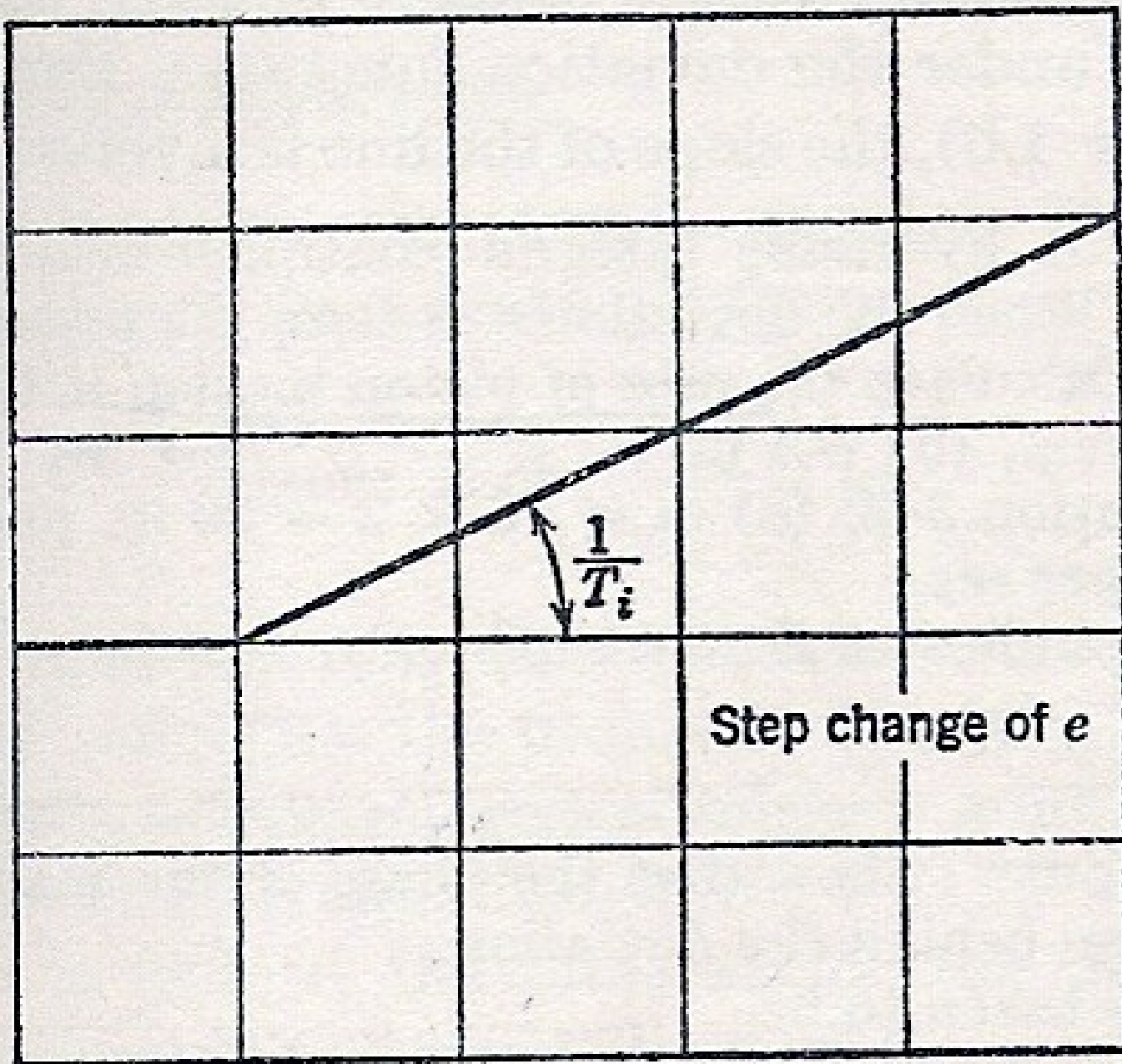
(dm/dt) prop. To e

or m is proportional to Integral of $e dt$

$$m = (K_c/T_i) \int e dt + M$$

where T_i = integral time

Manipulated variable, m \longrightarrow



Time, t \longrightarrow

Step change of e

PI-CONTROLLER



The additive combination of Prop. & Integral control actions is known as PI-control

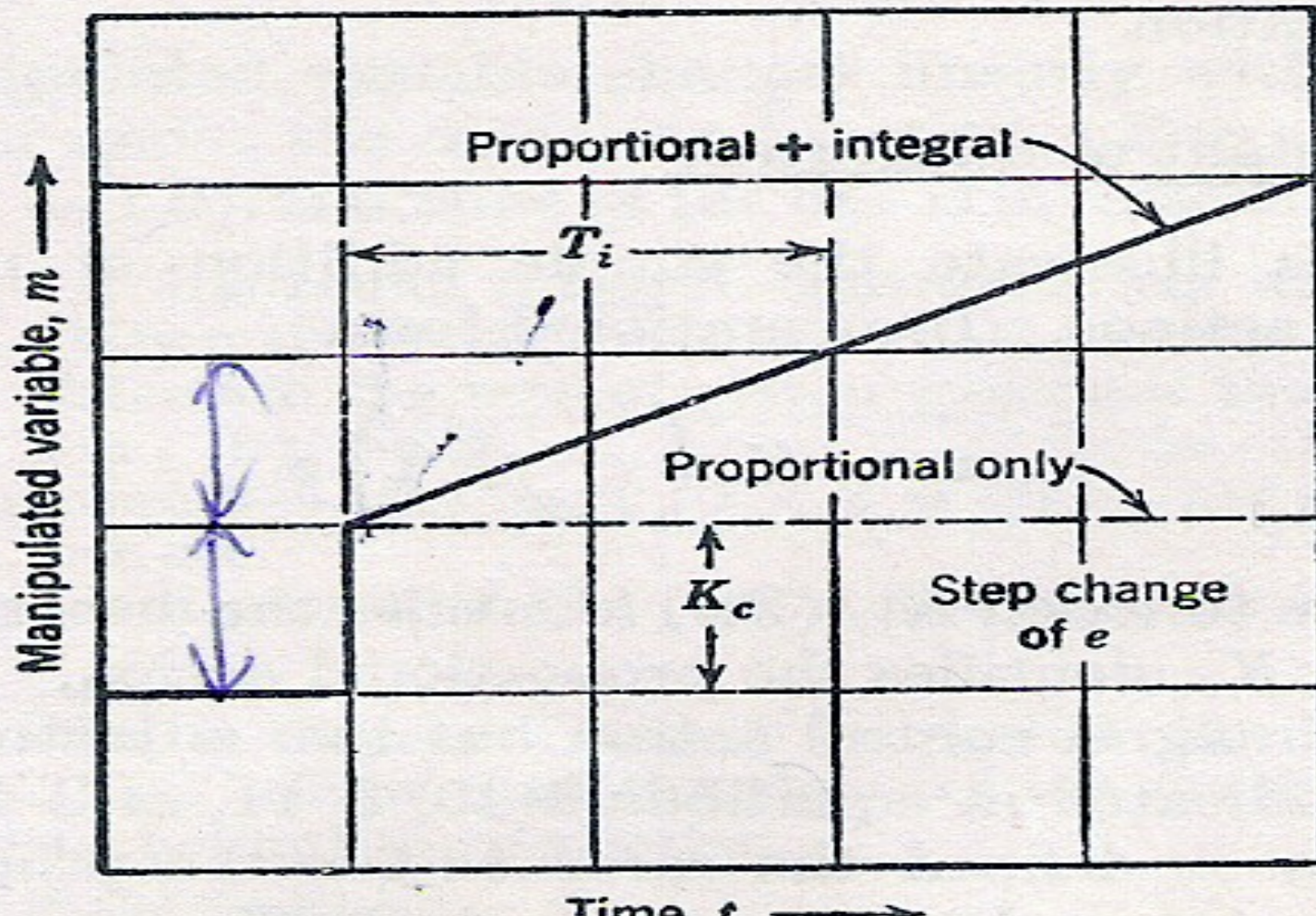
$$m = K_c * e + (K_c / T_i) * \int e \, dt + M$$

For a step change of deviation, the **integral time T_i** is the time required to add an increment of response equal to original step change of response.

Units : minutes or seconds per repeat

Reset rate is no. of times per minute that proportional part of response is duplicated / repeated and is reciprocal of T_i .

Units : Repeats per minute or second



PD-CONTROLLER



The additive combination of Prop. & Derivative control actions is known as PD-control

$$m = K_c * e + (K_c * T_d) * (de/dt) + M \quad \text{or}$$

$$m - M = K_c (1 + T_d * s) e$$

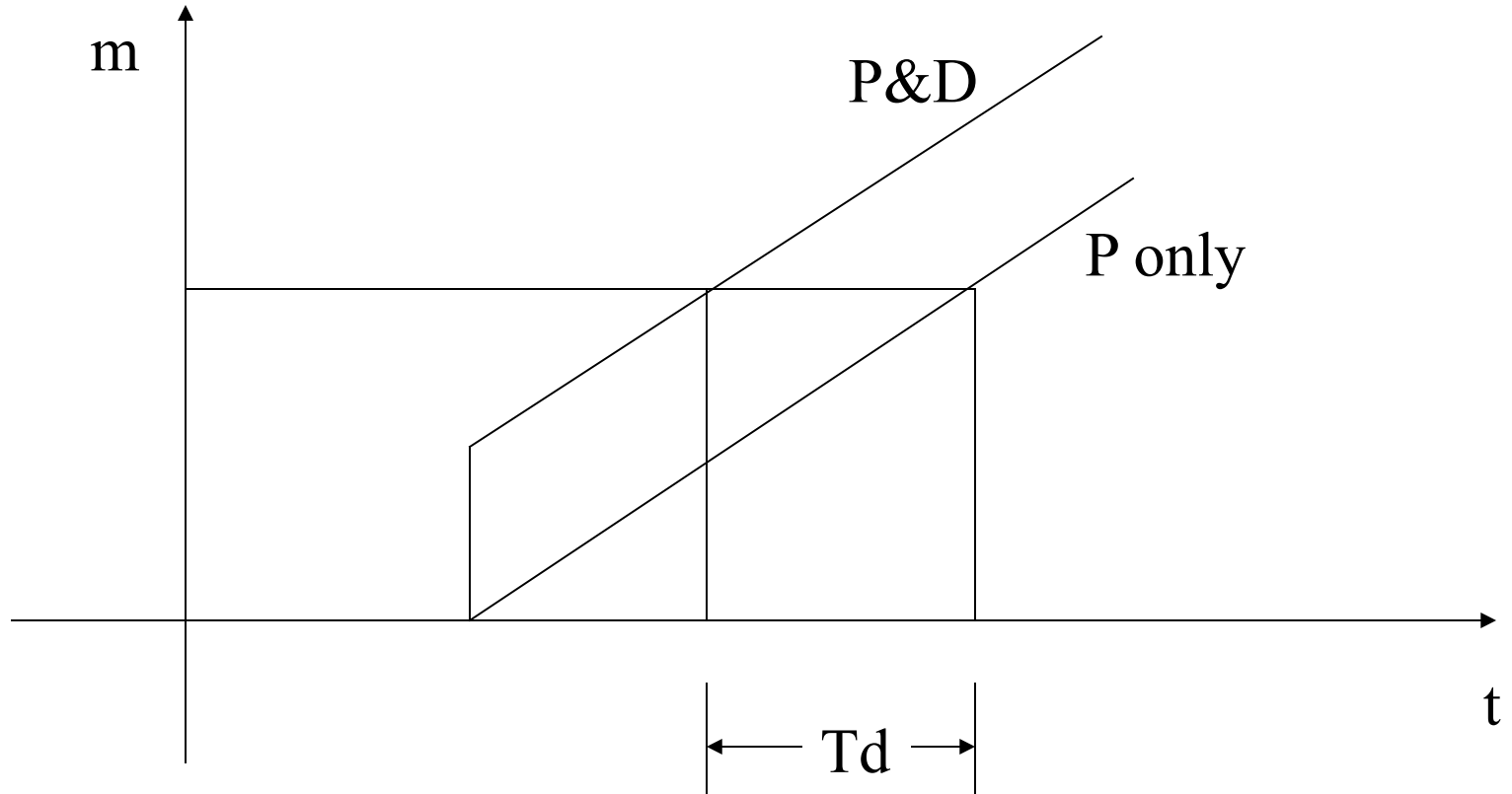
For a linear change of deviation : $e = Et$

$$m - M = K_c (1 + T_d * s) Et$$

$$m - M = K_c E (t + T_d)$$

Deviation, e is defined at time t while the manipulated variable is defined at time $(t+T_d)$.

So net effect is to shift the manipulated variable m , ahead by a Time T_d , the derivative time.



PID CONTROLLER

The additive combination of Prop. , Integral & Derivative control actions is known as PID-control.

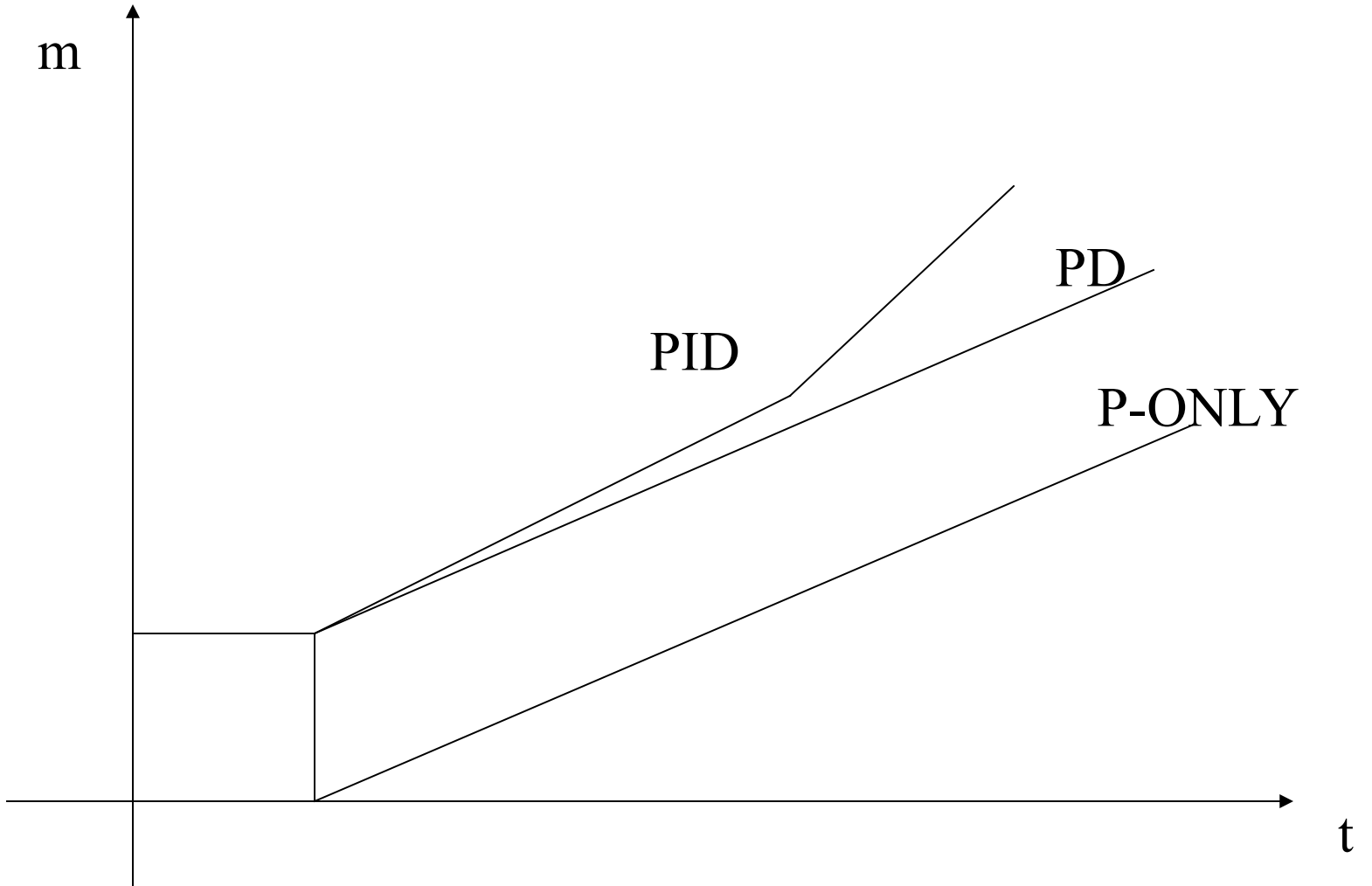
$$m = K_c * e + (K_c / T_i) * \int e \, dt + (K_c * T_d) * (de/dt) + M$$

$$m - M = K_c [1 + (1/T_i * s) + T_d * s] e$$

For a linear change of deviation : $e = Et$

$$m - M = K_c [1 + (1/T_i * s) + T_d * s] Et$$

$$m - M = K_c E (t + t^2/2T_i + T_d)$$



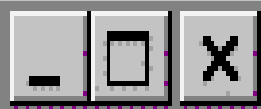
By using all three control algorithms together, process operators can:

- 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

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



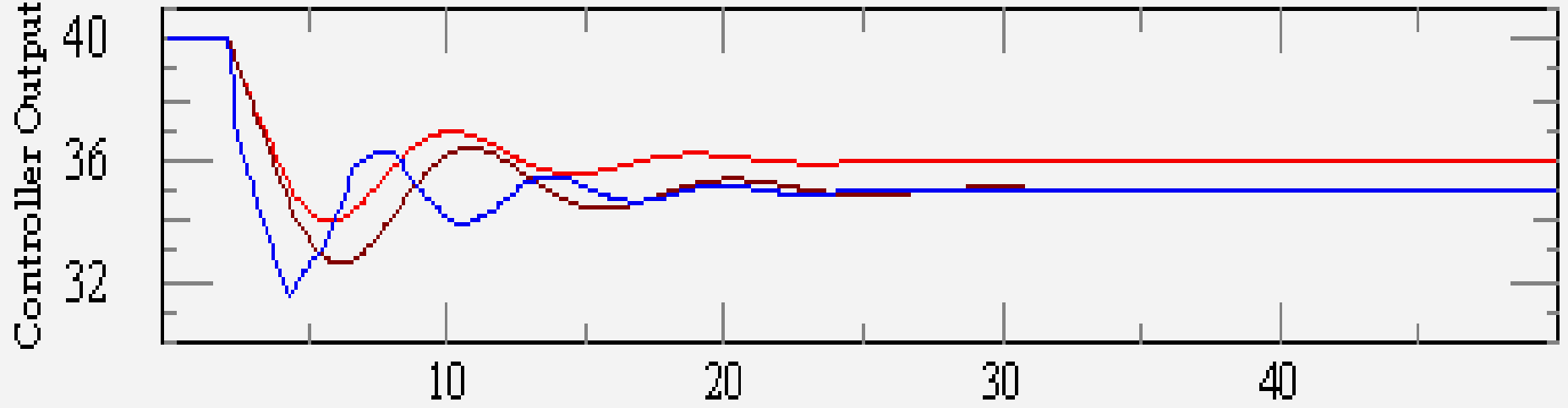
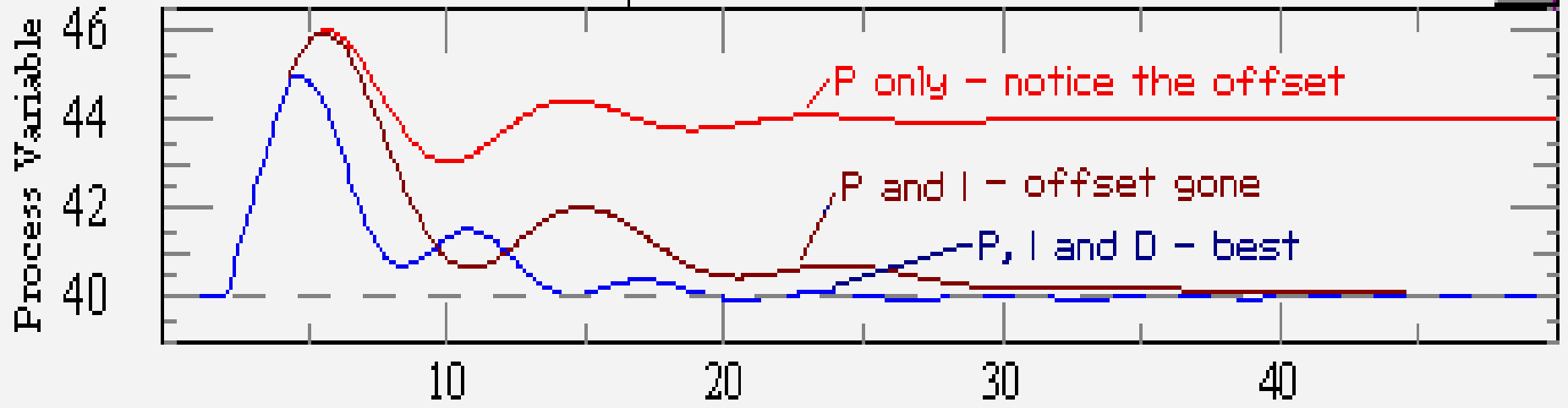
Load Step Time Response



File X-Axis Range Y-Axis Range

IAE = 192.32

SSE = 790.695



Time (sec)

CLASSIFICATION OF CONTROLLERS ACCORDING TO THE ACTUATING MEDIUM

Depending upon the actuating medium, automatic controllers may also be classified as :

- Pneumatic Controllers
- Electronic Controllers

The kind of controller to be used for a particular application should be decided by the nature of the plant and operating conditions, including such considerations as safety, cost, reliability, availability, accuracy, weight & size.

CONTROLLERS

[Single Loop Process Controllers](#)



[Multi-Loop Process Controller](#)



[Pneumatic Controllers](#)



[Process Dual Loop Controllers](#)



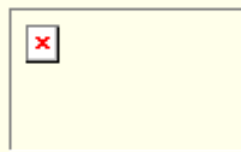
[Refrigeration Controller](#)



[Temperature Controller](#)



Browse By Products



Browse By Model No.

PNEUMATIC CONTROLLERS

These controllers made the beginning in old generation automatic process control. Today also these are extensively used in industrial process controls due to their inherent flame/explosion proof characteristics as no electric currents are used/ generated. Pneumatic Controllers come as Panel mounting type and also field mounting type with weather proof enclosures.

There are two basic components of pneumatic controllers :

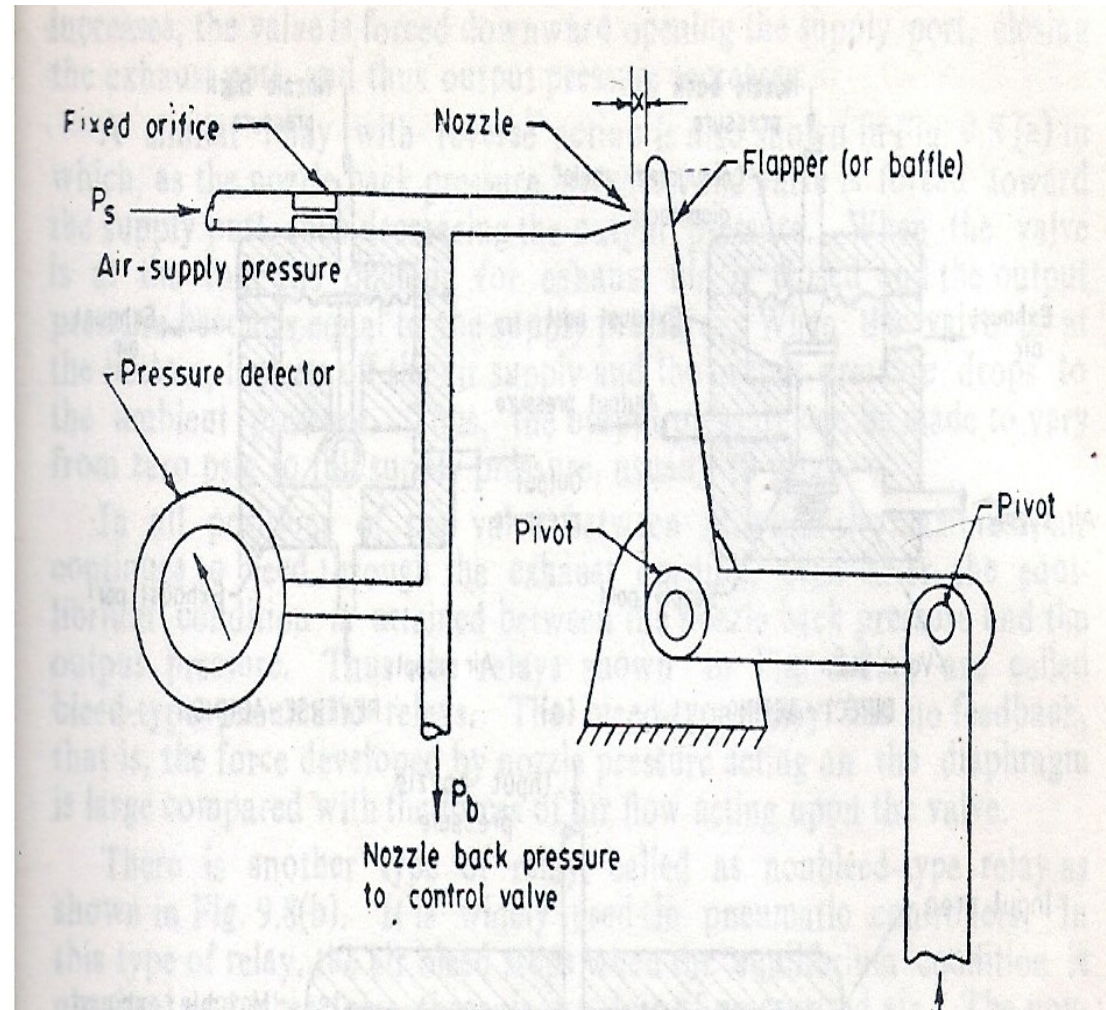
- Displacement sensing device (Flapper Nozzle system)
- Pneumatic Relays

Pneumatic Flapper Nozzle

It is a displacer type pneumatic detector which converts displacement into a pressure signal.

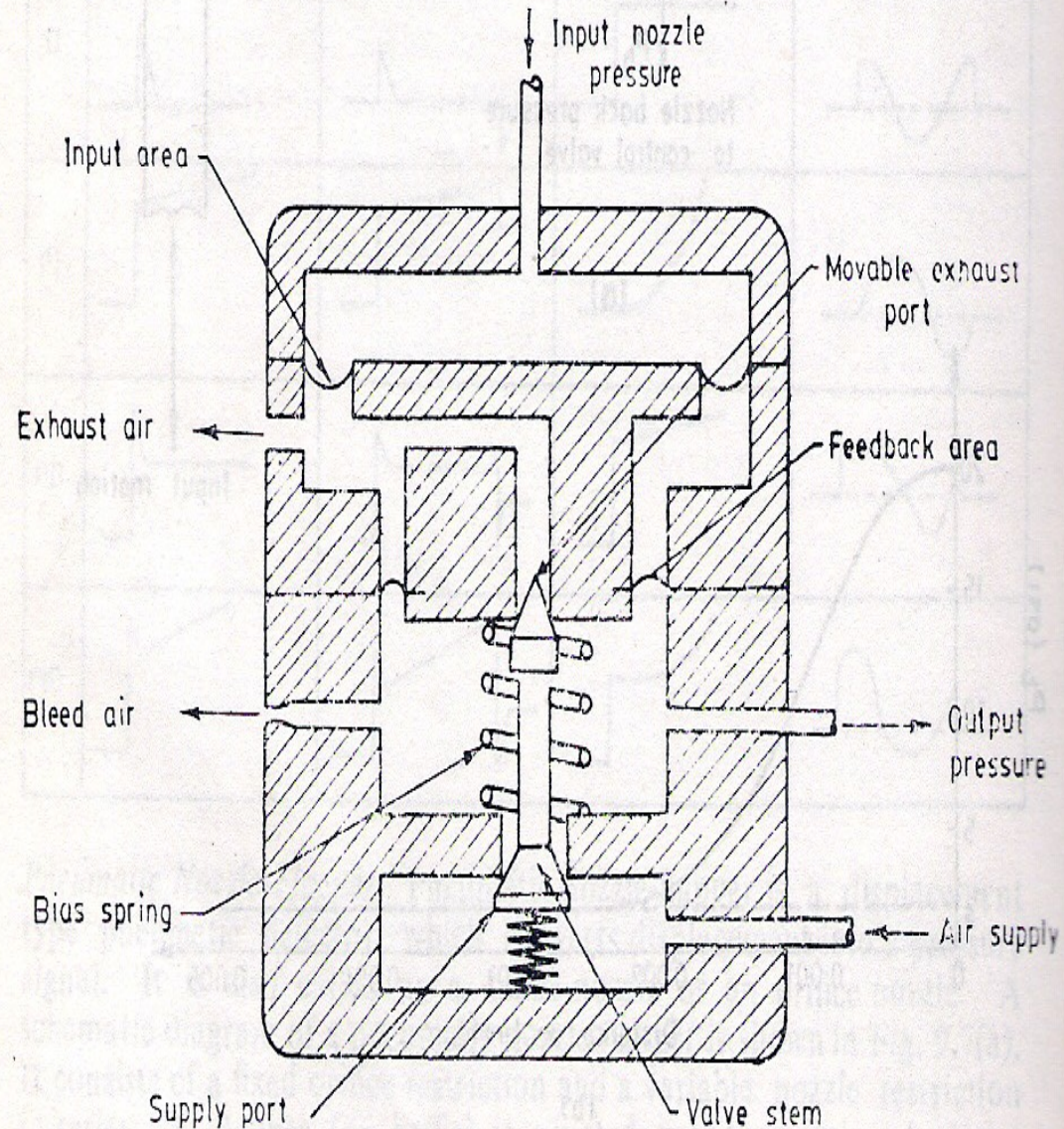
The diameter of the orifice is of the order of 0.25 mm & that of nozzle is 0.625 mm.

The nozzle diameter should be larger than the orifice diameter.



PNEUMATIC RELAYS

It acts as the second stage amplifier . It is capable of handling a large quantity of air flow and is used to increase the gain in conjunction with a flapper nozzle .



ADVANTAGES OF PNEUMATIC CONTROLLER

- No fire hazard

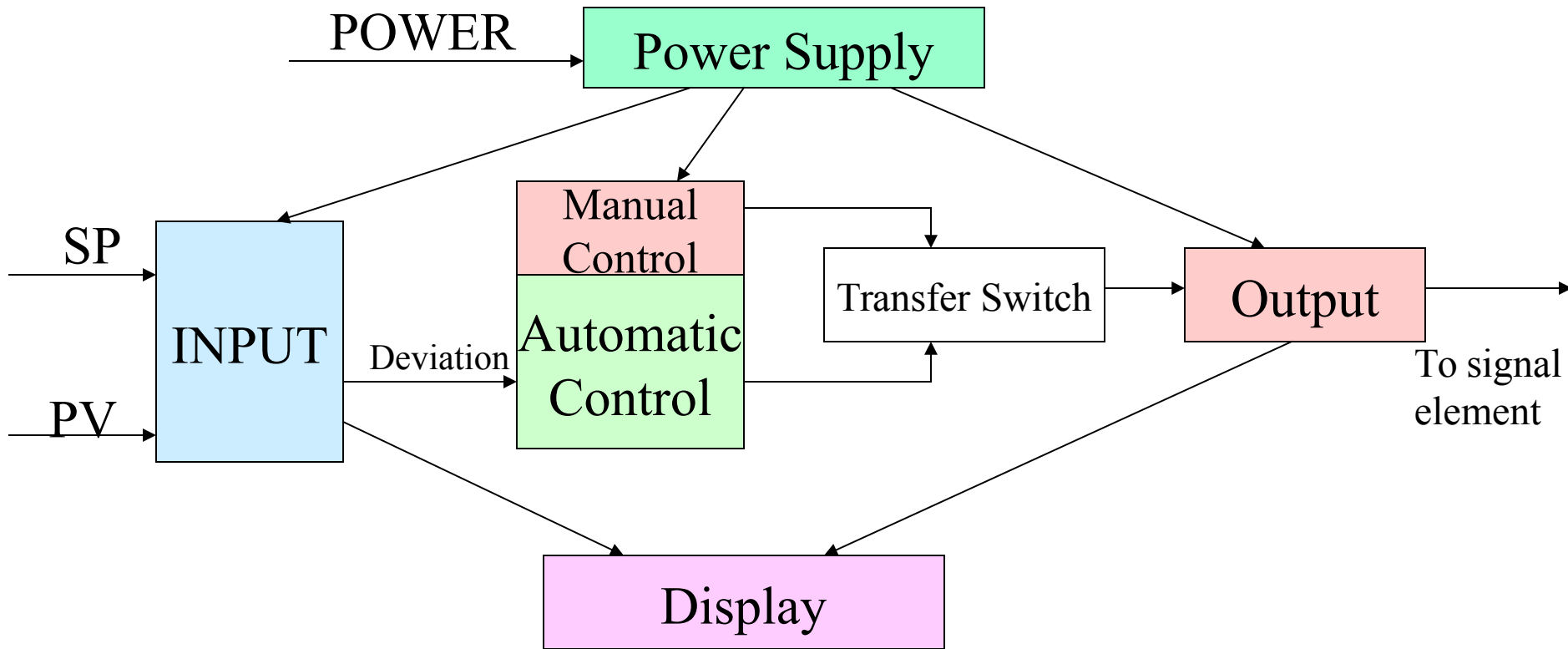
DISADVANTAGES :

- Slow response
- Condensate in instrument air causes choking action of the nozzle or relays.
- Not practicable to keep the actuator at a long distance
- Leakage in tubing can cause problems

ELECTRONIC CONTROLLER

Electronic controller use electric power to actuate the final control element. These types of controllers have a wide range of applications in modern process industries.

BASIC PARTS OF ELECTRONIC CONTROLLER



Electronic Loop Controller Characteristics

1. Simple PID control
2. Provisions for simple interlocking
3. User-initiated self-tuning
4. Multiple-level alarm priorities
5. External (upward) communications capability
6. Continuous self tuning
7. Hard-manual control station
8. Adaptive control
9. User-defined algorithms
10. Multiple loop-control capability with trend display

VARIOUS TYPES OF ELECTRONIC CONTROLLERS GENERALLY USED

- Yokogawa YS-170 controller
- Yokogawa SLPC controller
- ASCON AC-20 controller
- SIEMENS PAC-353 controller
- Bells 760 / 761 controller

YOKOGAWA YS170 CONTROLLER



MAIN FEATURES OF YS-170 CONTROLLER

- BARGRAPH / DIGITAL DISPLAY OF PV/SV/MV VALUES FOR ONE OR TWO LOOPS IS POSSIBLE.
- TREND DISPLAY OF PROCESS-VARIABLE
- BUILT-IN EEPROM TO STORE PARAMETERS AND USER PROGRAMS
- BUILT-IN ADJUSTABLE SET-POINT FILTER TO PROVIDE BETTER RESPONSE TO SP CHANGES
- OPTIMUM SELECTION OF PID PARAMETERS THROUGH SELF-TUNING FUNCTION
- COMMUNICATION FACILITY WITH DCS OR PC
- SELF-DIAGNOSTIC FEATURE
- **HARD-MANUAL OPERATION AND ON-LINE REPLACEMENT OF CONTROLLER , IN CASE OF FAILURE , IS POSSIBLE**

I/O SPECIFICATIONS

- 4 NO. OF 1-5V DC ANALOG INPUTS
- 1 NO. DIRECT INPUT (mV, TC , RTD , 4-20mA FROM 2-WIRE Tx. Or FREQ. INPUT
- 1 NO. 4-20mA ANALOG OUTPUT
- 2 NO. 1-5V DC ANALOG OUTPUTS
- 6 NO. STATUS I/Os (ON SHARING BASIS)
- 1 NO. FAIL OUTPUT SIGNAL

FEATURES

Controller modes:

Programmable mode

- Single-loop mode
- Cascade mode

Programming functions:

- Versatile computation
- Sequence logic computing function
- Program capacity of up to 400 steps

Control methods:

- Basic PID control (built-in nonlinear control function)
- Proportional control
- Sampling PI control
- Batch PID control
- Feedforward control

Variable set point filtering

Self-tuning

Alarm functions

Input computing functions

Output computing functions

Trend recording:

- Time span: 1.5 minutes to 45 hours
- Interval: 1 second to 30 minutes

Communication functions:

- YS-net for Peer to Peer communication
- RS-485 communication
- DCS-LCS communication

SLPC - SINGLE LOOP PROGRAMMABLE CONTROLLER

The SLPC Programmable Indicating Controller is a microprocessor - based , user programmable instrument which provides signal computation and control functions as well as sequence logic functions. A single SLPC can simulate 2 PID controllers in cascade control or auto selector control configuration

CONTROL MODULES

BASIC CONTROL MODULE

A single control module

CASCADE CONTROL MODULE

Two control modules connected in cascade

SIGNAL SELECTOR CONTROL MODULE

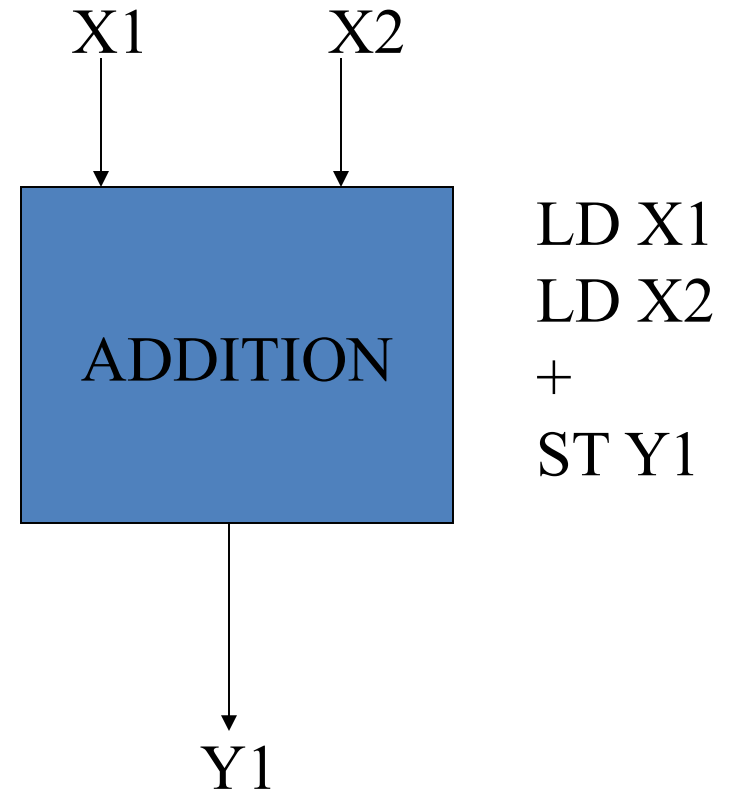
Two control modules connected in parallel

OPERATING CIRCUITS

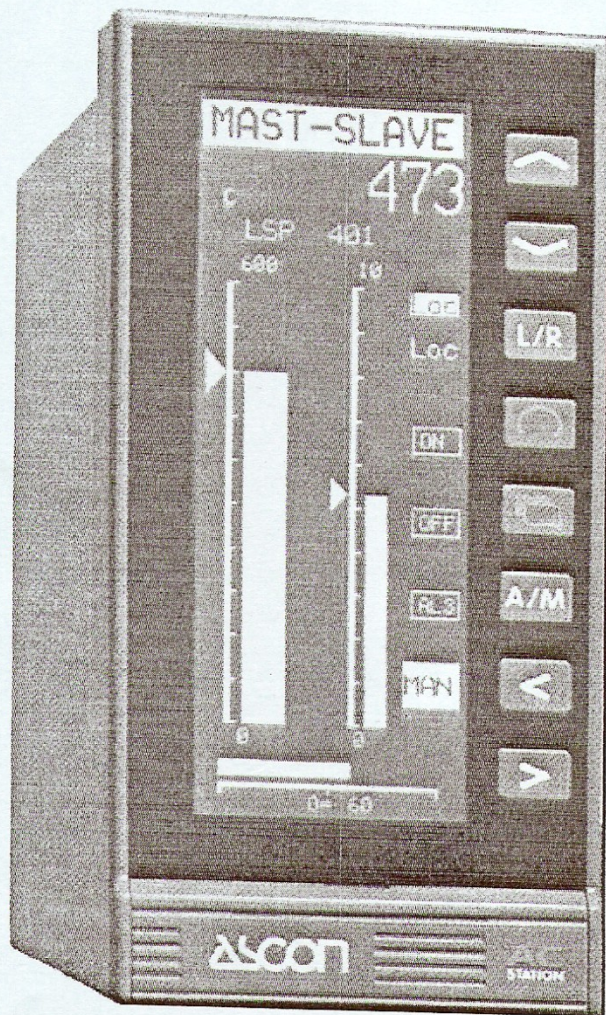
- ANALOG INPUT CIRCUIT
- A/D CONVERTER CIRCUIT
- DIGITAL INPUT CIRCUIT
- DIGITAL COMPUTING CIRCUIT
- DIGITAL OUTPUT CIRCUIT
- D/A CONVERTER CIRCUIT
- ANALOG OUTPUT CIRCUIT

COMPUTATION FUNCTIONS

- READS THE INPUT SIGNAL
- COMPUTES AND
- OUTPUTS THE COMPUTED RESULT



ASCION AC 20 CONTROLLER



MAIN FEATURES:

- 4 CONTROL LOOPS
- 8 ANALOG INPUTS
- 4 ANALOG OUTPUTS
- 8 OPTO-ISOLATED DIGITAL I/O
- 1 FREQUENCY INPUT
- 12 CONTROL STRATEGIES STORED IN INSTRUMENT MEMORY
- LCD GRAPHIC DISPLAY, BACKLIGHTED BY COOL-CATHODE LAMP

ASCON AC 20 CONTROLLER STATION CAN PERFORM

- DATA ACQUISITION AND MONITORING
- REGULATION AND CONTROL
- COMPLEX MATHEMATICAL FUNCTIONS
- LOGIC AND SEQUENCING
- ALARM FUNCTIONS
- LOCAL MONITORING OF PROCESS
DATA, CONTROL-FUNCTIONS, ALARMS &
EVENTS
- AUTOMATIC AND MANUAL COMMANDS

SERIAL COMMUNICATION PORTS

- **RS485 MAIN COM PORT**

For communication with a supervisory computer

Line Length: 1200 m maximum

Units per line: 32 controllers with twisted pair cable

Transmission Rate: 19200 baud

- **RS485 AUX COM PORT**

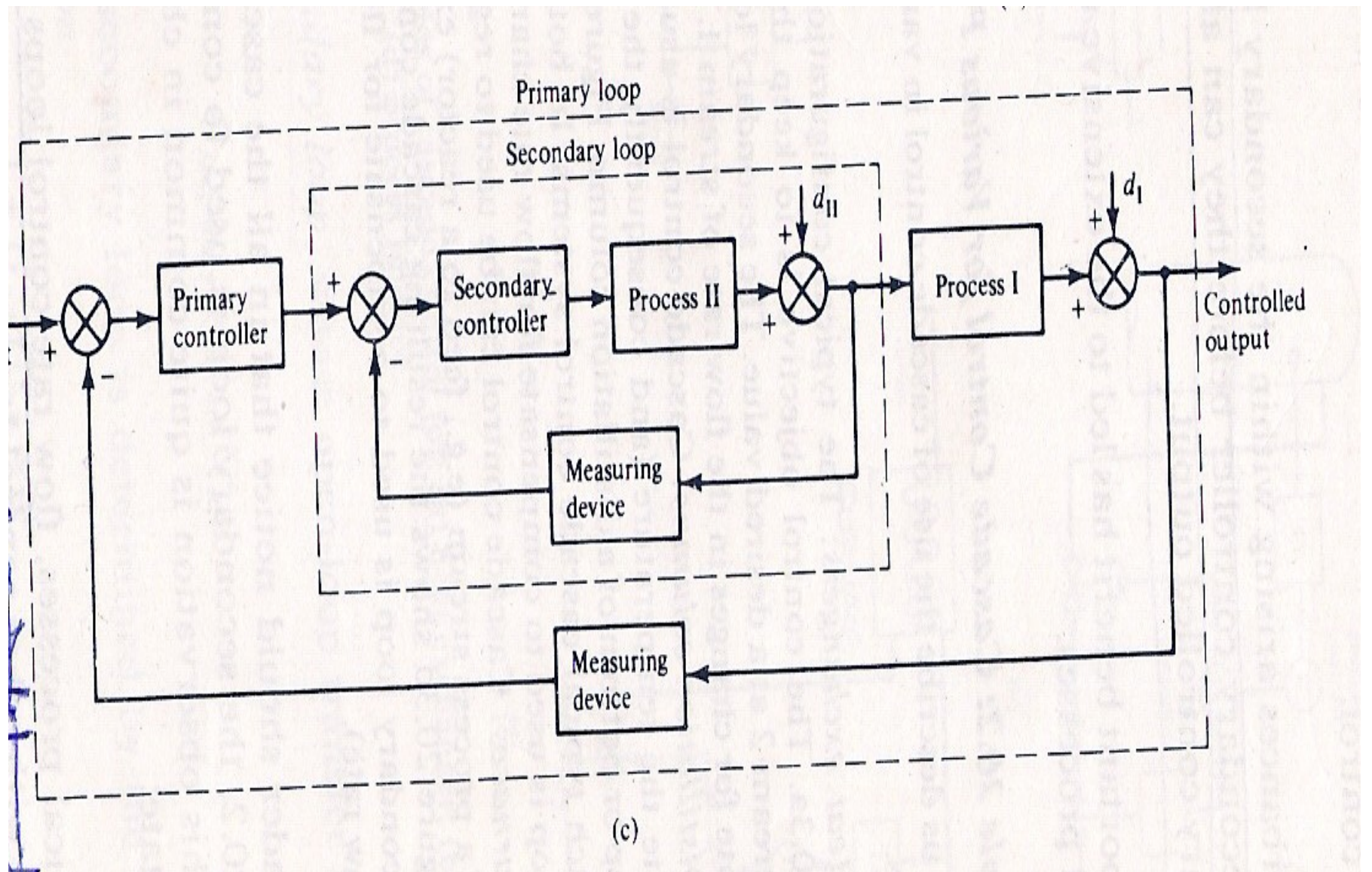
For commn. To Expansion units or to a computer for the backup of a data

- **RS 232 PROGRAMMING PORT**

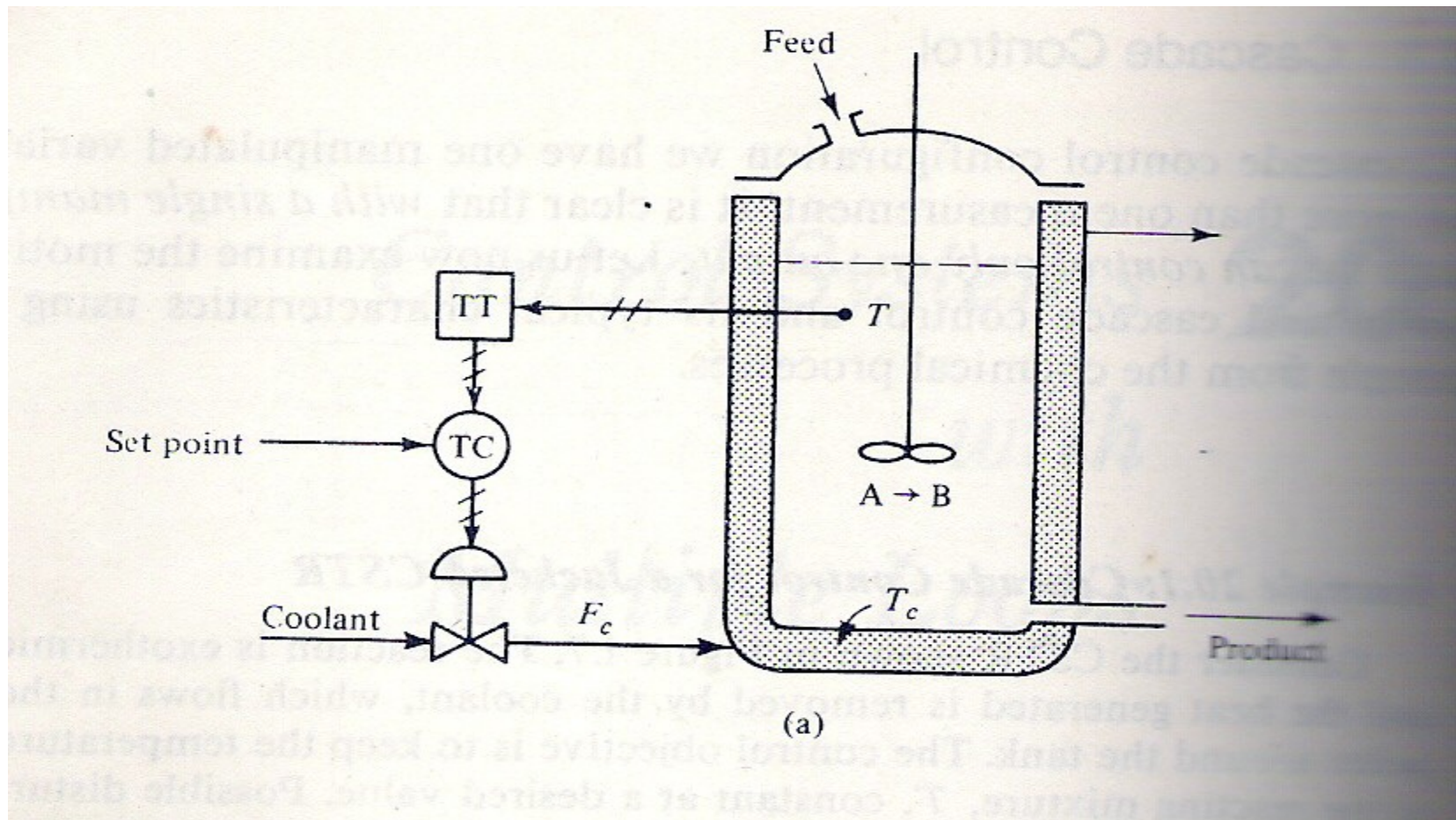
For commn. To a PC running AC-Prograph for the design and testing of control strategies

CASCADE CONTROL

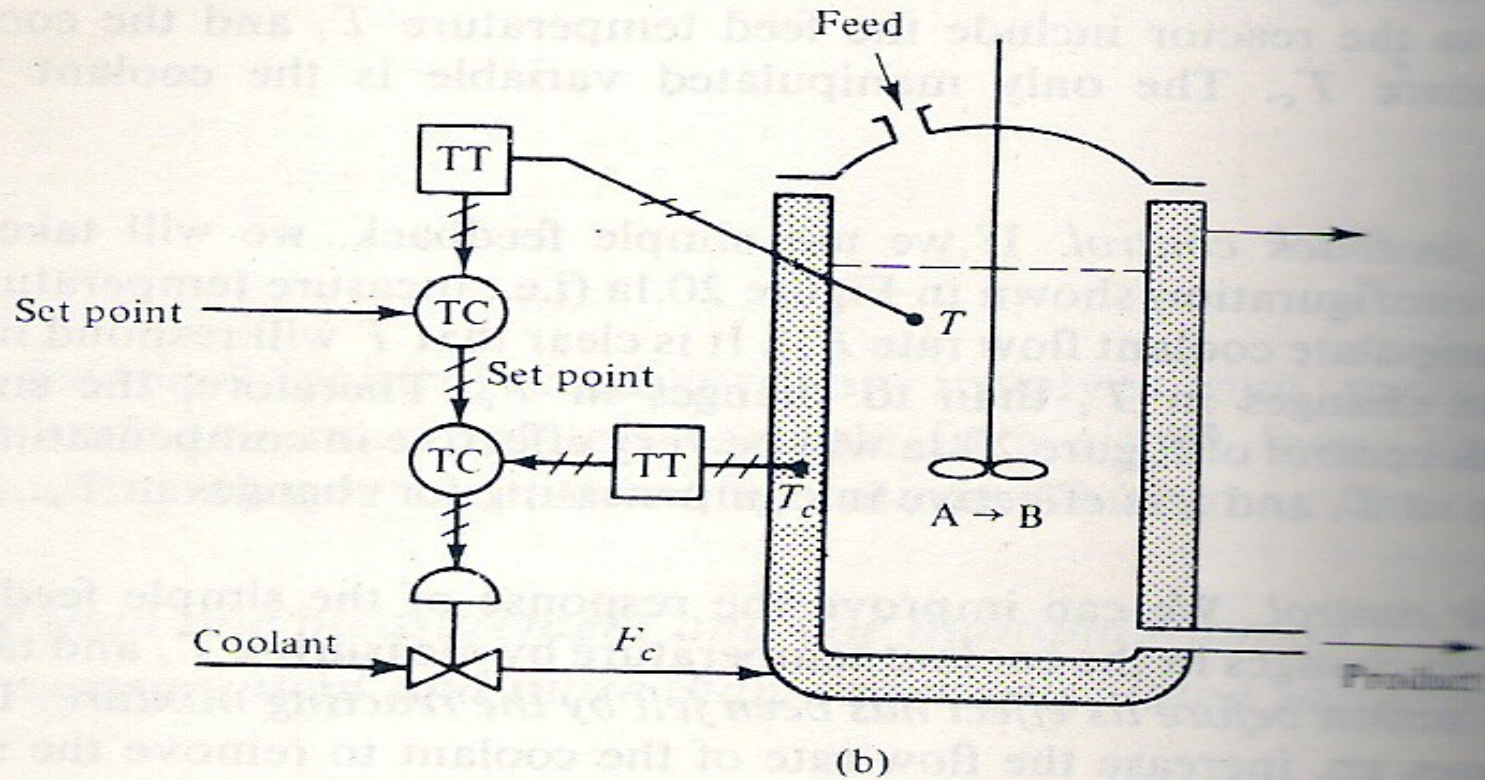
Cascade control is the most common multiloop control scheme in use. In this control scheme, the output of one primary controller is used to manipulate the setpoint of a secondary controller. The two controllers are cascaded with each other, but each has its own process variable input. The primary controller has an independent setpoint; its output goes to the secondary controller. It accepts the primary controller's output as its setpoint input and has its control output as the output to the process. This secondary controller is a closed loop within the primary loop.



CONVENTIONAL CONTROL OF REACTOR TEMP.



CASCADE CONTROL OF REACTOR TEMP.



TT, temperature sensor and transmitter
TC, temperature controller

USE CASCADE CONTROL WHEN

- The primary variable has a slow response to disturbances.
- Process changes cause serious upsets in the controlled variable.
- Another variable is affected by disturbances and is closely related to the control variable.
- The secondary variable can be controlled, and it responds quickly to the primary controller.

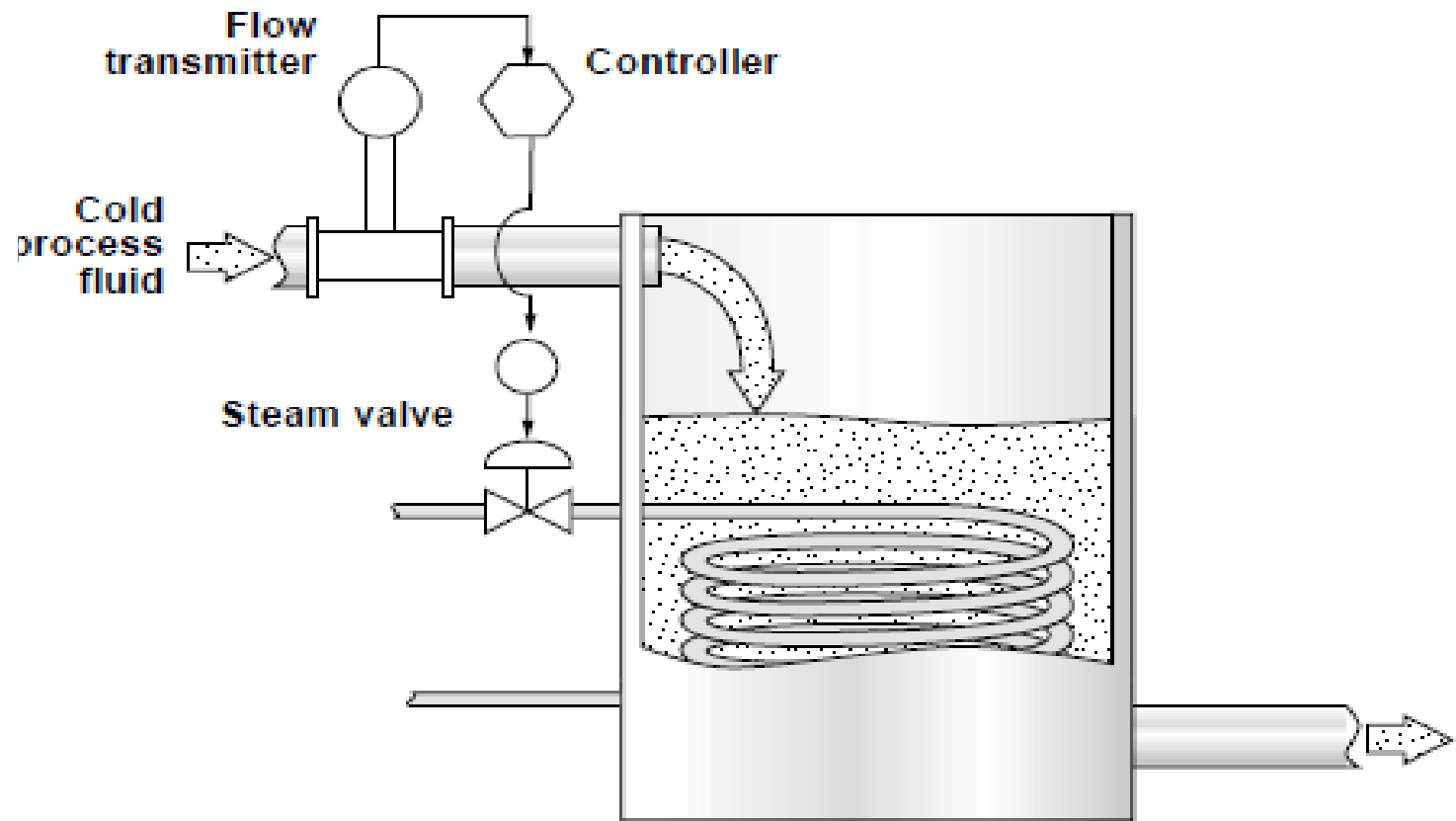
FEED-FORWARD CONTROL

For cascade control to be an option, the variable causing the disturbance must be controllable. However, in some applications, a disturbance that cannot be controlled may occur.

Feed-forward control measures the disturbance and feeds it directly to the output of the PID algorithm.

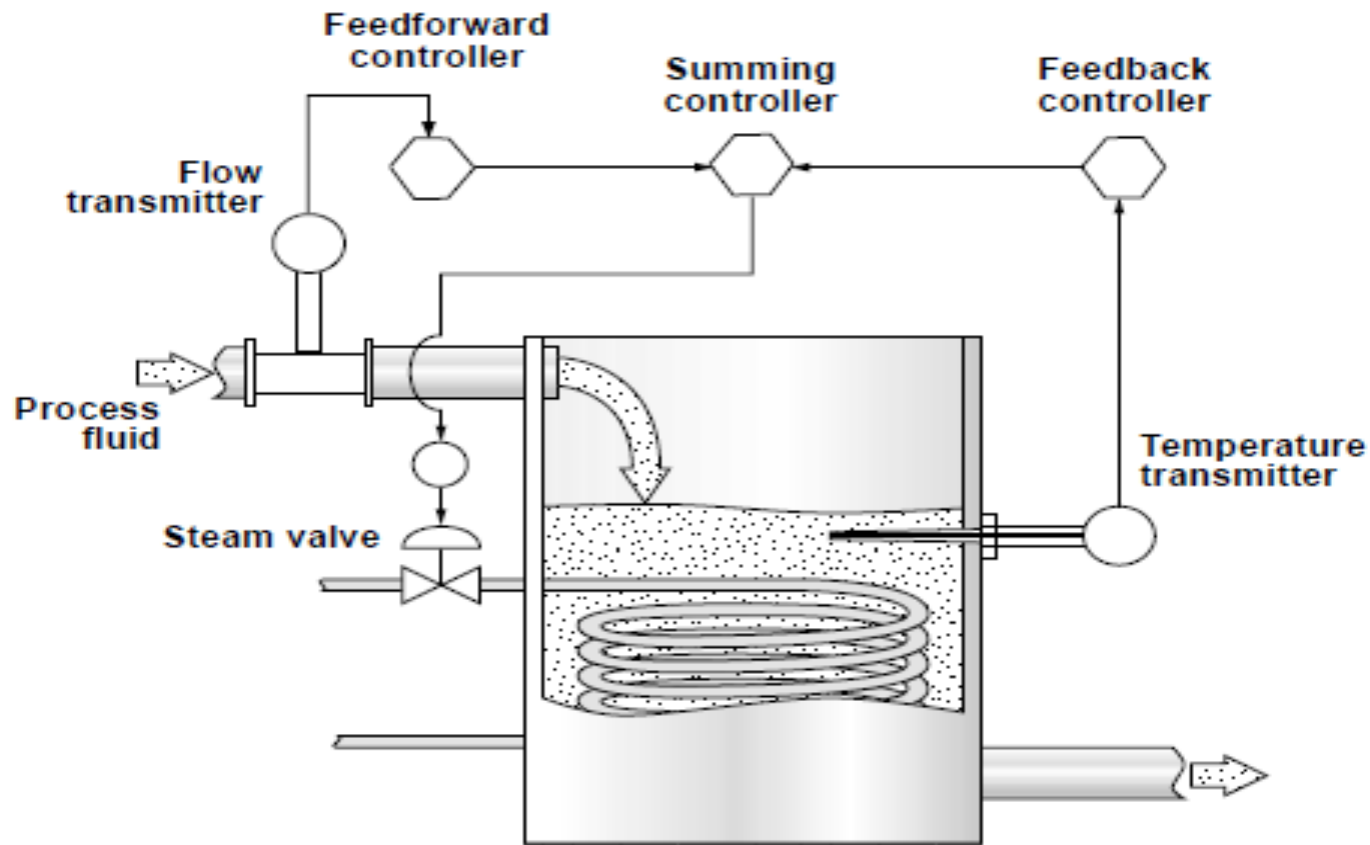
Feedforward control is a control system that anticipates load disturbances and controls them before they can impact the process variable.

Feedforward systems should be used in cases where the controlled variable has the potential of being a major load disturbance on the process variable ultimately being controlled



Feedforward control

An advantage of feedforward control is that error is prevented, rather than corrected



Feedforward Plus Feedback Control System

feedforward-plus-feedback loop in which both a flow transmitter and a temperature transmitter provide information for controlling a hot steam valve

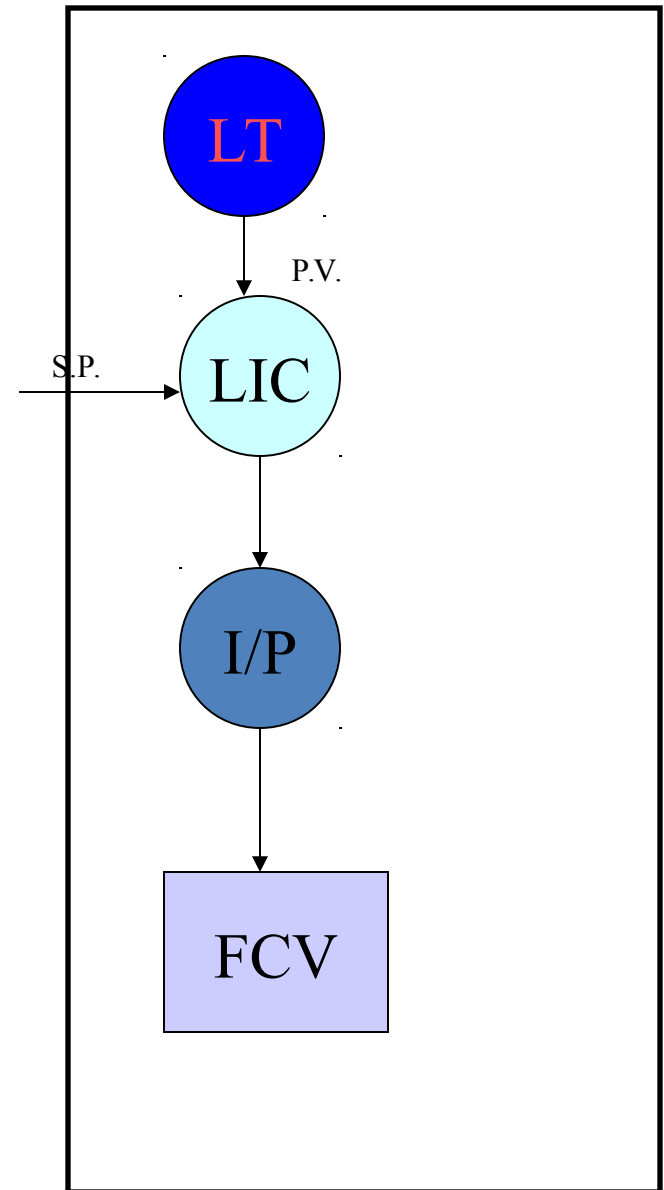
SINGLE ELEMENT DRUM LEVEL CONTROL

Single element control is the simplest strategy. In this system drum level is measured using a single measurement device & provides a control signal to the feed water control valve in direct relation to the current operating drum level.

The single element drum level strategy is only effective for smaller boilers with relatively steady demands & slow to very moderate load changes. This is because the **SHRINK & SWELL** effect causes an incorrect initial control reaction which can lead to over / under filling of the drum.

As steam demand increases, there is an initial lowering of drum pressure resulting in an artificial rise in drum level as the steam bubbles expand and swell the drum water level. This phenomenon sends a false control signal to reduce feed water flow, when in fact the feed water flow should be increasing to maintain mass balance.

Conversely, on a loss of steam demand, there is an initial rising of steam drum pressure which acts to lower the drum level by compressing the steam bubbles & shrinking the drum level. This sends a false signal to increase feed water flow when in fact it should be decreasing to maintain mass balance.



TWO ELEMENT DRUM LEVEL

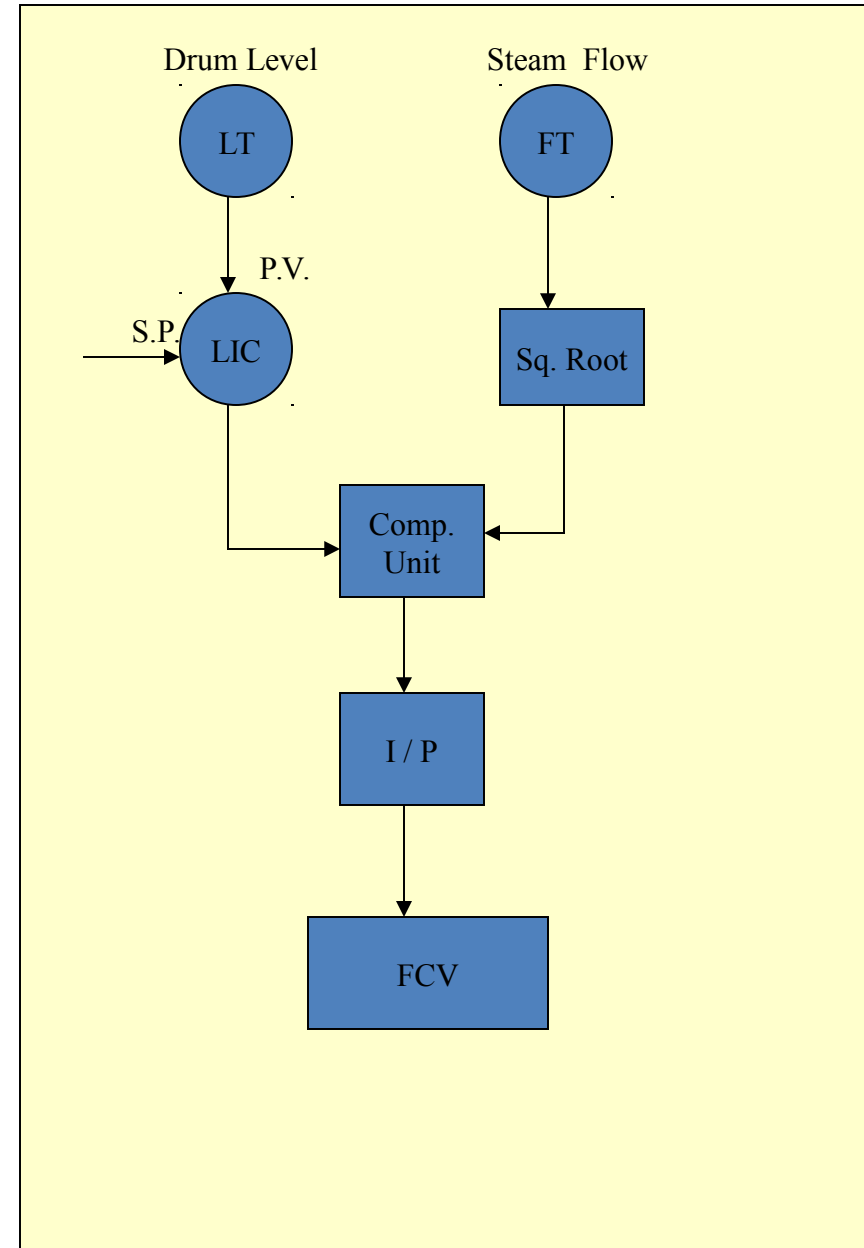
CONTROL

The Two element drum level strategy is suitable for processes with moderate load swings & speeds and it can be used on any size of boiler. This system uses the two variables, drum level & steam flow to mass balance the feed water demand.

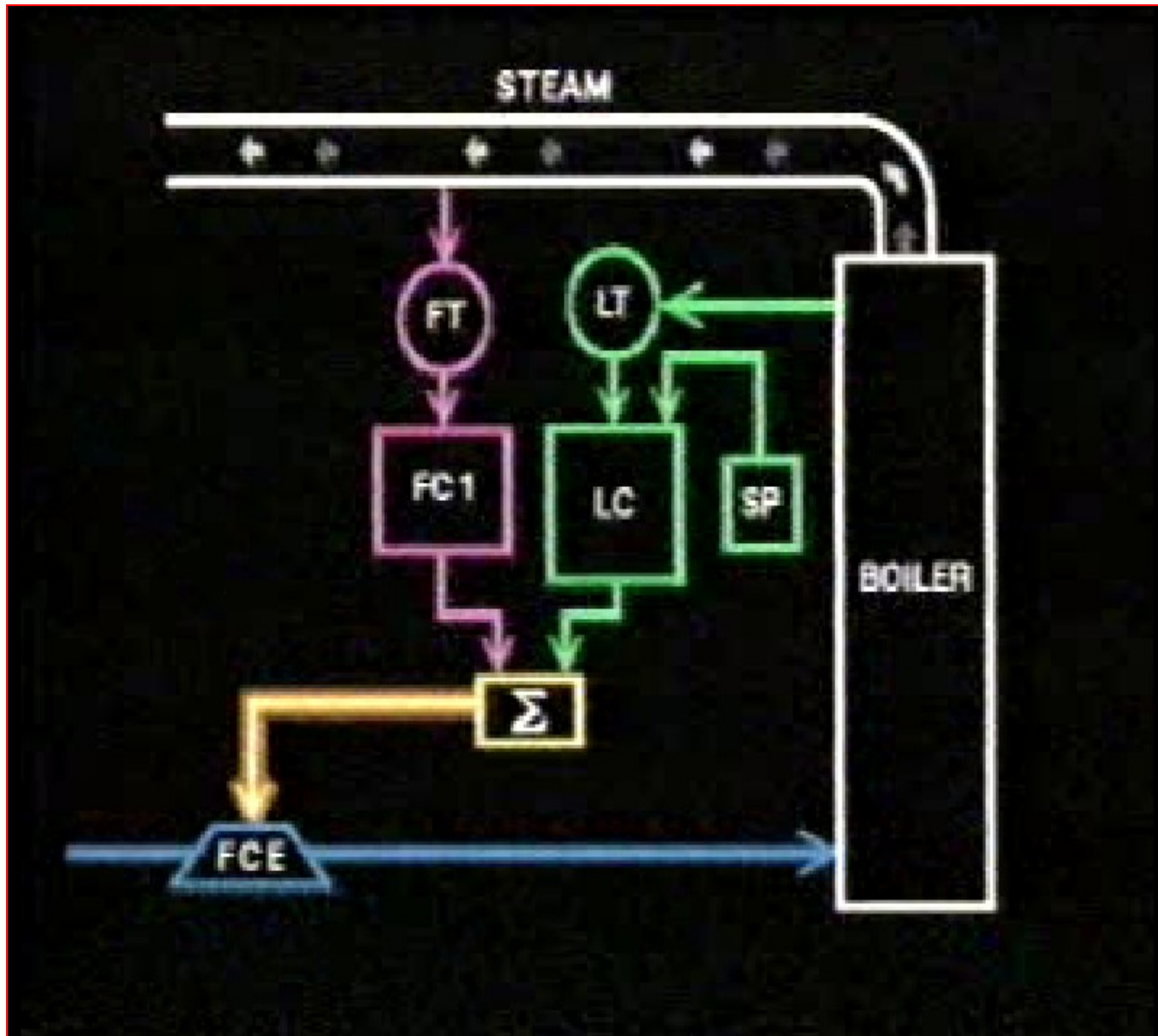
In two element control, steam flow is measured along with boiler drum level. The steam flow signal is used in a feed forward control loop to anticipate the need for an increase in feed water to maintain a constant drum level.

This strategy has two drawbacks :

- (i) Like the single element strategy the two element control can not adjust for pressure or load disturbances in feed water supply, as this is not a measured variable in this strategy.
- (ii) The two element control can not eliminate phasing interaction between feed water flow & drum level because only the relatively slow process of drum level is controlled.



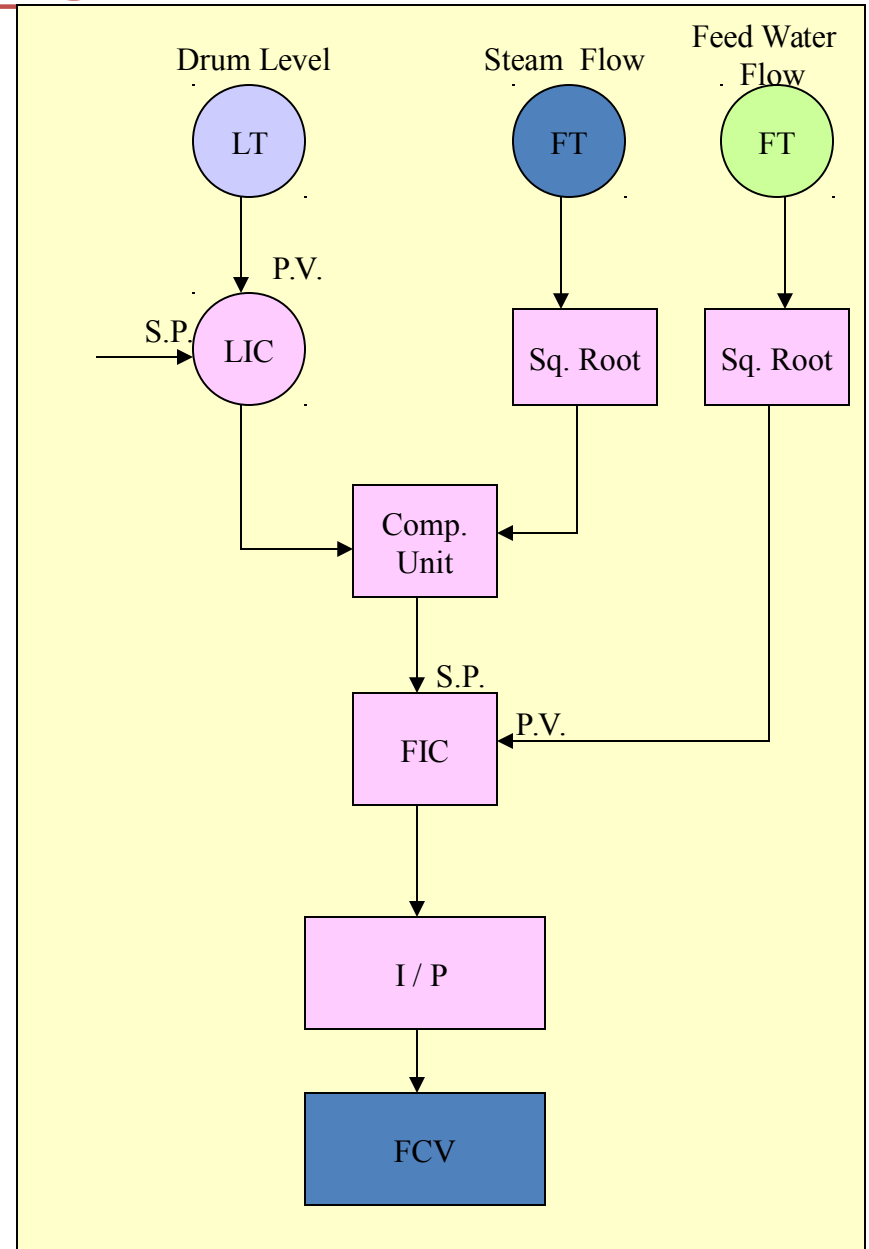
TWO ELEMENT DRUM LEVEL CONTROL



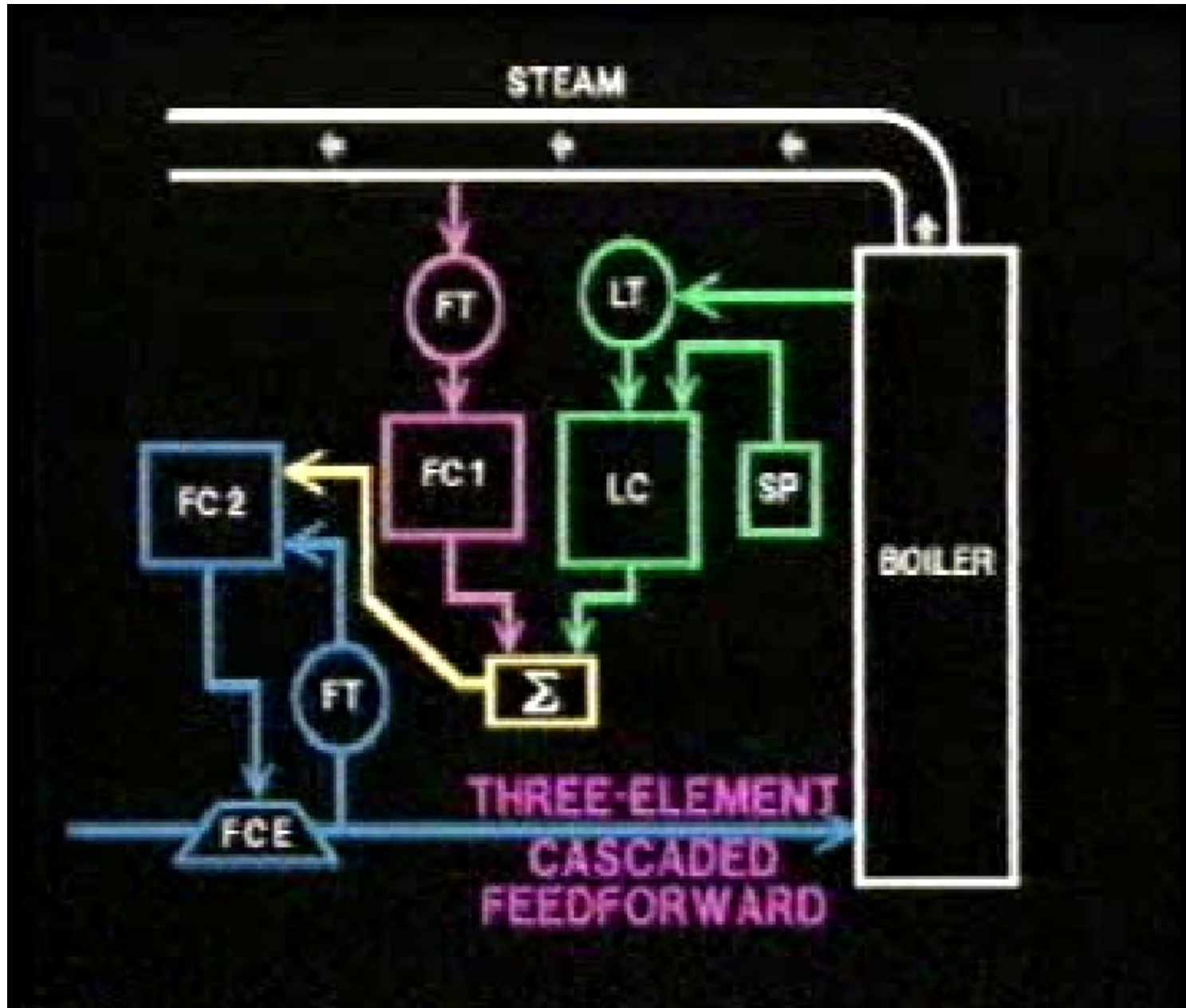
THREE ELEMENT DRUM LEVEL CONTROL

Three element drum level control adds a feed water flow signal to the steam flow & boiler drum level signals used in two element feed water control. The drum level controller manipulates the feed water flow set point in conjunction with feed forward from steam flow measurement. The feed forward component keeps the the feed water supply in balance with the steam demand. The drum level controller trims the feed water flow set point to compensate for errors in the flow measurement or any other unmeasured load disturbances that may effect drum level.

The three element control is used in boilers that experiences wide , fast load changes.



THREE ELEMENT DRUM LEVEL CONTROL



REFERENCES

- Fundamental of control -: PACONTROL.com
- NFL Lectures
- Yokogawa sites

Thanks