

PROCESS CONTROL SCHEMES**JGS 210-120-1-13E**

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CONTENTS

	<u>PAGE</u>
1. SCOPE.....	3
2. WORK PROCEDURE.....	3
2.1 Input to the Design	3
2.2 Output from the Design	3
2.3 Work Steps	3
2.4 Check List.....	3
3. DESIGN.....	4
3.1 Control Loops Basis	4
3.1.1 Four Elements of a Control Loop	4
3.1.2 Process Control Center	5
3.1.3 PID Controller Notations	6
3.1.4 DCS (Distributed Control System).....	7
3.1.5 Single Feedback Control Loop	7
3.1.6 PID Controller.....	7
3.1.7 PID Tuning Parameters and Tuning Practice.....	8
3.1.8 FC (Flow Control).....	8
3.1.9 LC (Level Control)	9
3.1.10 PC (Pressure Control).....	10
3.1.11 TC (Temperature Control).....	10
3.1.12 Direct/Reverse Action of PID controller.....	10
3.1.13 FO/FC (Failure Open/Failure Close) of CV.....	10
3.1.14 Basic Check Points of Finding Erroneous Control Configurations:.....	10
3.1.15 Positionner of a Control Valve	12
3.2 Selection Procedure	12
3.2.1 General Precautions to be Taken.....	12
3.2.2 Selection of Controlled Variables and Manipulated Variables	13
3.2.3 Product Quality Control.....	13
3.3 Integrated Control	13
3.3.1 Cascade Control (CAS Control).....	14
3.3.2 Split Range Control (S.R. Control)	15
3.3.3 Selective Control (Override Control) (LSS/HSS).....	16
3.3.4 Averaging Level Control.....	17
3.3.5 Ratio Control.....	18
3.3.6 Feedforward Control.....	18
3.4 Advanced Process Control (APC)	19
3.5 Control Schemes for Pumps.....	20
3.6 Control Schemes for Heat Exchangers	22
3.7 Control Schemes for Drums.....	25
3.8 Control Schemes for Distillation Towers	26
3.8.1 Pressure Control	26
3.8.2 Temperature Control	30
3.8.3 Flow Control	32
3.8.4 Level Control	32
3.8.5 Reboiler Control.....	32
3.8.6 Internal Reflux Control.....	37
3.8.7 Quality Control	38

3.9 Control Schemes for Reactors.....	41
3.10 Control Schemes for Furnaces	42
3.11 Control Schemes for Compressors	43
3.12 Control Schemes for Absorbers/Regenerators (Amine)	44
3.13 Control Schemes for Extractors	45
4. RELATED DOCUMENTS.....	46
5. ABBREVIATION.....	47

1. SCOPE

- (1) This standard practice provides the guidelines of control schemes for process plants in the preparation of P&I Diagrams.
The main target of this guideline is to provide the guidelines not only for designing a single process control loop, but also for designing the overall plant control loop configurations.
- (2) This standard practice does not cover the Emergency Shutdown System, Sequence Control or selection of the type of sensing elements or control valves.
- (3) Recent development of computers has large effects in the field of process control systems. Process computers are available for use with various schemes, but herein computer controls will not be taken up for discussion. Refer to specific APC (Advanced Process Control) design guidelines and consult with APC specialists for details.

2. WORK PROCEDURE**2.1 Input to the Design**

- Operational philosophy from the Client and Process Licensors.
- Instrument and Control Standards
- Process Unit Arrangements
- Operating Conditions.
Operation Manuals
Operation modes.
- Start-up procedures
- Emergency operations
- Shut down procedures
- Protective control for plant safety

2.2 Output from the Design

- Plantwide control loop configurations on PFD.
- Representation of control loop on P&IDs.

2.3 Work Steps

The following must be considered in the planning of control systems and the execution of the engineering.

- Owner's philosophy of process control
- Grade, economics, operability and safety of control systems
- Utilization of DCS microprocessor systems (CRT-display) as a man-machine interface.
- PFD preparation from the control point of view.
- P&ID representation for detailed designs of control loops.
- Control narratives

2.4 Check List

- Clarification how to use sensors (Indication use (Local and/or CCR), Control use and ESD use.)
- Confirm proper compensations on flow measurement by operating temperature/pressure and molecular weight.
- Confirm proper combination of controlled variables and manipulated variables.
- Confirm the degree of freedom of control loop configurations to avoid the conflicts between control loops.
- Confirm how the pressure of vapor phase is controlled, and also confirm how the vapor overpressure will be protected in case of unit upset.
- Confirm Anti-reset-wind-up functions are specified for controllers which are usually not in operation.
- Confirm that proper control loops are considered for abnormal plant conditions.
- Confirm FO/FC specifications for each CVs and proper control signal conditionings.
- Confirm that SR (Split Range) charts are clearly shown.
- Confirm that control loop variables (PV/SV/MV) are clear on P&IDs.
- Confirm whether control loops are adequate for start-up operations and also for changes of operation modes.

3. DESIGN

There are many ways and variations of workable control loop configuration for a particular process plant, but it should be noted that care has to be taken to avoid control conflicts between two or more control loops. If there exist control conflicts in a plant, it will make the entire plant inoperable.

3.1 Control Loops Basis

It is required for a continuous process plant that stable operating conditions be maintained at each step of processing under various disturbances. Maintaining dynamic stability of the operating conditions or "controlling" them is the target of automatic process control.

There are many possible plant control loop configurations which can regulate the process conditions for continuous plant operation. Some control loop configurations would work better than other control loop configurations. The philosophy on control loop configuration will be instructed by Process Licensors, Engineering Contractor, Package Unit Vendors and the Client, depending on the requirements of plant operation needs.

However, JGC must avoid unworkable control loop formation and make the overall control loop configurations workable. Unworkable or wrong control loop could be formed if one designs a control loop carelessly without noticing the interactive conflicting effects between controllers. This process control design manual is intended to be useful for control loop design aiming not to form wrong control loop configurations as the minimum engineering practices.

3.1.1 Four Elements of a Control Loop

The purpose of process controls is to regulate the process conditions at predetermined values so that the process plant should meet the ultimate production targets, fulfilling product specifications under various operational modes. Common process conditions to be regulated are flow rates (F), temperatures (T), pressures (P) and liquid levels (L).

Other specific process conditions to be regulated are product compositions (A), rotating speed (N) of rotary machinery, and physical properties such as viscosities (μ), pH, etc, depending on the specific process requirements.

Any process control loop consists of four elements;

- (1) Measurement of process condition to be controlled (Sensor)
- (2) Control mechanism (Controller function)
- (3) Manipulating element (usually a Valve)
- (4) Process unit (Plant performance)

These four control elements form a cyclic loop in a dynamic characteristics.

- (1) Measurements of process conditions are carried out by sensing elements; eg. orifice plate for flow rate measurement (F), thermocouple for temperature measurement (T), a diaphragm for pressure measurement (P) and differential pressure for liquid level measurement (L).
- (2) Typical controller mechanism is a PID (Proportional-plus-Integral-plus-Derivative action) regulator. A PID controller compares the measured value against a predetermined Set Point value, and, if there exists a deviation between measured process value and set point value, the PID controller sends out a corrective action to a control valve to force back the process condition to the set point value according to the PID algorithm.
- (3) The final manipulative element receives the corrective action signal from the PID controller to affect the process conditions. The final manipulative elements in process plant are usually valves. A change of valve stroke will cause changes of flow as a primary effect, and this change of flow will cause changes of temperature, pressure and/or liquid level due to mixing, heat transfer or inventory change depending on the process.

(4) Process plant is the target to be controlled, and a change of control valve opening will eventually affect temperature (T), pressure (P) and level (L) as well as flow rate (F). These changes of process conditions will be measured again for the next control action. There is a time delay in process dynamic response more or less due to the existence of holdups or heat capacities.

These four elements of process control loops interact continuously, and process control configurations have to be properly designed in order to keep the process conditions at predetermined target set point conditions under various disturbances.

3.1.2 Process Control Center

Controller functions are usually centralized in a CCB or CCR (Central Control Bureau/Room), and measurement signals at the field process units are sent to CCB through instrument cables. The instrument signal is standardized worldwide; typically,

- 4-20 mA DC electrical signal range, or
- 0.2-1.0 Kg/cm²G pneumatic signal range or
- 1-5V electric voltage.

Measured values of process conditions (flow, temperature, pressure and level) are converted into the standard instrument signal by signal transmitters at the field. The lowest value of measurement range is converted to 4 mA DC signal and the highest value of measurement range is converted to 20 mA DC.

Likewise, the controller output signals from CCB are sent out to the final manipulating element, control valves, through instrument cables, typically 4-20 mA DC electrical signal.

The 4 mA DC control signal will command the control valve to close fully, and the 20 mA DC control signal will command the control valve to a full open position. The conversion of control signal to valve stroke will be carried out by a transducer at the valve actuator.

3.1.3 PID Controller Notations

Traditional PID Controller is the basic control algorithm and is adopted almost universally in process industries. Therefore, it is important to understand the concept and functional performance of a PID controller.

The Figure 3.1.3a below shows a schematic diagram of control loop configuration.

Fig. 3.1.3a Schematic Diagram of a Control Loop Configuration

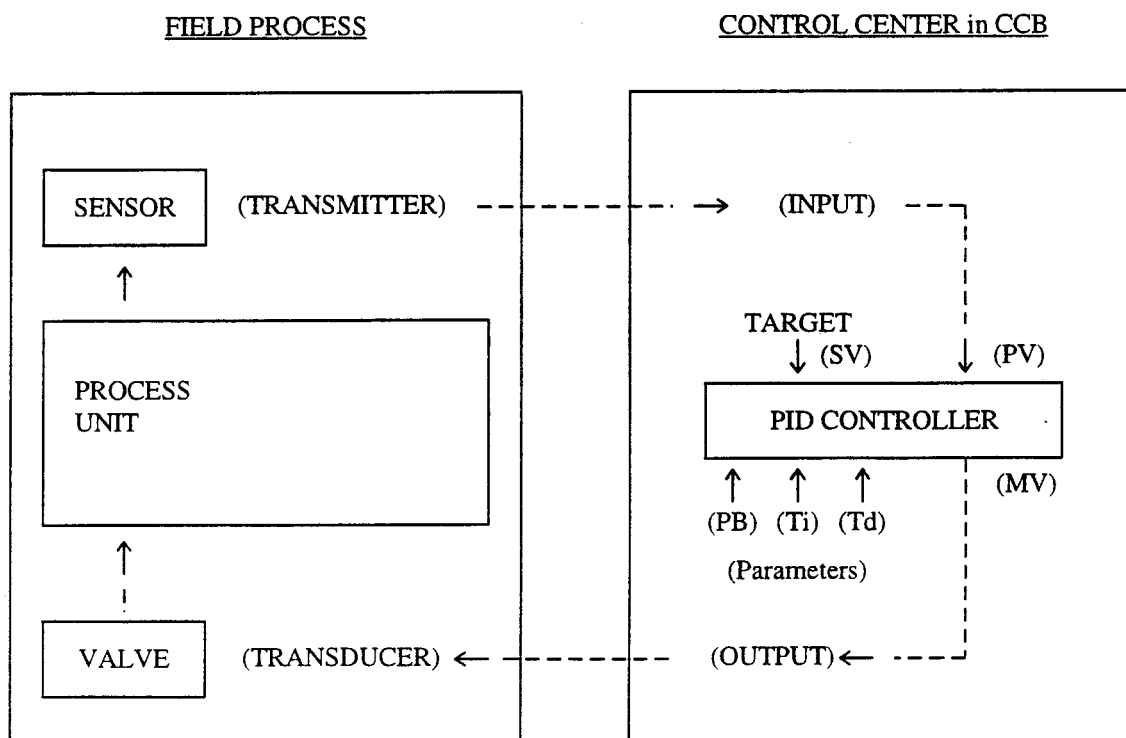
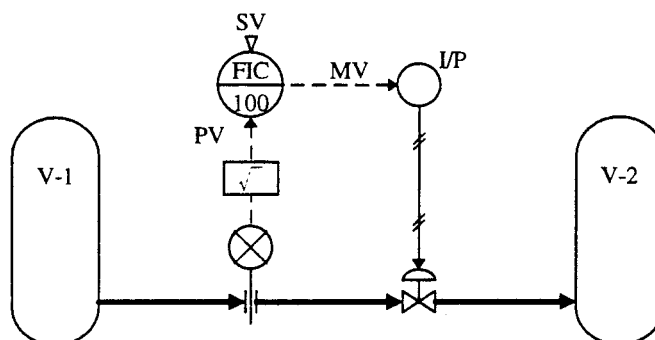


Fig. 3.1.3b shows a typical representation of flow control, however, when there is no ambiguity, [SV], [PV] and [MV] will not be shown on the P & I diagram.

Fig. 3.1.3b Typical Flow Control Loop on P&ID



In the control loop diagram, PV, SV and MV are denoted as follows;

- PV (CV) : Process Value, (Controlled Variable) from measurement.
- SV (SP) : Set Value, (Set Point) as the target point for a controller.
- MV (OP) : Manipulative Value (Controller OutPut) to valve stroke.

The PID control algorithm is expressed by the following mathematical formula, as a sum of Proportional action, Integral action and Derivative action on deviation, “e”.

$$MV = \frac{100 [\%]}{PB [\%] \cdot RANGE} \left\{ e + \frac{1}{Ti} \int e \cdot dt + Td \frac{de}{dt} \right\}$$

(P-Action) (I-Action) (D-Action)

where e = PV - SV (Deviation for Direct control action)
 = SV - PV (Deviation for Reverse control action) (Refer to 3.1.12)

This PID expression is the basic theoretical representation, and the actual PID algorithm could be in a slightly different form and modified depending on controller manufacturers.

In DCS, an incremental PID algorithm is employed, but this topic is not taken up in this text.

In order to improve or stabilize the closed loop response for dynamic stability, “parameter tuning” of a PID controller will be carried out by adjusting three parameters; PB [%], Ti [sec] and Td [sec]

PB [%] : Proportional Band

Ti [sec] : Integral Time (Reset Time)

Td [sec] : Derivative Time (Rate Time)

It should be noted that PB and Ti appear in the denominators and Td appears in the numerator. The less PB or Ti is, the bigger the control action is for a given error “e”.

3.1.4 DCS (Distributed Control System)

At the advent of computer microprocessor, process controllers are nowadays installed in microprocessors specialized for process control purposes, which is now commonly called DCS (Distributed Control System), incorporating PID control mechanism as computerized control software algorithm.

The advantages of DCS over conventional analog controllers are ease of operation by CRT (Cathodic Ray Tube) operation, ease of maintenance for later modifications. Furthermore, DCS is inexpensive in investment, compact in layout and reliable in comparison with conventional board mounted panel instrumentation.

Therefore, DCS is now widely employed for process control fields.

However, the basic functions of PID controller remain the same as before, with some minor improvements in operational functions. DCS is installed in a CCB (Central Control Bureau) and plant operation is mainly conducted on DCS by operators in CCB.

3.1.5 Single Feedback Control Loop

Single feedback controls are basic control loop configurations and used in most cases where the effects of external disturbances on the process operation are sufficiently small, compared with the required control range, and the cycles of the external disturbances are long, compared with the response in the process operation. Single feedback controls of FC, PC, LC and TC are widely used as basic regulatory process controllers. (See any PFDs or P&IDs)

3.1.6 PID Controller

(1) Proportional Control (P-action Control)

The proportional control is the basis of a PID controller, but P-action controller alone is not usually employed because the P-action control has the demerit of undesirable offset. By setting a smaller parameter for PB, P controller can reduce the offset but may cause dynamic instability as well.

Offset: Existence of undiminished error between PV and SV.

(2) Proportional plus reset control (PI Control)

The P+I action control is most often employed, because it can eliminate an offset by I-action.

However, tuning has to be carried out carefully. If Ti (Integral time or reset time) is selected too small, I-action becomes excessive and closed loop response would become oscillatory or “hunting”.

(3) Proportional plus reset plus rate control (PID Control)

D-action control will be effective for processes with large capacity or slow open loop response such as temperature control for heaters with huge heat capacities. D-action control detects the slope or rate of deviation change, and when it finds that PV is departing from SV very fast, the D-action control output will act to bring back PV to SV in proportion to the departing speed of PV from SV together with the P-I action.

3.1.7 PID Tuning Parameters and Tuning Practice

- : PB (Proportional Band)
- : Ti (Integral Time or Reset Time)
- : Td (Derivative Time or Rate Time)

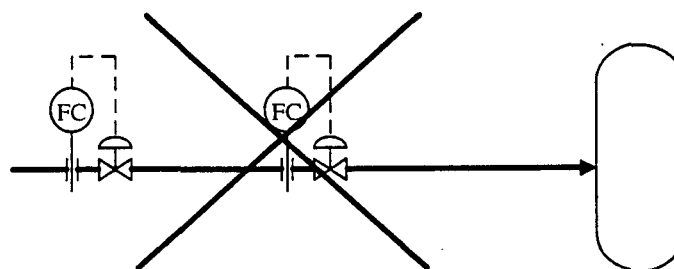
Parameter tuning of PID controllers would be important to make the plant operable, and it is sometimes required for an Engineering Company Engineer to tune PID controllers as a part of commissioning activities at site. The best values of tuning parameters depend on the process dynamics, and guides of tuning practices are discussed in various textbooks.

3.1.8 FC (Flow Control)

- (1) Square root calculation ($\sqrt{\quad}$) is required to convert the measured value of differential pressure across the orifice plate into flow rate, because the differential pressure at orifice plate is proportional to the square of flow rate.
- (2) To control or measure the exact mass flow, flow compensation by operating temperature, operating pressure and operating density would be necessary to correct the flow measurement by orifice plate against the design point of the orifice plate.

Gas flow rate	:	Pressure and temperature compensation.
Liquid flow rate	:	Temperature compensation.
- (3) FCV (Flow Control Valve) is almost always located adjacent at the downstream side of orifice measurement point, because an orifice plate for flow measurement requires at least 10 D straight pipe length in the upstream side to establish a stable flow pattern. Hence, as a valve would generate flow turbulence in the outlet side, a FCV should be located at the downstream side of the orifice plate.
- (4) The control response of FC is fast and noisy, and P-I control is usually employed for flow control without D-action.
- (5) As can be seen in Fig. 3.1.8 below, two FC's should not be placed along the same stream line, because these two FCs conflict each other and one of two FCV will become fully open. In the same context, at junction points of three or more stream lines, all stream lines should not be FC controlled but one stream has to be left free from FC control. The flow rate of this stream should be established by flow controllers of other flow controllers. Control loop configurations must satisfy the degree of freedom of process control.

Fig. 3.1.8 Two FC's on Onstream (Wrong Configuration)

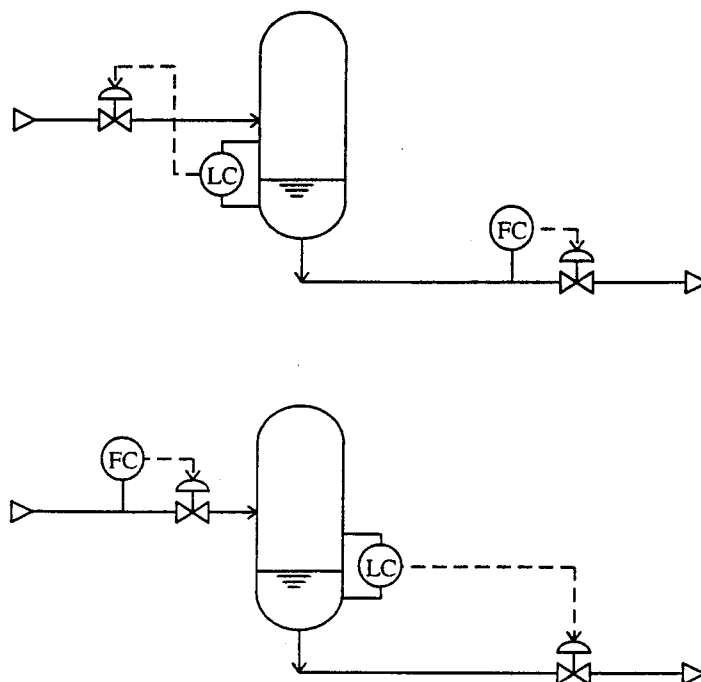


3.1.9 LC (Level Control)

LC is a kind of hold up control, and there are two cases of LC application; one case is that LCV (Level Control Valve) is located at the upstream of a drum, and another case is that LCV is located at the down stream of a drum.

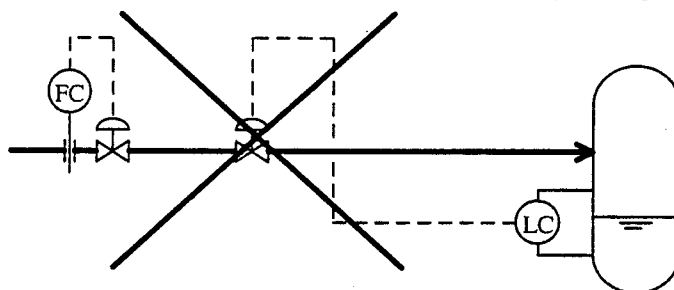
The selection of up-stream LCV or down-stream LCV depends on whether incoming flow rate is set or outgoing flow rate is set. When in-coming flow rate is set, LCV has to be located at the down-stream side, and conversely when outgoing flow rate is set, LCV has to be located at up-stream side as shown in Fig. 3.1.9a.

Fig. 3.1.9a Level Control



If up-stream flow rate is set and LCV is also located at up-stream side, this control configuration is unworkable because FC and LC conflict each other as shown in Fig. 3.1.9b below and both FCV and LCV cannot be placed along the same stream line. If this control configuration is employed, FCV or LCV reaches at a full open position due to the violation of the degree of control freedom.

Fig. 3.1.9b FCV and LCV on One Stream Line (Wrong Configuration)



3.1.10 PC (Pressure Control)

- (1) PC is used for keeping the process condition at the required pressure so that product specifications be met for reaction condition or separation condition.
- (2) PC is also considered as a hold up control for gas phase similar to LC for liquid.
There are two cases of PC application; one case is that PCV (Pressure Control Valve) is located at the upstream of the drum, or PCV is located at the down stream of the drum.
The selection of up-stream PCV or down-stream PCV depends on whether incoming gas flow rate is set or outgoing gas flow rate is set. When the in-coming gas flow rate is set, PCV has to be located at down-stream side, and conversely when the outgoing gas flow rate is set, PCV has to be located at up-stream side. This is the same argument as described for liquid level control.
- (3) The pressure in a region enclosed by control valves, pumps and compressors is essentially the same with some pressure drops along the pipe length. Therefore, two or more pressure controllers should not be placed in the same region, because these redundant pressure controllers conflict each other.
However, as an exception, PSV or PC for the purpose of emergency blow-off can be placed for the same gas phase region, because PSV or PC for evacuation is usually not in operation during normal operation but only active during abnormal conditions for safety reason.

3.1.11 TC (Temperature Control)

Temperatures are important operation conditions for reaction and separation processes. Usually dynamic response of temperature change is slow due to large heat capacity and/or slow heat transfer rate, and in order to make the closed response faster, P+I+D controller are employed for temperature control.
However, temperature control for line mixig is rather fast, and please note that temperature sensor for mixing needs to be installed at 10 D or more distance from the mixing point to ensure complete mixing.

3.1.12 Direct/Reverse Action of PID controller

If, when PV becomes greater than SV, the control valve needs to move to open direction from process point of view, then the controller has to be designed to be a Direct Action controller.
On the contrary, if, when PV becomes greater than SV, the control valve needs to move to closing direction from process point of view, then the controller has to be designed to be a Reverse Action controller.
For an example, FC has to be a Reverse Action controller, because, when the flow rate becomes greater than the target value, the control valve needs to move to a closing direction to force the flow rate to be reduced and brought back to the target set point value of flow rate.

Note: The argument above is valid only for a CV which is failure close type valve. When a CV is failure open type valve, Direct/Reverse selection must be reversed from the view point of control signal.

3.1.13 FO/FC (Failure Open/Failure Close) of CV

Any control valves have to be carefully defined whether it should be FO (Failure Open) or FC (Failure Close) or FL (Failure Lock) when valve actuator functions are lost. This aspect is discussed in JGS 210-120-1-60E "Control valves".

There are several failure possibilities at valve actuators: loss of actuator power source (eg, pneumatic air supply loss), and loss of control signal due to cable disconnection.

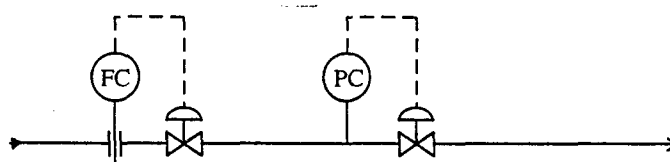
The selection of controller Direct/Reverse Action and LSS/HSS (Refer to 3.3.3) or SR (Refer to 3.3.2) definition of control signals should be carefully made based on the FO/FC selection of CV (control valve). Signal reverser may be required to be inserted properly in the control signal loop.

3.1.14 Basic Check Points of Finding Erroneous Control Configurations:

- (1) First of all, find or determine major flow controllers which define the throughput or total charge rates to the plant and this FC determines the plant production capacity instructed or commanded from Production Planning Department.
- (2) Mark the stream line in the up-stream direction and down-stream direction, starting the FCV defining the plant throughput, until junction point or branch point or vessells/drums so that the flow rate of the stream line is determined by this throughput FC.

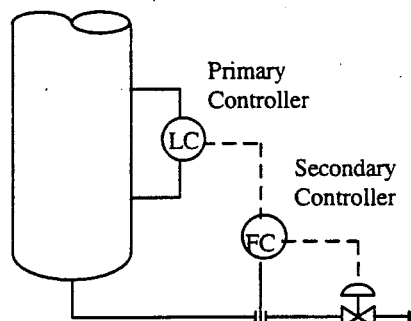
- (3) Mark the region of gas phase for which a PC controls the pressure.
Make sure that there is only one PC for the region during normal operation. Also mark the region for which pressure is not positively controlled but established by hydraulic balance of incoming/outgoing flow under the PC loop.
- (4) At drums, e.g. flash drums or surge drums, the vapor/liquid ratio is dependent of its operating temperature, pressure and stream compositions, and the drum pressure has to be controlled for proper operation.
- (5) Confirm that flow rate of every stream line is positively established by a controller. Check and report if the flow rate of a stream line is indeterminate depending on pressure balance. An example of indeterminate flow, for which the stream flow rate is not positively controlled, is symmetric piping arrangement for a furnace intended for even distribution among parallel branches. This symmetric piping arrangement intended for even distribution is not good practice from the control point of view, because each flow rates are dependent on the piping frictions which may not be the same and may vary with time. Nevertheless, this symmetric piping for even distribution without any FC controllers is adopted, because small pressure drop is preferred.
(For example, process pipings for Air Cooled Heat Exchanger (AFC))
- (6) HCV is usually required for occasional manual adjustment for load changes. Manual valves should be generally minimized from the control point of view. If that HCV is just only for start-up operation, it is acceptable from the control point of view.
- (7) Along the entire procedure of control scheme design, make sure that control conflicts do not show up: There are many design variations of workable control loop schemes, and each workable control schemes have merits and demerits depending on the particular applications. However, as the minimum, care has to be taken to avoid control conflicts between loops which are not workable in practice. This is the most important point in designing the plantwide basic regulatory control loop configurations, and it is important to understand what "control loop conflict" or "degree of control freedom" means.
- (a) there should not be two or more FCs or flow regulating control on the same stream line (e.g. Fig. 3.1.8).
If found, check and report the control conflict and correct the control loop configuration.
- (b) At junction point or branch point, flow rate of one stream line has to be left without FC but determined from other stream lines FCs according to material balance. If redundant FC controllers are found, check and report the control conflicts and correct the control loop configuration.
- (c) The pressure of one region should not be controlled by two or more PC's. If redundant PC's are found, check and report the PC conflicts.
- (d) LC or PC has to be arranged in accordance of material balance control configuration. If it is found that control configuration are violating material balancing, check and report the conflicts. (e.g. Fig. 3.1.9b)
- (e) Confirm and make sure how the flow rates of each stream lines are established from the overall control point of view.
- (f) Two FC control loops in series on one stream line are not workable due to control conflicts.
However, FC control loop with PC control loop on one stream line in series is workable from the point of degree of control freedom. See Fig. 3.1.14a.
However, it should be noted that successive PCs on one stream line should have adequate gas volume between control valves.
- (g) PC, which looks to be violating the degree of freedom of control configuration, is employed for relieving excessive vapor to flare, but, in this PC application, the pressure set point is above the normal operating pressure and is usually not in operation.

Fig. 3.1.14a FCV and PCV on One Stream Line (Workable)



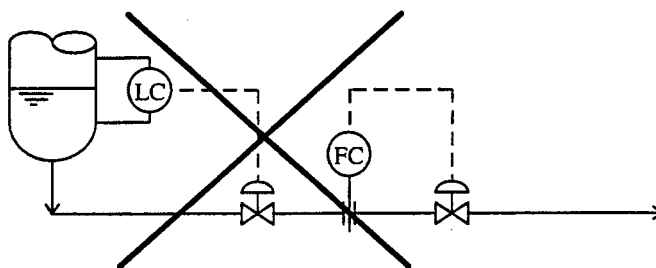
(h) LC-FC cascade control at the discharge line out of a vessel is workable (e.g. Fig. 3.1.14b)

Fig. 3.1.14b Cascade Control



LC control together with another FC control at the discharge of a vessel is not workable because they conflict each other. See Fig. 3.1.14c.

Fig. 3.1.14c LCV and FCV on One Stream Line (Wrong Configuration)



3.1.15 Positioner of a Control Valve

Although a control command signal of 4-20 mADC is sent out from a PID controller to adjust the stroke of a control valve, the actual valve opening may not follow the command signal due to internal unbalanced force or friction between the valve stem and the packing material. In order to overcome these forces, a "valve positioner" is sometimes used at the valve actuator. The valve positioner is in a sense a position controller with a fixed narrow proportional band to force the valve opening to match the command signal.

3.2 Selection Procedure

3.2.1 General Precautions to be Taken

- (1) To design a well-fitted control scheme, it is very important to select correct control objects, measuring points and controlling point with the full understanding the followings:
 - (a) Characteristics of the processes concerned
 - quality specifications of outlet streams
 - which outlet streams are products
 - which outlet streams are wastes
 - relative importance of each product streams and qualities
 - operating condition requirements on temperature, pressure, and flow rates.
 - (b) Control techniques and their principles
 - (c) Functions of each control equipment
- (2) Control scheme design and process design cannot be planned independently or separately. The process flow schemes, equipment types and their operating conditions must be studied together with the planing of control schemes.

- (3) It should be noted that local control configuration, instead of centralized control, should be employed for controlling minor line streams or intermittent streams for the design economy.

3.2.2 Selection of Controlled Variables and Manipulated Variables

The important thing in the planning of control schemes is selection of controlled variables and manipulated variables from among many process variables. For this, the following can be pointed out as general criteria:

(A) Selection of Controlled Variables

- (1) Select process variables representative of the process objectives.
- (2) Select other process variables which can affect the above variables dominantly.
- (3) However, in many actual cases, measurement may be difficult and/or time lags may be too large for direct control.
- (4) Therefore, review the fluctuation ranges and the degree of importance of the product quality, yield and cost, and decide on the controlled variables with consideration given to ease of their measurement, their dynamic characteristics, the effects of external disturbances and other relevant matters.
- (5) The stream pressure propagates very fast within a enclosed space at the speed of sound, but the stream composition would move at the speed of stream flow itself.
The temperature change is relatively slow due to heat transfer and heat capacities. However, the temperature response at a mixing point is not so slow.

(B) Selection of Manipulated Variables

- (1) Select process variables which can vary the controlled variables primarily; namely variables which can change the intended variables largely without affecting other conditions (variables).
- (2) The time lag must be small in comparison with the control amount.
- (3) The controllable ranges of the variables must be sufficiently large for the correction control; namely, their allowances must be sufficient for changes in the set point and for external disturbances.

3.2.3 Product Quality Control

- (1) Normally, product quality control is not provided by so-called "direct control" in which the composition is directly measured and controlled. So-called "inferential control is used", in which the product quality is evaluated and controlled indirectly by measuring process variables such as temperatures, pressures, flow rates, and liquid level.
- (2) For example, the quality of overhead products from usual distillation towers can be substantially regulated by temperature control with the pressure fixed at a certain level.
- (3) The major reasons why direct control is not used, are as follows:
 - (a) Analyzer's time lag is long (including sampling time of a Gas Chromatography).
 - (b) Analyzer's reliability is low.
 - (c) Direct control itself is difficult.
- (4) Also, there are limitations in inferential control: when the operating conditions vary, variations will occur in the relationships between the product quality and control amount. However, as analyzers reliabilities have been recently improved, direct controls have been already used in some plants by Advanced Process Control techniques.

3.3 Integrated Control

Depending on the conditions of process disturbances, single feedback controls cannot (may not) serve the purpose owing to various reasons. In such cases, the following measures are used:

- (1) To remove disturbances by using minor cascaded control loops before they affect the major controlled variables.
(For example, cascade control)
- (2) Measuring external disturbances incoming and predicting the dynamic effects on the process unit, to adjust the manipulated variables to cancel out the disturbances before their effects show up considerably later.
(For example, Feedforward control)
- (3) Switch the control loop to another control valve which is suitable for the type and/or size of the disturbance.
(For example, selective control or split range control)

3.3.1 Cascade Control (CAS Control)

- (1) Cascade control loop consists of two controllers.
The control output (MV) of the primary (major) controller resets the set point of the secondary (minor) controller.
- (2) Cascade control is intended to improve the response, reducing the effects of time lag and/or several other disturbances.
- (3) If the response of the secondary controller is not sufficiently fast, compared with that of primary controller, interference may occur between the two controllers. For this reason, the secondary controller must be of quick response type, usually flow control.
- (4) Fig. 3.1.14b is an example of cascade control used for liquid draw-off from a vessel.

The cascade loop, (LC-FC-Valve) is beneficial compared with a single loop, (LC-Valve), in the following sense;

When a single loop (LC-CV) is used and the pressure around the CV (upstream pressure or downstream pressure) varies by some reasons, the flow rate through the CV varies and its flow variation will eventually affect the liquid level in the drum, and only after the level change is detected by LC, LC starts corrective control action and it may be too late for the level control.

On the other hand, when a LC-FC-Valve cascade loop is applied, the secondary FC detects the flow rate change due to pressure variation and controls the flow rate beforehand without any changes in the vessel liquid level.

LC for a water boot level control is usually a simple LC-Valve arrangement.

3.3.2 Split Range Control (S.R. Control)

- (1) Split Range control uses two or more manipulated CVs for the same control purpose, depending on the MV range of the controller.

This SR control is effective and widely used to control a variable in a broad range.

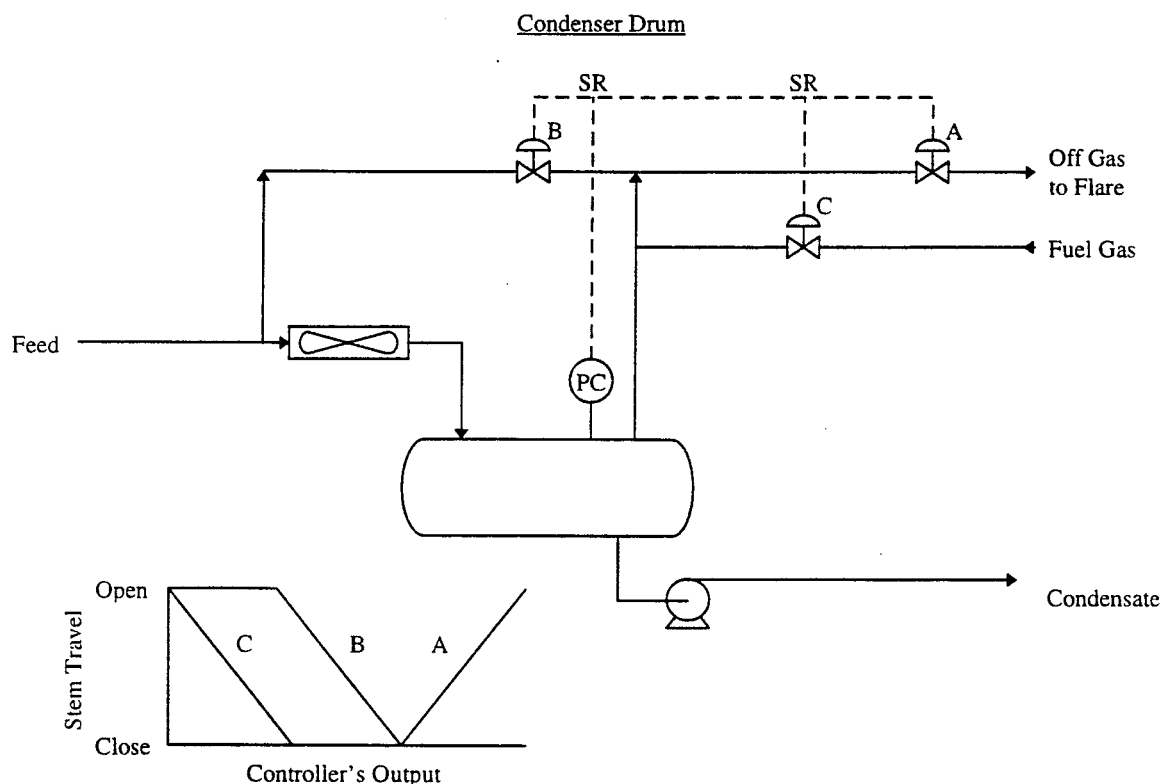
- (2) Fig. 3.3.2 shows an example of split range control used for a drum pressure, in which case three control valves are used since both total condensation and partial condensation are expected to occur in the air fin cooler outlet line.

The SR pattern in this application works as follows:

The drum pressure is usually controlled by throttling the control valve B, and, when the vapor rate becomes too small, the control action will move down to the control valve C to introduce additional Fuel Gas.

On the other hand, when the vapor rate is excessive, the control action will move up to the control valve A to relieve the excessive vapor to Flare.

Fig. 3.3.2 Split Range Control



- (3) There are several types of split range control patterns; (hat type, v-type, scissors type and X-type). This S.R. pattern has to be clearly shown on the P&ID for avoiding confusion during control scheme implementation and plant operation.
- (4) The S.R. control uses two or more CV's depending on MV from a PID Controller. Hence, controllability of the PID controller may differ from one CV to another CV depending on SR range width, and the parameter tuning would become troublesome. It is sometimes required to apply two single PID controllers for each CV thesedays instead of SR control for ease of tuning and operation.