02
Engineering Chemical Process Systems

Objectives

When you have completed study of this chapter you should be able to:

- Know the various models used to represent the chemical process systems;
- Understand the importance of a Process Flow sheet;
- Prepare a Piping and Instrumentation diagram (P&ID);
- Know the links between a Process diagrams and plant operation;
- Explain the significance of a plant layout.

2.1 Process Drawings

These drawings are used in the chemical process plants to facilitate operations, maintenance and revamp. The technical knowledge needed to run the plant should be contained in the relevant drawings.

Without the drawings, it would be difficult to explain or understand the processes that take place in the Process Industry and it would be even more complicated to try and make repairs or modifications.

The purpose of process systems drawings:

- Used by Process personnel to understand or explain a process
- Utilized by Process Technicians to repair equipment and understand relationships
- Referred by Operating staff to become familiar with the process in a safe environment
- Provides a Process Technician with visual representation of the process and equipment

All drawings have certain objectives in common:

Simplify - Drawings simplify complicated processes by using symbols to represent unit operations.

Explain - Drawings illustrate how all the parts or components of a system work together. A drawing can clearly and quickly show the details of a system that might otherwise take many written pages to explain.

Standardize - Drawings standardize information. Each industrial drawing has its unique symbol that represents a specific component. These symbols (with some fine changes) are used globally. If Process personnel are aware of these symbols, this knowledge will allow them to interpret drawings at any chemical plant .

2.2 Common Components of Process Drawings

All process system drawings have certain similar components that are universal to drawings. These components include:

Legend

This is a table that explains or defines all the information of a drawing. The information defined in this table includes:

- Symbols
- Abbreviations
- Numbers
- Tolerances
- Any other specific detail

Title Block

These are normally located in the bottom right-hand corner of drawings. The information included in the title block includes:

- Drawing number
- Revision number
- Drawing title
- Sheet number
- Signatures
- Allowances

Application Block

- Dimensions
- Shapes
- Descriptions

- Relative position
- Material of construction
- Functions

2.3 Types of Process Drawings

- Block Flow Diagrams (BFD)
- Process Flow Diagrams (PFD)
- Piping and Instrument Diagrams (P&ID)
- Electrical Schematics
- Isometrics

2.3.1 Block Flow Diagram (BFD)

Theses are the simplest drawings that are used in the Process Industry. They provide a very broad overview of the process and contain very few specific details. Block Flow diagrams represent sections of the process as blocks and they show the order and relationship between sections using flow arrows. Block Flow diagrams are useful in getting a high level initial understanding of a process.

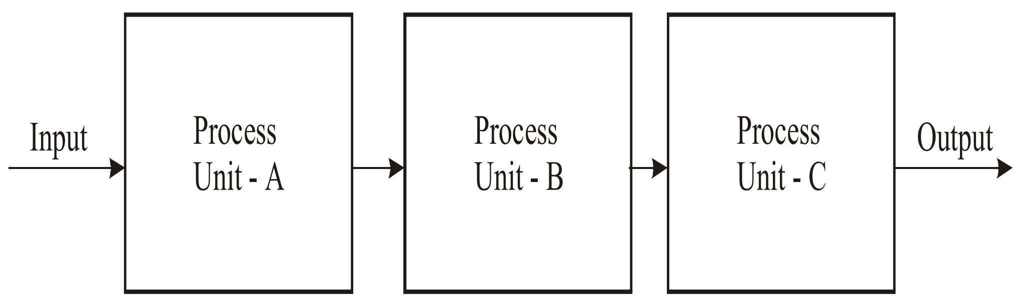

Figure 2.1
Typical Block Flow Diagram

2.3.2 Process Flow Diagram (PFD)

A process flow diagram is one in which all incoming and outgoing materials along with related utilities are indicated. It should be clearly understood that such a diagram is different from the P&ID.

Contents of a Process Flow Diagram

PFD's essentially illustrates the following:

- Indicates the critical equipments and instrumentation along with process conditions of pressure, flow, and temperature. May also include a material balance including compositions of the streams
- Are used to trace the process flow through a chemical plant or refinery
- Shows all the major equipments and piping, temperatures, and pressures at critical points, and the flow of the process
- Represents with symbols, a fluid system and the equipment associated with a fluid system
- Are valuable to Process technicians because they show how the process works and the steps associated with the process

It also provides critical information about:

- The major instruments in each area of the plant and where they are located
- The kind of equipment and the type of piping used in each stage of the process
- The utilities used in a process

PFD's contain information about the following types of equipments utilized in a chemical process system:

- Vessels
- Heat exchangers
- Pumps
- Compressors
- Heaters
- Instruments
- Valves
- Piping

Generation of a Process Flow Diagram

To develop a process flow diagram a considerable amount of information needs to be gathered. The essential details that needs to be reflected in a PFD are:

- Flow rate or quantity of each stream
- Operating conditions of each stream, such as pressure and temperature
- Heat added/removed in particular equipment
- Any other specific information, which is useful in understanding the process

From the above, it is clear that the PFD is a very useful diagram in the chemical process industry. It effectively communicates design information. It helps the operator in adjusting his parameters, the supervisor in checking/controlling the plant operation. If the basic process is simple and involves only a few steps, the P&ID and the PFD can be combined into one sheet.

Check List for the Preparation of Process Diagrams

- Identify an equipment arrangement diagram and describe the kinds of information available on it
- Identify an elevation plan diagram and describe the kinds of information available on it
- Identify a block diagram and describe the kinds of information available on it
- Identify a flow diagram and describe the kinds of information available on it

Typical Process Flow Diagram

A typical process flow diagram for Lime-Sulphuric Acid recovery process is shown below:

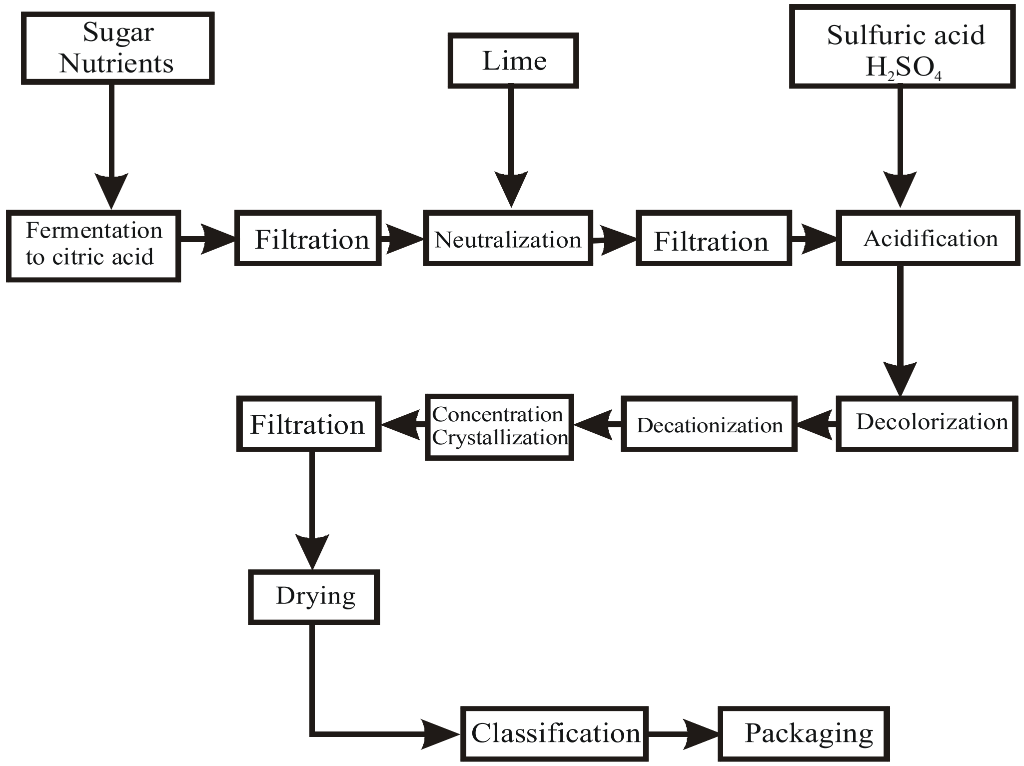

Figure 2.2
Typical PFD for a Lime –Sulphuric Acid Recovery Plant

To make it more complete, material and energy balance calculations are required to indicate the flow components into each unit operations and has been excluded to make it more simple.

2.3.3 Piping and Instrument Diagram (P&ID)

P&ID's are detailed drawings that reflect the piping, instrumentation and equipments along with design information such as piping size and other specifications.

P&ID's include:

- All the equipments used
- Complete instrumentation methodology
- Size and type of pipe
- Design conditions of the equipment

It contain information about the ways in which piping sections are connected and the instruments associated with the system. P&ID's describe the way in which fluids are directed and controlled. The majority of information about the piping systems comes from instruments that help control and monitor the system. It is critical that process personnel know where in the system the instruments are located.

They illustrate the equipment in detail and give information on piping dimensions and types. They show all the instruments used and the operating conditions of all the steps in a stage. It also provides valuable information about maintenance and repair work on piping systems.

P&ID- Basic Concepts

The P&ID is the major document used for publishing, reviewing and issuing process, piping, mechanical & instrumentation details. The P&ID's are ultimately the responsibility of the process discipline as it is here that they are first defined. However, all disciplines have an input to information that either exists directly on the P&ID or is referenced elsewhere through components that exist on the P&ID.

P&ID's are maintained throughout the life of the project / plant, being constantly reviewed, added to and modified. Any application used to create and modify these documents must be intuitive and easy to use, providing an intelligent / rule based environment.

Requirement & Definitions

The P&ID shows the following:

- ***Processing equipment details***

  All piping, electrical and instrument connections.

- ***Piping details***

  All isolation valves, check valves, strainers, drains and vents, line sizes, line numbers, valve numbering, line rating and material or service designations, connections to equipments, flanges required for special process and maintenance requirements, etc.

- ***Insulation requirements***

  Insulation required for piping and equipment for heat conservation, anti-sweat, and personnel protection, insulation thickness shall be also indicated.

- ***Instrumentation***

  Control and data logging loops are shown in detail to shown all functions and other special features. Connections to equipments and piping, interrelationships with the process and other instrument loops, all local gauges, instrument tag numbers.

- ***Special process requirements***

  They are indicated by notes and other specific means to make it more apparent.

- ***Hydraulic details***

  They include elevations required to supply NPSH to pumps and flow meters.

- P&ID is also essential for computing the following:
  - Tentative cost estimates
  - Project scope
  - Record of the as built plant configuration
  - Operational procedures and training aspects
  - Hazard and operability analysis
  - Process safety management

Drawing Format

These are the broad guidelines to be kept in mind when configuring a P&ID.

1. Only two to three sections of a equipment shall display on each drawing. This is to eliminate the possibility of the drawing to be split into two or more drawings at a later time as the details are added to it.
2. A pump and its spare parts shall be considered as one piece of equipment.
3. A very elaborate instrumented or equipment with a complex piping system shall be handled as one piece of equipment and explained in one drawing sheet. Typical examples of equipments that shall have their own P&ID's are:
   - High horsepower compressors
   - Individual tanks in a tank line
   - Separate tanks in a effluent treatment plant
   - Fired heaters and boilers
   - Combustion air turbines
   - Distillation columns, strippers, scrubbers, etc
   - Individual effects in multiple effect evaporator, etc
   - Product/ Feedstock transfer metering systems
4. Multiple P &ID's shall be arranged so that the main feed enters on the first one and the products exit on the last one.
5. All general flows shall be from left to right. Streams flowing to equipment on a previous drawing in the series shall exit to the left of the sheet.
6. Streams that are flowing to the immediately preceding or the next following drawing shall match at the match mark lines on the drawing edges.

7. Streams that are flowing to the drawings that are not adjacent do have to match up. It is a good practice to have the process streams leave and enter in the same general location where possible. A stream leaving the drawing near the top shall enter the referenced drawing near the top. Also, these streams are indicated in the intervening drawings.

8. It is always a thumb rule that all the streams shall leave a drawing only at the right or left margins-never at the top or bottom margin.

9. Streams shall enter a drawing only at the left or right margin-never at the top or bottom margins.

10. Process streams entering a drawing shall have an open arrow at the drawing margin indicating the direction of flow. It is required that the following details be included inside the arrow:

    - Stream name (Commodity)
    - Starting from (equipment number)

11. Drawing number or sheet number

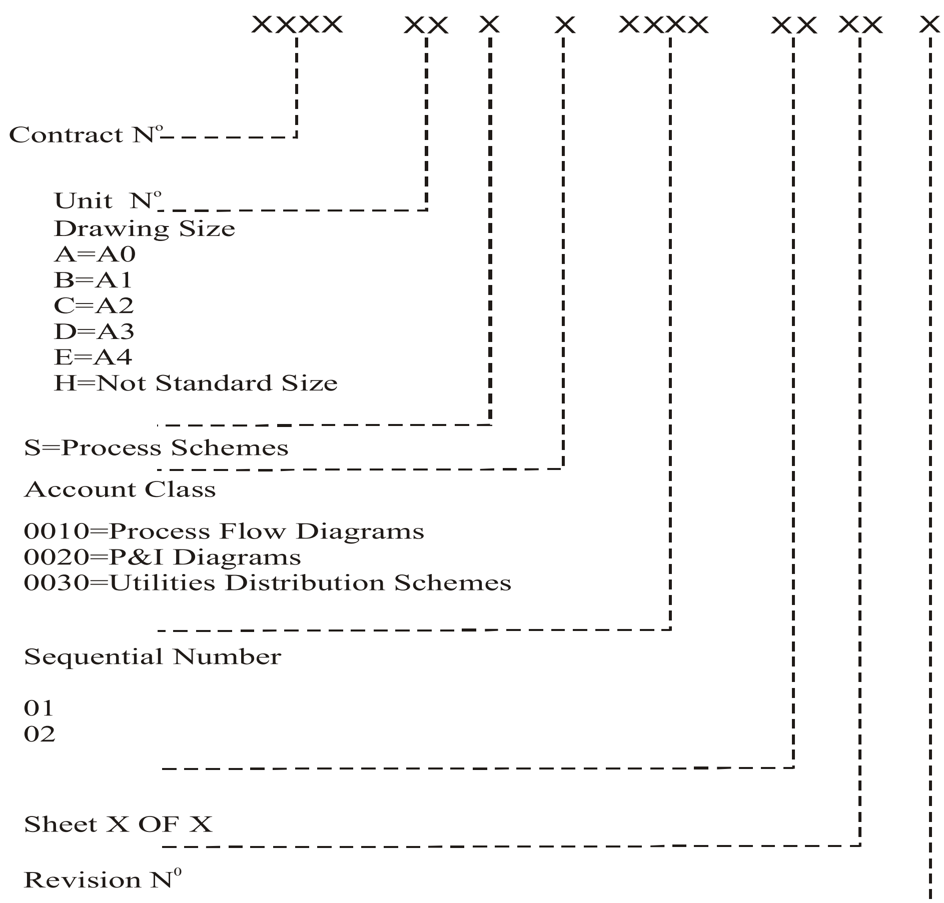

Figure 2.3
Drawing Numbering System

12. Process streams leaving a drawing shall have an open arrow at the drawing margin

    - Stream name (Commodity)
    - Starting from (equipment number)

13 Utility streams normally enter the P &ID from a box near the user equipment. The utility streams are referenced in boxes.

S. No	Description	S. No	Description
1	Fire Water	15	BFW
2	Service Water	16	Plant Air
3	Cooling Water	17	Instrument Air
4	Potable Water	18	Nitrogen
5	DM Water	19	Hot Oil
6	Treated Water	20	Fuel Oil
7	Quench Water	21	Fuel Gas
8	HHP Steam	22	Hot Flare
9	HP Steam	23	Cold Flare
10	MP Steam	24	Hot Blow down
11	LP Steam	25	Cold Bow down
12	HP Condensate	26	Closed Drain
13	MP Condensate	27	Acid Flare
14	LP Condensate		

Table 2.1
Utilities Identification

14. The box contains the following information:

    - Utility name
    - To or from utility drawing number

15. The direction of flow shall be indicated on the line entering/leaving the box.
16. The top two inches of the drawing shall be reserved for process equipment titles and information.
17. The bottom two inches of the drawing shall be reserved for rotating equipment titles and information.
18. Equipment shall be shown on the P&ID in vertical or elevation profile and in outline form so that all piping and instrument connections can be shown. Standard symbols can be used for equipment that is generally in a known standard configuration such as centrifugal pumps, metering pumps, etc. Equipment such as vessels and heat exchangers are shown in actual profile so that all connections can be located.
19. Internals are indicated, especially in vessels, so that connections may be shown relative to the internals. This is particularly true in vessels where baffles, trays, vortex breakers, packing and draw-off sumps are always shown. Tubes are not shown in heat exchangers. A solid line shall be used to indicate the tube sheets so that shell and tube sides can be distinguished. Flow paths in cold boxes and brazed aluminum heat exchangers are indicated by zigzag lines.
20. Trays are shown in enough detail to indicate the number of passes, which trays have center down comers and which trays have outside down comers. Also shown are draw off sumps and chimney trays, etc.
21. Pipeline specification changes for pressure rating, materials, etc. are shown on the P&ID. The specification change point shall be shown with a light line indicating where the change occurs. Pipeline insulation changes are shown in the same way. Also, pipe class schedules are commonly used to show these differences.

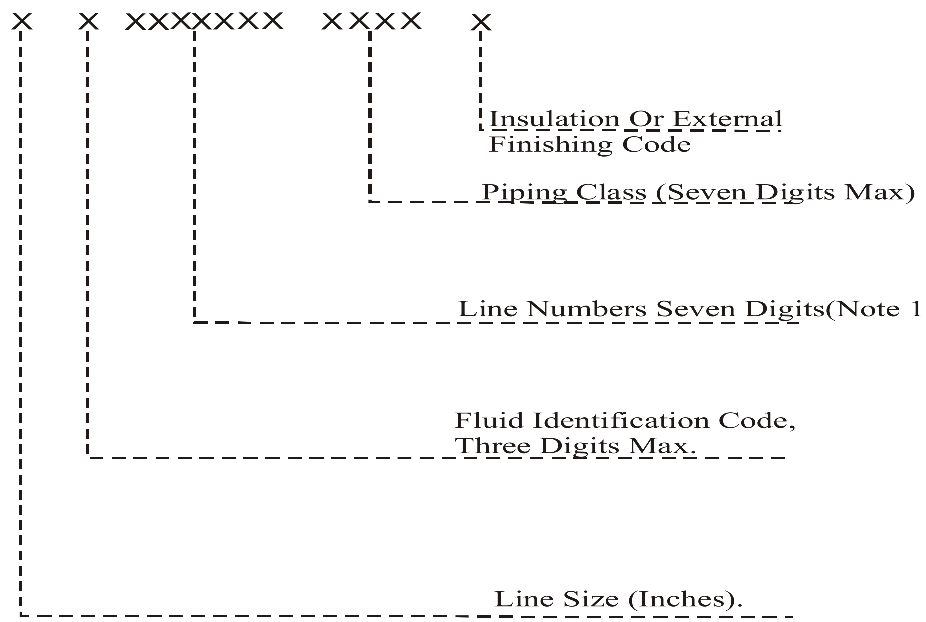

Figure 2.4
Pipeline Numbering System

Note

The seven digits are defined as follows:

- The first two digits denote the plant Units
- The second two digits are referred to the P&I where the line is generated (01,02…..)
- The last three digits are relevant to the sequential line number
- Process lines (001 — 299)
- Utilities lines (301 – 399)
- Miscellaneous equipment connections (401 – 499)

22. Use of "TYPICAL to ##" for displaying information on identical items shall be avoided; it shall only be used as reference. It is unacceptable:

    - To call out on the drawing "TYPICAL" and not list the instrument or piping device tag numbers of the items not shown.
    - Where identical items of unit process equipment are replicated and directly connected in a processing system, to show the detail for one piece of equipment and call out on the drawing "TYPICAL OF ##". Every piece of unit process equipment must be displayed on the P&ID's.

2.4 Equipment Data

- ***Master Equipment List***

1. The equipment list, or master numbering/naming identifiers will be provided by the project engineer or be developed together between the company and the supplier/designer.
2. The controlling engineering document for equipment numbers and equipment titles is the Master Equipment List.
3. Equipment numbers and titles shall be shown exactly as listed on the Equipment List. Care must be exercised on any engineering drawing or document concerning equipment to prevent confusion as to which equipment is being discussed.

Class	***Subject***	***Description***
A	Mixing Equipment	Agitators, Aerators, Mechanical Mixers
B	Blowers	Centrifugal Blowers, Positive Displacement Blowers, Fans
C	Compressors	Centrifugal, Reciprocating, Screw, Vacuum
D	Mechanical Drivers	Electric and Pneumatic Motors, Diesel Engines, Steam and Gas Turbines
E	Heat Exchangers	Unfired Heat Exchangers, Condensers, Coolers, Reboilers, Vaporizers and Heating Coils, Double Pipe, Spiral, Plate & Frame, Air Coolers
F	Furnaces	Fired Heaters, Furnaces, Boilers, Kilns
P	Pumps	Horizontal and Vertical Centrifugal, Positive Displacement, Vertical Canned, Screw, Gear, Pump
R	Reactors	
T	Towers / Columns	
TK	Tanks	API atmospheric and low pressure
U	Miscellaneous Equipment	Filters, Bins, Silos
V	Drums	Separators, Driers, Accumulators

Table 2.2
Equipment Classification

- ***Equipment Number Location***

  1. The equipment number shall be shown in two locations. First, inside or near the equipment symbol. Second, either at the top or at the bottom of the drawing depending on the type of equipment.
  2. The project engineer will provide specific information showing the location of the titles and the equipment data by equipment type.
  3. The equipment number shall be 0.125" high and shall be always underlined.
  4. The equipment title shall be shown under the equipment number at either the top or at the bottom of the drawing. The entire equipment title shall be shown exactly as shown on the equipment list. The equipment title shall be 0.125" high and shall be underlined.

- ***Equipment Size Notation***

  1. The equipment size/design capacity shall be shown under the equipment title. The equipment design data shall be used on the P&ID as opposed to the operating data shown on the process flow diagram. The design capacity often differs from the operating capacity by some capacity factor which depends on the Owner and the type of equipment.
  2. The design size/capacity data shown on the P&ID depends on the type of equipment. The size/design capacity data shall be 0.100" high and shall be not underlined.

- ***Insulation Notation***

  1. The equipment insulation requirements shall also be shown under the size/design capacity data. This information includes the type (purpose) of insulation and the thickness in inches.
  2. The insulation data shall be 0.100" high and shall be not underlined.
  3. Insulation type shall be always indicated for all process equipment except for process heaters. Typical insulation notes would appear as follows:

     Insulation: None

     Hot Insulation: Ih 1 1/2"

     Cold Insulation: Ic 2"
  4. Insulation thickness is worked out between the Process and Piping/Mechanical Departments.

2.5 Symbols

The equipment and piping symbols are standardized uniformly so that it can be used to represent and generate drawings. These documents are vital for design and plant operation.

Figure 2.5
Process Equipment Symbols

(Refer Appendix A)

- Instrumentation symbology will be per the latest revisions of the following Instrument Society of America (ISA) standards.
    a. ISA-S5.1, Instrumentation Symbols and Identification
    b. ISA-S5.2, Binary Logic Diagrams for Process Operations
    c. ISA-S5.3, Graphics Symbols for Distributed Control/Shared Display instrumentation, Logic and Computer Systems

There are numerous instruments and control loops in CPI's. All of them are standardized and are used in a process flow sheet that can be read and used for plant operation.

Figure 2.6
Instrument Representation

(Refer-Appendix B)

- The Piping and Instrument Diagram (P&ID) symbols are generally less schematic than the Process Flow Diagram symbols. For vessels, towers, etc. the symbol shall reflect the general outline of the vessel. If the tower is swaged, the swage shall be shown. If the vessel is squat, that shall be shown.

2.6 Responsibilities

- The engineer responsible for the development of the P&ID's and the operability and safety of the plant is referred to as the "Process Engineer" in this document regardless of engineering discipline.
- The Process Engineer is responsible for the development of the P&ID's. Information is added to the P&ID'S by the Piping Engineer, the Piping/Mechanical Designer and the Control Systems Engineer, but the Process Engineer has overall responsibility for P&ID content and format.

- The Piping/Mechanical Engineer and Designer are responsible for adding pipeline numbers to the drawings. They are also responsible, along with the Process Engineer, for pressure rating of the pipelines and with the material of construction for the piping (or selection of pipe class) and for the points of change for the material(specification breaks). The Piping/Mechanical Engineer also shares responsibility with the Process Engineer for insulation requirements and specifications.

- The Piping Designer is responsible for assuring that the piping drawings and the P&ID'S are in agreement. He adds information to the P&ID'S as the piping design progresses. The Piping Designer makes revisions to the piping shown on the P&ID with the approval of the Process Engineer. These changes generally occur as the physical design of the piping is developed and represents the steps necessary to convert from paper work to reality.

- The Process Engineer makes the first pass at the control scheme of the process. Using standard ISA standard symbols, the Process Engineer describes the process control requirements and a system that shall work. The Control Systems Engineer modifies this control scheme to show how the system is put together using the hardware that is to be used on the project. The Control Systems Engineer works out improvements to the proposed system with the approval of the Process Engineer. The Control Systems and Process Engineers have to work very closely to ensure that the completed plant will start up and shut down safely and can be successfully operated.

- The Control Systems Engineer has the sole responsibility of assigning tag numbers to the instrumentation.

2.7 Revision Control Procedures

The following suggested steps are recommended to ensure the quality of the P&ID. These should be adhered to, particularly if design is done by multiple vendors or engineering firms. The exact method of development of the drawing is up to the project engineer as long as standards set in other sections of this procedure are followed.

- ***Development Revision A***

  1. The Process Engineer develops the P&ID as Revision A. This revision shall include the following information as a minimum requirement:

     a. All Process Equipment Including Equipment Numbers and Titles

     b. All of the Major Process Lines

     c. All Control Valve Stations

     d. All Major Control Loops in Simple Format

     e. Major Utility Connections

2. Revision A is not an official issue and is not governed by the Project Procedure Manual. Its purpose is to get an early copy of the P&ID to those people who contribute to its development.
3. Revision A shall be issued to the other subsystem designers (piping, control, mechanical) and the project manager.

- ***Development Revision B***

1. The Process Engineer adds information provided by control systems and piping as well as information provided by the equipment vendors as it becomes available. During this period the following information is added to the P&ID, which becomes Revision B.
    - Pipeline Sizes
    - Pipe Material and Specification Breaks
    - Insulation/Heat Tracing Requirement and Specification Breaks
    - Remaining Instrumentation
    - All Utility Connections
    - Emergency Shutdown Systems
    - Relief Valve Setting and Sizes
    - Equipment Elevations where required for Process Reasons
    - Instrument Numbers if Available*
    - Pipeline and Valve Numbers if Available*

    **If these items are not available, then a note such as "instrument numbers to come" is put on the Revision B drawing.*
2. Revision B is issued internally within the Project Team to the people who received Revision A.
3. An internal line-by-line review shall be held, conducted by the Process Engineer.

    The following shall be present:
    - Project Engineer and relevant management
    - Process Engineer
    - Piping/Mechanical Engineer
    - Control Systems Engineer
    - Lead Piping Designer

- ***Development Revision C***

1. Comments from this internal review and any additional supplier data shall be added to make Revision C and the P&ID shall be issued officially for approval.
2. Revision C shall be used for the P&ID review with the team to gain formal approval by the project manager. This is a line-by-line review. This review P&ID shall be formally signed (by both Supplier and owner) and kept on file.

- ***Approved Design***

1. The P&ID shall be updated by the Process Engineer (or under his direction) per the Owner review comments and shall be issued as Approved For Design Revision 0.
2. Additional numbered revisions are issued as deemed necessary by the Process and Project Engineers. During the life of the job a P&ID master shall be maintained on the design floor. This master is marked up as required by the Process Engineer, the Control Systems Engineer, the Piping Engineer, and the Piping Designers. The marks are periodically reviewed and approved or disapproved by the Project Engineer. These marks form the basis for the additional numbered revisions.
3. P&ID progress can be accounted in general as follows:

Milestone	***% Complete***
Initial Drawing - Revision A	30%
Developed Drawing - Revision B	45%
Internal Review - Revision C	50%
Owner Review - Issued for Design - Revision 0	60%
Owner Review - Issued for Design - Revision 1	70%
Owner Review - Issued for Design - Revision 2	80%
Owner Review - Issued for Design - Revision 3	90%
Owner Review - Issued for Design - Revision 4	95%
Owner Review - Issued for Design - Revision 5	97.5%

and so on…..

2.8 Utility Flow Diagram (UFD)

They primarily indicate the following details:

- Show the piping and major instrumentation used to operate the utilities in a process
- UFD's are basically a P&ID drawing for utilities
- Show the way in which utilities are connected to the process equipment for service

Typical utilities include:

- Steam
- Condensate
- Fuel oil
- Instrument air
- Utility air
- Cooling water
- Drains
- Process and reclaim water
- Flares

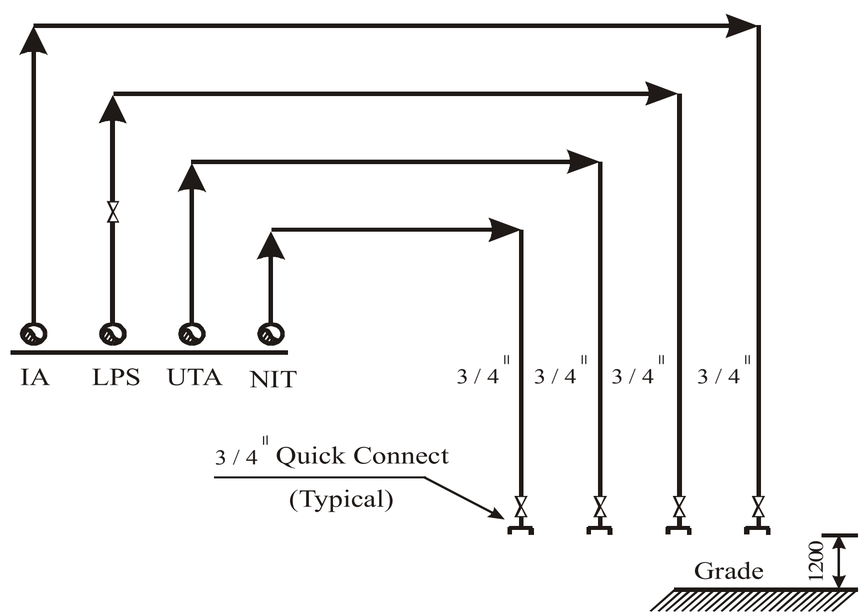

Figure 2.7
Typical Utility Flow Diagram

2.9 Electrical Drawings

- Most equipment used in the process industry is powered by electricity. For this reason, it is important that a process technician understand the system, how it works, and how it is maintain.
- Electrical drawings contain information on how electrical components and devices are connected to provide electrical functions
- Wiring diagrams show the interconnecting wiring between field and control room devices including routing and cable numbers
- Are intended to show the physical layout of the wires
- Used when specific information is needed about the way in which components are connected
- Used when information is needed about where components are physically located

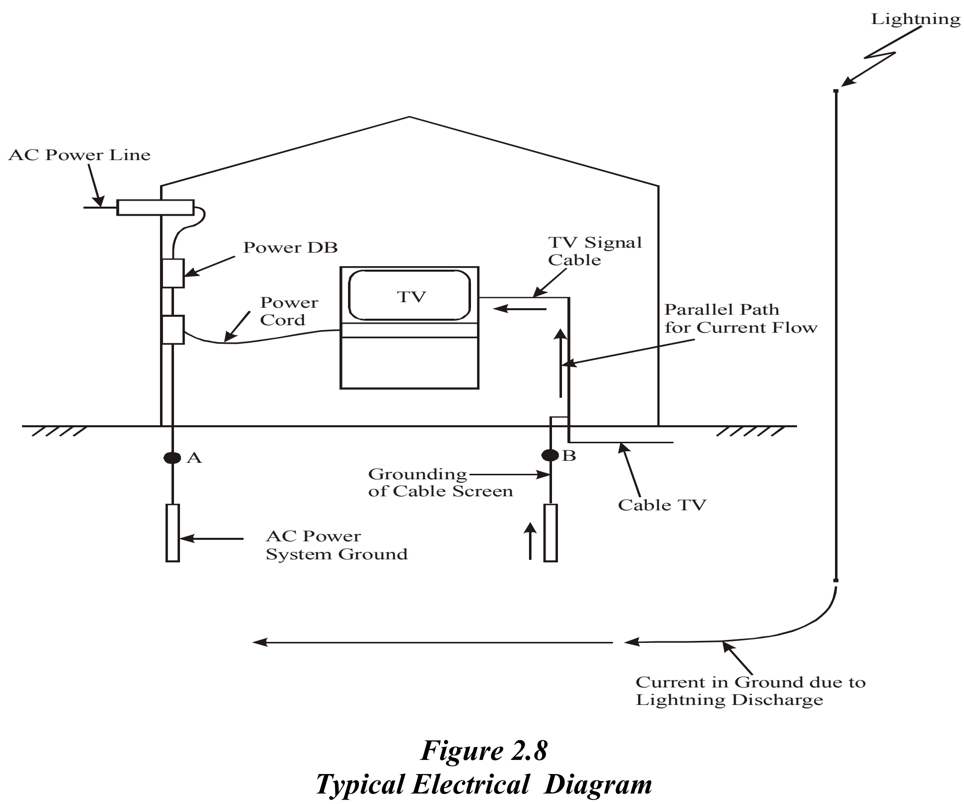

Figure 2.8
Typical Electrical Diagram

2.10 Schematics

They are essentially used to serve the following purpose:

- Show the electrical connections between all components in a circuit or device
- Used to determine a troubleshooting strategy for the circuit
- Used to locate test points in a device or circuit
- Shows expected voltages for troubleshooting
- Used to see how current flows between two or more circuits that form a large system

2.11 Data Sheets

Data sheets are specific formats used to arrive at equipment and instrument specifications. They may be classified into the following categories:

- ***Process data sheets***

  They define the operating and design parameters for a equipment or a rotating machinery envisaged for a plant or unit operation. They form the basic document to consolidate on the basic engineering package for any project

- ***Instrument data sheets***

  These formats explains the instruments involved in a project and the control philosophy adopted for plant operation and safety

- ***Mechanical data sheets***

  It explains the mechanical aspects for all the stationary and moving machinery including heavy equipments like cranes ,trucks etc

- ***Electrical data sheets***

  All the motors ,switches , transformers and other circuits are indicated in these formats

- ***Civil data sheets***

  Plant layouts designs , foundations, structural details etc are mentioned in these formats

2.12 Plant Layout

Importance of a Plant Layout

Plant layout is the physical arrangement of the proposed unit operations on the selected site. Due attention must be given to logically locate the process units in terms of approach, piping networks, safety, future expansion, etc. A good layout will integrate the above functions in the most economical way. It should be kept in mind that the site design depends on natural and social factors. Hence it is very important that efforts should be made to get familiar with the proposed site and its neighborhood.

Past experience has revealed that a proper layout will

- Improve the aesthetic appeal of the site
- Meet the operational requirements of the plant processes
- Suit the maintenance personnel need
- Reduce construction and operational costs
- Offers scope for future expansion and modifications
- Preserves the landscaping and plant structures in harmony with the environment

Criteria for Plant Layouts

Site Topography and Geology

The plant layout should take into consideration existing site features such as character, topography and shoreline.

These factors should be given priority in the design of a layout:

- A site on a side-hill slope can facilitate gravity flow that will reduce pumping requirement. Also, the normal sequence of units can be minimized without excessive excavation and fill
- When landscaping is utilized, it should reflect the character of the surrounding areas
- Site development should alter existing, naturally established site contours and drainage patterns as little as possible. Consideration must also be given to limit erosion
- The developed site should be well suited with the existing land uses and development plans

Foundation Considerations

The results of the soil consideration should be utilized in locating the process units, buildings and heavy equipment. Importance must be attached to load bearing capacities, water table, floatation effects and piling.

Site Development

A relatively compact site plan can minimize piping requirements. Modular design and centralization of similar process units, equipment and personnel will reduce total staff size as well as optimize plant supervision and operation facilities.

Access Roads

They should be included in plant layout to provide access to plant areas. Space for employee parking and visitors should be provided. Traffic movement should be regularized within the plant.

Odor and Aerosol Sources

Processes causing odor pollution should be located downwind from public spaces. Protective barriers such as heavy plantation, large trees and buffer lands should also be taken into account.

Noise Sources

Noise should be controlled to prevent discomfort to plant personnel and neighbors. Sound producing equipment (pumps, compressors, etc) should be isolated and wherever required, sound barriers should accompany noise sources. Vehicular noise should also be considered in plant layout.

Buildings

They are needed for plant personnel, process equipment and visitors. The following consideration should be given to building design and location:

- Location of equipment at the point of maximum usage will be helpful
- Buildings may be located as barrier to hide undesired views of the process units
- The climate of the local area should be considered for minimal heating, ventilation, lighting and air-conditioning costs
- Area and space requirements should be based on the number of workers and future expansion
- The administration building should be located near the entrance and should be in public view
- Other buildings include tools and storerooms, garages, pump houses etc

Shoreline Planning

Erosion of banks and waterways, as well as destruction of various ecologically sensitive areas are to be protected from damage.

Flood Plan Avoidance

Plant sitting in low-lying areas should be avoided. A storm water management system with floodgates, storm water pumps and emergency ponds, must be designed in such a way as to allow for drainage of floodwater under critical conditions.

Landscaping

Planting should be considered for control of slope erosion and surface runoff and to provide sound and odor control barriers. Local soils and climatologically and biological conditions should be carefully investigated by a landscape architect.

Lighting

Proper lighting at process units promotes safer operation, efficiency and security. Considerations should be interior, exterior, safety and security lighting.

Plant Utilities

The utilities at the treatment plant include electrical power, natural gas, water lines, effluent lines, telephone lines and communication system. The design of the utility system should conform to the applicable codes and regulations of the local authorities and to the operating rules of the concerned utilities.

Occupational Heath and Safety

Important factors for which proper safeguards must be provided include chemical handling and biological vectors, toxic gases, fire protection and explosion burns, electric shocks, rotating machinery parts, materials and equipment handling.

Security

All access to the treatment plant should be controlled. Fences and other barriers should be provided to enclose the facility. Proper signs should be displayed at all accesses indicating the name and owner of the facility.

Provision for future plant expansion must be made taking into consideration the following

- Future space requirements
- Plant expansion with least interruption to existing operations
- Process modification

Classification of Plant Layout

Plant layouts can be broadly classified as follows

A Series (in-line or consecutive) Layout

In a series layout as indicated in figure 2.9, the process stream leaving the preceding vessel enters the next, and the stream flows through each unit only once.

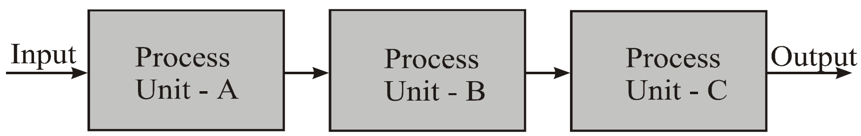

Figure 2.9
Series Layout

Parallel Layout

Here, the feed steam is divided into several smaller streams and these enter several system elements (plant items) at the same time (fig 2.10). The streams leaving these elements may merge together or they may be withdrawn from the system separately. A parallel layout is advantageous when the same feedback is used to obtain two or more intermediates, which then proceed to make a single end product.

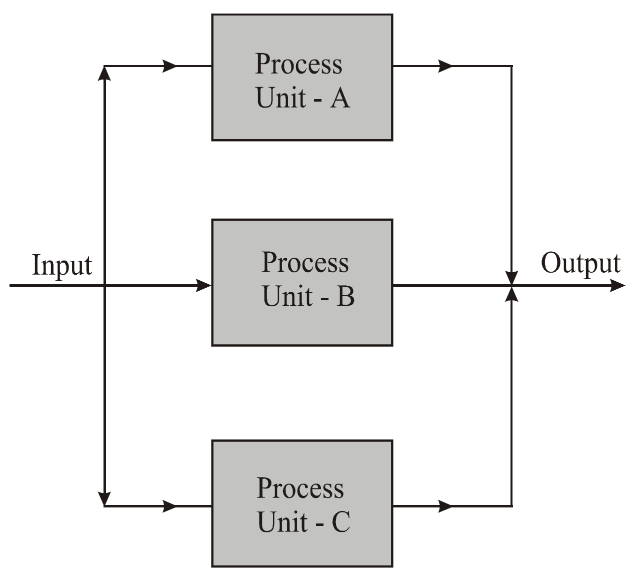

Figure 2.10
Parallel Layout

Layout with a Bypass

A layout with a bypass (fig 2.11) is a series-connection of plant items through which only some of the total process stream entering the system is allowed to pass. The remainder of the feed steam is routed around one or several plant items and then merges with the main body of the stream.

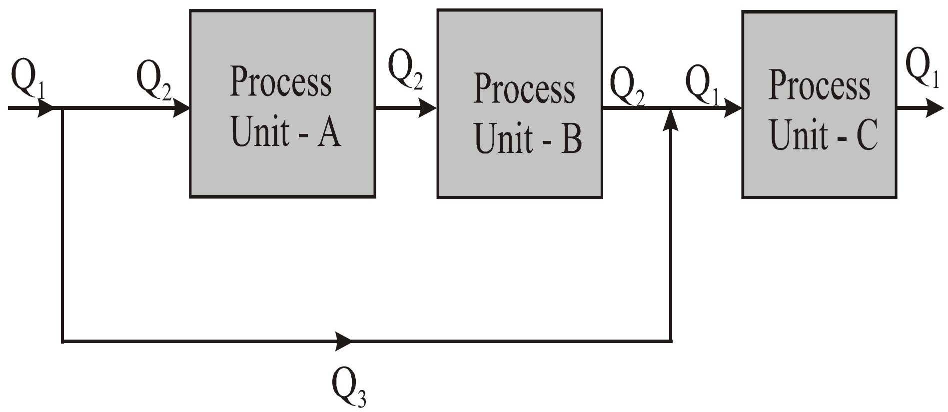

Figure 2.11
Layout with bypass

The stream Q_1 entering the system is called the forward stream. It divides into two parts. One part, Q_2, is passed through the plant items. This main stream controls the course of the process in the reactors. The other part, Q_3, is routed around the reactors and ultimately joins the main stream. This is a bypass stream. In the reactor layout with a bypass, the two streams flow in the same direction, and each stream passes through any section of the plant only once.

With a bypass layout, the residence time of the reactants is increased and the reactants conversions enhanced because the quantity of feed in the main stream (the one passing through the reactor) is decreased.

Bypassing is widely used to assure optimal temperature conditions of reversible exothermic reactions. As will be recalled, there is a need, in the case of such reactions, to bring down the process temperature from reactor to reactor or from one stage to the next. Bypassing solves this problem. The main stream passing through the reactor is heated due to the exothermic reaction that is effected there and leaves the vessel hot. Before it enters the next reactor or state, this stream must be cooled. This is done by adding the cold bypass stream to the main stream in such a way that an optimal temperature is obtained at the inlet to the next reactor.

Bypassing has one more beneficial effect on the system. The bypass stream does not undergo a chemical conversion and carries the reactant in a high concentration. Mixing the bypass and main streams assures a high reactant concentration exactly at the temperature that is optimal at the inlet to the next reactor.