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Creating Process Industry Drawings

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1. INTRODUCTION

As a point of reference let us assume that the process industries consist of those facilities making some sort of modifications to chemicals. In the real world those changes to the chemicals may be as complex as copolymerization and extrusion and as simple as distilling and bottling water. Whatever the process activity there is a need to design, to estimate a cost for the facility, to permit, to build, to operate, to maintain and to modify the facility. Process drawings are a tool used to transmit information to others who will accomplish the various "to" tasks listed above.
Although we will be looking specifically at drawings produced by the process group we will also touch on the electrical, structural and other drawings as we go through this material. In the process industries the process drawings are generally the first produced and are used by other groups as their starting point for the design effort. The Process drawings provide

- the electrical group with what needs to be powered
- the instrumentation group with information about what needs to be controlled,
- the structural group with what needs to be supported
- the civil group with what needs to be enclosed in buildings
- the environmental and safety group with what needs to be monitored and guarded
- the operational group with what they will use to produce the product and
- the administrative group with what must be permitted and insured

2. DRAWING SYMBOLS

Before we go into details on drawings we need to establish a common base for drawing symbolism for use in this course material. Drawing symbols vary widely company to company, see Sketch 1 for some examples. Some companies have standardized on ISA (Instrument Society of America) symbols, others use symbols common in their specific industry and still others have created symbol sets specifically to confuse competitors who might come into possession of the drawings.

Either way the symbols must generally be defined in order to transmit the desired information. Confusing a gate valve symbol with a globe valve symbol can create estimate, installation and operating problems. Symbol sheets are generally the first sheet after the title sheet in a set of drawings and are frequently called "Lead" sheets.

Many equipment and piping items have either a pictorial symbol or a diagrammatic symbol, see the heat exchanger on Sketch 1. Either symbol can convey the necessary information and to some extent it depends on who the drawing is primarily intended to serve as to which is the better symbol choice. Remember the goal is the accurate transmission of information. Within a facility symbol consistency is probably more important than which symbol is used.

3. WHAT DO THE DRAWINGS ACCOMPLISH?

As with all engineering drawings the goal is to transmit information with a minimum of confusion and as briefly as possible. Part of creating a specific drawing or selecting which drawing to issue to whom is a critical portion of the "transmission of information" goal. Not all drawings should go to all individuals as you will see later.

See Sketch 2 as an example of what the drawings will accomplish. This is a portion of a P&ID followed by a description of some of the piping. The partial drawing actually contains enough information, with the addition of some pipe lengths, for a contractor to estimate the cost of the piping and components he needs to provide. The partial written instructions are far from complete and are insufficient for estimate or construction purposes. A properly prepared drawing eliminates a lot of verbiage and confusion. A written "Scope of Work" for piping activity may include a detailed written description of the work to be done. The difficulty with this is "getting the whole picture" of the project from several lengthy paragraphs of verbiage verses looking at a drawing on one page which depicts all of the piping. When combined with plant pipe codes, electrical standards and other plant standards a full set of drawings provides the total picture of the work to be done.

A full set of written instructions to accomplish the piping on one reasonably complex P&ID would run on to many pages and probably even then not leave a clear impression of the multiple piping interconnections.

4. GENERAL DRAWING COMMENTS

A few words about drawings in general for future use. Process drawings in the USA generally are produced on ANSI sizes of paper, those sizes are:

- A 8.5" by 11"
- B 11" by 17"
- C 17" by 22"
- D 22" by 34"
- E 34" by 44"

There are several other paper sizes in common use for machine and architectural drawings and full sets to meet DIN, ISO and JIS standards. Most drawing today is accomplished using one of several CAD systems and these generally contain preset print controls for the various common sizes of paper.

Since most drawings will receive multiple reviews by one or more individuals either singly or in meetings the "C" size seems to be the most convenient for both meetings and for use on an individual's desk.

5. DRAWING CONTENT AND CLARITY

Individual drawings need to be reviewed for logical content and the whole set of drawings for “connectivity”. A large percentage of individual pipelines on a drawing will start at one piece of equipment and end on another. Most likely the second piece of equipment will exist on another P&ID, connectivity is achieved when an individual pipeline can be traced from drawing to drawing.

Part of achieving this essential goal is a working system for numbering pipelines. An individual pipeline showing on two or more drawings should maintain the same “line” number on all drawings. See Sketch 3.

Pipeline numbers change at each branch in the pipe line and in some companies change at each piece of equipment even though the equipment may show as nothing more than a wide spot in the line. For example a shell and tube heat exchanger with a process pipe connected to the inlet end (tube side) and a continuation of that line from the outlet end should receive a separate number for each pipe; however if the same line entered an inline strainer the pipe line number generally continues through the strainer. See Sketch 5.

The inline strainer is considered a pipe fitting rather than a piece of equipment. Generally valves, check valves, flow glasses, inline instruments, orifices, and attached instruments (ie. pressure gage) are treated like the strainer in Sketch 5.

6. WHAT DRAWINGS DO WE NEED?

The following is a listing of common “process” drawings used in industry. Drawing titles vary from company to company, the following are in frequent industry use but will not necessarily match those in your company. In addition to drawing title differences drawing content and level of detail may vary considerably facility to facility.

6.1 P&ID (Sketch 6)

Process and Instrument Drawing (Piping and Instrumentation Diagram). This is a symbolic drawing of the process piping showing all equipment and equipment connections. Depending on the system complexity this drawing may depict process and utilities feeding one item of equipment on separate sheets. In complex systems it is generally clearer to show one major item of equipment on a single P&ID sheet. It is common for a facility P&ID to cover many individual drawing sheets.

Levels of detail vary but usually pipe sizes, pipe codes, insulation thickness, tracing with type and pipe materials of construction are shown; these five items are frequently incorporated into the pipe line number, see Sketch 2. Flow rates are generally not included nor are pressures in the pipes or equipment. Except for specific instances pipe lengths are not included, an exception to this rule might be the height of a water seal leg on a vacuum tank for example or a note showing minimum pipe length from an elbow to an instrument.

Equipment details are usually presented as a note on the P&ID and include a variety of information including but not limited to:

- Name
- Equipment Number
- Equipment Type (reactor, storage tank)
- Size in gallons, etc.
- Materials of Construction
- Pressure and temperature ratings (MAWP)
- Flow rate if applicable
- Manufacturer and serial number

This drawing is generally used as the basis for Process Design and Process Safety reviews since it shows all connections (more than one sheet perhaps) and instrumentation on the equipment.

Instrumentation shown may include set points or ranges to assist in the process reviews, safety analysis and preparation of operational SOP's. All pipelines are numbered as are all valves and other pipeline components. See Sketch 3 for critical "nozzle" numbering for use on these drawings.

This one drawing contains significant proprietary information and is generally classified "Confidential." In most cases the P&ID is generated from the PFD (Process Flow Diagram); however the P&ID feeds off the PFD and vice versa so they generally are both complete at about the same point in the initial design process.

6.2 PFD (Process Flow Diagram)(See "SAMPLE PFD")

The PFD provides the engineer with sufficient data to size equipment including pumps, tanks, heat exchangers, etc. By itself the PFD generally does not provide sufficient detail to size pipes nor select specific pumps as these items are dependent on distances between items of equipment. This drawing is the result of a stoichiometric analysis of the process under design and provides chemistry, temperatures, desired and expected flow rates, densities and other physical properties at each step in the process. The stoichiometric nature of the drawing covers all pipe lines so that flows, temperatures, etc. are given for raw materials, intermediate process streams, finished product and utilities such as steam and cooling water.

Occasionally for clarity of the drawing some details are not included in tabulations; as an example the latent heat for steam or viscosity of water might be left off to conserve space since these are specified when the temperature of the stream is provided.

PFD's do not show valving or common instrumentation nor is much mechanical equipment detail provided. This drawing is also classified "Confidential" since it provides the actual chemistry involved in production.

6.3 EQUIPMENT ARRANGEMENTS

This drawing provides physical relationships between pieces of equipment in the process and generally shows enough building background details (column lines) to locate the equipment in the facility.

Equipment is generally dimensioned including nozzle locations (using the same designations as on the P&ID) and dimensions between different pieces of equipment are given to easily identified points of each item. This drawing will be used to install the equipment and position it correctly within the facility. From this drawing sufficiently accurate pipe lengths can be determined to use for final pump and pipe sizing.

The complete process design can be constructed from the PFD, P&ID and Equipment Arrangements. Sufficient information is available from these three drawings to size all equipment including horsepower for all motors.

6.4 PIPE ROUTINGS

The Pipe Routing drawings provide the path the various pipes will take through the facility. These are used by the piping designer to develop Piping Arrangements and by the structural engineer to determine support loads. The process engineer finalizes his pressure drop calculations from these drawings which give him accurate pipe lengths and fitting counts.

6.5 PIPING ARRANGEMENTS

The Piping Arrangements are the most detailed of the piping drawings and show each pipe fitting in its final location relative to the equipment and building components. With these drawing the process engineer can confirm pressure drops and final pipe sizes. These drawings are the best for developing piping and pipe insulation cost estimates.

6.6 PIPE SUPPORT DETAILS

This drawing may be produced by the process group or the structural department depending on how the company is organized. The details generated here are used to purchase pipe hangers and by the construction company to develop the cost estimate.

Occasionally the pipe routing drawings will reference plant standard pipe supports and this drawing will not be necessary.

6.7 INSTRUMENT PIPING CONNECTIONS

These may well fall under plant standards from the instrument group and are details for the installation of each type of instrument showing for example how pressure gages are to be installed and how thermowells are installed in pipe and equipment.

These are generally produced by the instrument group and are used by the piping designer to ensure space and fittings are provided and by the contractor for estimating purposes.

6.8 FACILITY BACKGROUNDS

When developing the Equipment Arrangement these building layout drawings are used as the base. These drawing provide locations of building support columns and beams as well as door and window positions. The process designer will locate equipment on a background consisting of building columns line centers; these centers provide points of departure for locating each item of equipment as well as pipelines. Pipelines generally travel parallel to the column lines.

To simplify future discussions about location of components when the building column lines do not run true north and south or east and west a "plant north" will be established on this or an architectural drawing. The attempt is to establish this "false north" as near to true north as practical; it is then generally referred to as "plant north" which implies it is not a compass north.

6.9 UNDERGROUND DRAWINGS

The tendency today is away from underground piping with the exception of storm water and sanitary sewers. However these lines and all other buried utilities (electrical and communications cables for example) need to be located for initial cost estimating and future reference use.

Drawings in this group are usually not part of the process drawings but may become background drawings for process storage tank foundations.

6.10 UTILITY DRAWINGS

Utilities vary from plant to plant; some facilities consider nitrogen gas as a utility while others class it as a raw material. Either way a defined set of utilities is required by the process and these drawings are generally developed by the process group.

Frequently utility pipes are both inside the building and outside on pipe racks. This means they may show up on multiple drawings; it is critical that "connectivity" occurs with the pipes drawing to drawing. Considerable confusion occurs when a numbered steam line enters a building and is given a different number as it changes drawings.

Tracing pipes is one purpose of the drawings and this type of error complicates that already complicated task.

In some organizations utility piping comes under the mechanical group when outside the building walls and under the process group when inside the walls. This situation requires extra care since not only does the pipe extend over more than one drawing but in this case to a different design group all together.

Drawing errors have considerable impact of the contractor's ability to produce accurate budgets for the project. These errors invariably end up resulting in change orders and cost overruns.

6.11 INSTRUMENT LOOP SHEETS, MOTOR SINGLE LINES AND POWER DRAWINGS

This set of drawings is produced by the electrical design group and is generated once the P&ID's are completed; they definitely require input from the process engineer. Parts of this set may be required for safety or process hazards analysis; a full set will be required by the contractor for estimating purposes.

6.12 ABOVE GROUND OUTDOOR DRAWINGS

Depending on the facility these may not constitute a separate drawing set; they will be required by the structural group to determine outdoor pipe rack supports. Examples include cooling tower pipelines, steam lines from boiler houses, bulk gases (nitrogen), etc.

A full set of these drawings will be needed by the structural group to plan for pipe bridges. The piping and civil contractors will use these to estimate concrete for pipe support footers and actual piping labor and materials. The insulation contractor may use them as well.

6.13 STORM WATER CONTROL DRAWINGS

These are generated by the civil group in larger facilities and will involve items not normally part of the process engineer's experience such as rainwater runoff rates and outfalls to local streams. A few process lines may be involved especially if the facility uses once-through river water. These drawings will be part of any permitting effort in today's environment.

6.14 SPILL CONTAINMENT DRAWINGS

Although usually sized by the process engineer these are another set of drawings from the civil structural group. Generally the process group will specify how much spill control volume is required and what chemicals will need to be contained. Others will design the containment and necessary coatings to resist the chemicals.

7. WHO GETS WHICH DRAWING

We have touched on several common types of drawings which might be generated in the process of building a chemical plant. Not all of the drawings are generated by the process group but most have some input from that group. Going back to the beginning we need to remember that the purpose of the drawings is to transmit information in order to design, estimate the cost, and build and operate the facility. Let's look at the various groups of people interested in drawing content by drawing type. This is one possible distribution breakdown by drawing type.

In the table below the following assumptions were made:

The Electrical and Instrument engineers are separate individuals
The Operations Manager is responsible for the creation of Operating SOP's
The Civil and Structural engineers are the same individual.
The Mechanical Contractor does all the pipe work.
The local permit offices do not require submittal of proprietary information.

TABLE 1 – DRAWING DISTRIBUTION

DRAWING TITLE	R & D Chemist	Engineering Manager	Process Engineer	Electrical Engineer	Instrument Engineer	Structural Engineer	Operations Manager	Maintenance Manager	Safety Engineer	Environmental Engineer	Mechanical Contractor	Electrical Contractor	Civil Structural Contractor	Local Permit Offices
PFD	X	X	X	X	X		X		X	X				
P&ID	X	X	X	X	X		X	X	X	X	X	X	X	
Equipment Arrangements		X	X	X	X	X	X	X	X		X	X	X	X
Pipe Routings			X		X	X	X	X	X		X	X	X	X
Piping Arrangements			X		X	X		X			X	X	X	
Pipe Support Details		X	X			X		X			X	X	X	X
Instrument Piping Connections			X	X	X			X			X	X	X	
Facility Backgrounds		X	X	X		X					X	X	X	X
Underground Piping Drawings		X	X			X		X	X	X	X		X	X
Utility Drawings		X	X		X		X	X			X	X	X	X
Instrument Loop Sheets					X		X	X	X		X	X		
Motor Single Lines				X	X		X	X				X		X
Power Drawings				X				X				X		X
Above Ground Outdoor Drawings		X	X			X	X	X		X	X		X	X
Storm Water Control		X				X		X		X	X		X	X
Spill Containment Drawings		X				X		X		X	X		X	X

8. KEEPING DRAWINGS ORGANIZED

DEFINITION:
ISSUE or DISTRIBUTION. When a drawing or set of drawings is printed and sent to individuals working on or reviewing the project this is generally referred to as a "drawing issue".

Each drawing may receive multiple issues; the most common are listed below. A "REVISION" numbering system is generally used to help ensure that individuals are looking at the latest revision of a drawing and that everyone is referencing the same issue of a drawing during discussions. Perhaps the most critical check in this area is that the contractor is working from the most up to date drawings. With Revision numbers a quick glance at drawings on the construction foreman's desk confirms which drawings are being used to build the facility.

The various drawing issues are made to transmit the drawings with the latest changes incorporated. The size or number of changes which may cause a revision and new issue depends on company policy. Each new issue requires a modification to the drawing number to keep track of the latest issue. These new drawing numbers are generally created by adding a Revision number or letter to the original drawing number.

One such system uses Revision Letters for a drawing until they are issued "Construction Release" at which point the Revisions receive numbers.

Initial releases of a new drawing occurring prior to the "Construction" release.
- Drawing # 157-P&ID-53 Rev A
- Drawing # 157-P&ID-53 Rev B

First release as Construction release
- Drawing # 157-P&ID-53 Rev 0

Releases incorporating changes after the original Construction release
- Drawing # 157-P&ID-53 Rev 1
- Drawing # 157-P&ID-53 Rev 2

Sometimes it is critical to be able to reconstruct a drawing's history; that history is generally the result of changes to the drawing. When significant design changes are made the engineer should consider a written report documenting the changes and who approved those changes. Occasionally the engineer finds him or her self working with adversarial clientele and having documentation which is clear to non engineers is helpful if the problems in up in court.

Maintaining a hard copy file of each issue of a drawing until the work is complete works for small projects but becomes overwhelming on large projects with potentially hundreds of drawings. The task becomes easier if storage is electronic but can rapidly consume considerable computer memory as a simple P&ID on a title block drawing page rapidly exceeds 2MB of memory.

More often than not a simple table of changes at the bottom of the drawing is adequate to track changes. The amount of detail is dependent on the type of change noted, one advantage of this is that the specific location of changes can be noted on the drawing body without adding too much clutter. Once all changes have been approved and generally by the next drawing issue older change marks can be deleted from the drawing body and just the record at the bottom maintained.

SAMPLE DRAWING CHANGE TABLE

CHANGE #	DATE	BY	APPV'D	CHANGE
1	1/2/08	CW	AB	Removed ck valve
2	2/2/08	BW	AB	Added thermowell
3	2/2/08	DW	AB	Change motor to 5 Hp
4	3/1/08	FC	CW	Changed pipe code to 1S4
5	4/15/08	CW	DD	Replaced ck valve
6	4/20/08	DW	DD	Corrected spellings

In the body of the drawing a symbol is placed to indicate where the specific change was made. The symbol can take whatever shape is desired but is usually large enough to hold a number referencing the change table. For example a small triangle with a number could reference the change, see Sketch 2 and the small triangle before the pump, the "1" references Change # "1" in the table above and tells us "a check valve was removed from this area." To reduce the clutter in drawings the next issue of this drawing can remove the "1" triangle marker and leave the item in the change table.

9. DRAWING ISSUES

Drawings are issued for a variety of reasons as listed below:

"FOR COMMENT", "FOR REVIEW", "NOT FOR CONSTRUCTION", "INFORMATION ONLY" are the same and are used to obtain input from others working on or reviewing the project. If PE stamped by the responsible engineer then "PRELIMINARY" should be stamped on the drawing.

"INITIAL ISSUE", "PRELIMINARY" are generally just what the name suggests; issued at the beginning of the project with the expectations that comments will be made resulting in changes.

"FINAL ISSUE" Is generally issued once comments have been received from all interested parties. In some companies this is the "FOR CONSTRUCTION" issue and as such is PE stamped depending on the drawing type. If PE stamped then "FINAL" is also added.

"FOR CONSTRUCTION" This issue is considered as the final one for construction. In most states this drawing is stamped or sealed by the responsible engineer.

10. SEALING (STAMPING) DRAWINGS

When the design engineer is to stamp a drawing is dependent to a large extent on drawing content, type of drawing, company policy and state requirements. Some variation exists from state to state relative to which drawings must be stamped. The responsible engineer needs to be aware of the stamping requirements in both the state where the drawings were produced and the state in which they will be used. The facility stamping requirements may not match the local political jurisdiction and the logic behind what is stamped and what is not is not necessarily straight forward. The following sample is based on work in several different companies and states but is certainly not the requirement for everyone.

The following table covers those drawings generally classified as Process Drawings.

PE SEALING DRAWINGS - SOME INDUSTRY PRACTICES

DRAWING TYPE	GENERALLY SEALED	COMMENTS
P&ID		
INITIAL ISSUE	NO	If stamped mark PRELIMINARY or NOT FOR CONSTRUCTION
FINAL ISSUE	YES	When stamped mark CONSTRUCTION RELEASE or FINAL
PFD		
INITIAL ISSUE	NO	Normally does not include engineering calculations of concern to local authorities and is usually a confidential internal document.
FINAL ISSUE	NO	
EQUIPMENT ARRANGEMENTS		
INITIAL ISSUE	NO	If stamped mark PRELIMINARY or NOT FOR CONSTRUCTION
FINAL ISSUE	YES	When stamped mark CONSTRUCTION RELEASE or FINAL
PIPING ARRANGEMENTS		
INITIAL ISSUE	NO	If stamped mark PRELIMINARY or NOT FOR CONSTRUCTION
FINAL ISSUE	NO	If stamped mark FINAL or FOR CONSTRUCTION
PIPE ROUTINGS		
INITIAL ISSUE	NO	If stamped mark PRELIMINARY or NOT FOR CONSTRUCTION
FINAL ISSUE	NO	If stamped mark FINAL or FOR CONSTRUCTION

11. AS BUILTS

When the facility is complete and a thorough inspection is made discrepancies will be found between the drawings and how the system was actually built. These differences creep in because a fitting is slightly different from the design, some interference caused the pipe fitter to have to reroute a pipe or an instrument was ordered differently from what was called for in the design. Correction of the drawings to match what is actually in the field creates “as-built” drawings.

This correction activity is probably the most neglected part of the life of the project drawings; it is difficult to convince management to spend money to update drawings when the facility is complete and operational.

Certain drawings in particularly hazardous facilities or for certain chemicals, Process Safety Management facilities, are required to be updated to "As Builts" by OSHA. Likewise P&ID's in most pharmaceutical facilities need to be updated to meet FDA requirements.

The engineer needs to present management with beneficial reason to spend the necessary money to as built the drawings. The cost of as-builts can be controlled by only updating critical drawings. For example there is little benefit to updating a pipe routing drawing for straight runs of visible pipe when the updates will consist of changing a few dimensions.

The most benefit is derived from updating P&ID's, PFD's, electrical power and controls drawings and underground drawings.

12. REFERENCES

Instrument Society of America
67 Alexander Drive
Research Triangle Park, NC 27709

AutoDesk, Inc.
111 McInnis Parkway
San Rafael, CA 94903

Bently MicroStation
685 Stockton Drive
Exton, PA 19341

An Internet search yields multiple companies and organizations offering drawing symbols in a variety of forms and for various engineering disciplines.

13. CONCLUSION

A properly prepared set of drawings makes for smooth construction of the project; helps keep costs within budget and makes startup easier. Future maintenance and facility modifications in the project area are always easier when a complete set of the original drawings is available.

Most of the project drawings have a limited use life, the others including the P&ID's, PFD's, loop sheets and equipment arrangements have huge future value and should be protected.

