Second Edition

Process Piping Design Handbook

THE PLANNING GUIDE TO PIPING DESIGN

Richard Beale

Paul Bowers

THE PLANNING GUIDE TO PIPING DESIGN

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PROCESS PIPING DESIGN HANDBOOK

THE PLANNING GUIDE TO PIPING DESIGN

Second Edition

RICHARD BEALE
The Association of Science and Engineering Technology Professionals of Alberta (ASET)

PAUL BOWERS
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To all my family near and far, each of whom in your own way has supported, encouraged, and inspired me.

—Richard Beale

To my mother (for encouragement), grandfather (for teaching me to draw from an early age), and son (for inspiration). Also, thanks to all those engineers and designers who took the patience to inform and educate me over these past many years.

—Paul Bowers

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PREFACE

The first edition of this book was born out of the observation that the adaptation of the tried and true methods of control used in the manual design/drafting world was not keeping pace with the implementation of the new CAD technologies, with a resultant need for the creation of instructional material that could help fill the gap. While the reasons for this are debatable, the net outcome was that the efficiency and productivity gains new technology was expected to bring to the plant design and construction effort often fell short of the desired results. In our opinion this was largely attributable to a loss of mentorship and a shift toward a reliance on technology as a substitute for experience. While it was recognized that a book cannot replace a knowledgeable mentor, the goal of the first edition was to draw parallels between successful project outcomes and the capability of the piping leads to achieve this through project set-up and the development of procedures linked with the design tools.

This goal remains unchanged in this second edition and if anything has increased in need during the last several years. The drop in world oil and gas prices and subsequent cost cutting measures has seen a further loss of experienced personnel at the same time as there are advances in software to be tapped into. Software such as laser scanning for new design in existing areas and checking of construction accuracy, and automated pipe routing for front end engineering and design (FEED), provide promise to a struggling industry ever eager for efficiency improvement solutions. Couple these with other software for such as client demands for plant lifecycle data management and emerging virtual reality, and the need for innovative and effective problem solving leadership capable of understanding and overcoming the challenges of new software implementation is on the increase. Attainment of the key leaders with these capabilities will be achieved by drawing from the ranks of knowledgeable designers who have gained the wherewithal to recognize and create balanced practical approaches to managing design utilizing the new technologies. Because defining a balanced practical approach is nebulous, requiring of analysis and judgement calls, knowledge and experience play a major role. Without these we will never be able to realize the true efficiencies and optimal performance possible from new technologies. All designers

therefore must strive to possess practical experience in design, construction, and CAD in order to work effectively in a lead decision making role. It is our hope that this book will assist you in your quest toward attaining effective piping leadership.

Richard Beale and Paul Bowers

(September 2017)

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CHAPTER ONE

Before You Begin

1.1 INTRODUCTION

In order to execute the piping designs of a project efficiently, it is essential that you initially identify and address all of the prerequisites that must be in place for the piping designers to start work. In order to do this you must first recognize all the questions that must be asked and answered, assemble all the needed tools, and make decisions accordingly. As you progress in your career you will find that this ability is required for any project, and that the best piping leads are those who can create missing tools when the need arises.

The intent of this chapter is to provoke your thought process: it focuses on the questions to ask and the tools required in order to begin a project. Do you have everything you need to proceed?

A first step is to assemble and then make yourself familiar with the engineering company and/or client standards, specifications, and procedures to be used on the project. Larger clients will have certain requirements in place and mandate that those requirements be used on the project, whereas smaller clients will likely default entirely to the engineering company. Generally speaking, all projects will use a combination of engineering company and client standards, specifications, and procedures. You must ensure that you know which you are using and where they come from. As a piping lead it is doubly important to familiarize yourself with these requirements, not just so you can guide your team, but because you will likely have to explain your design basis to other departments and sometimes even to the client themselves. It is also up to you to insist that they be respected and adhered to, or that a formal deviation be approved by the client. On this note, you must inform yourself of the deviation procedure to be used on the project.

- Examples of standards are as follows:
  - Standard fabrication and installation details/drawings such as shoe design and base ell supports.

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  - Drawing standards such as layering, text heights, and drawing symbols.
  - Charts such as line spacing within racks.
- Examples of specifications are piping classes, equipment spacing requirements, and egress and ingress requirements (walkways, platforms, and ladders).
- Examples of procedures are drawing reviews, model reviews, checking, and as-builting.

Below are some brief explanations of standards, specifications, and procedures, and their most likely sources. There are no guarantees, so you will have to investigate each in turn. As we progress into further chapters we will highlight these in more detail, discuss the importance of decision making at an early stage, and discuss the links between the topics. Once you have investigated, assembled, and made all your decisions, you are ready to go, and you have set yourself on a path toward a successful piping execution. By the time you have completed your initial set-up you will have a greater understanding of the project, the expectations, and how you will achieve those expectations. Knowing the reasons behind all of the decisions you have made or helped to make will put you in a position to recognize when things are going wrong, and will aid greatly later in correcting them.

1.2 STANDARDS

To determine whether the standards to be used are going to come from your own company or your client, you must consult with your project management team and the client.

Standards include the following:

- Standard drawings
- Charts
- Drawing templates and drawing standards
- Drawing numbering
- 3D model numbering
- Material commodity codes

1.2.1 Standard drawings

Standard drawings are typical fabrication and installation details of commonly encountered items. These are assigned a tag number for easy reference on the piping arrangements and isometrics. The use of a standard

avoids detailing the same thing time after time. Commonly, standard drawings are as follows:

- Shoes
- Anchors: fixed and directional
- Guides
- Base ell supports
- Dummy legs
- Trunnions
- Field supports
- Reinforcing pads
- Slide plates
- Tracing details
- Insulation details
- Instrument connection details
- Orifice tap orientations
- Block and bleed details
- Vents and drains
- Utility Stations
- Heat Trace Manifolds

Where suitable, a standard will cover more than one Nominal Pipe Size (NPS), so that one fit for purpose design may be used on a range of pipe sizes. For instance, all companies will have shoe designs that will cover a range similar to the ones below:

- NPS 6 and under
- NPS 8 to NPS 12
- NPS 14 to NPS 18
- NPS 20 to NPS 24

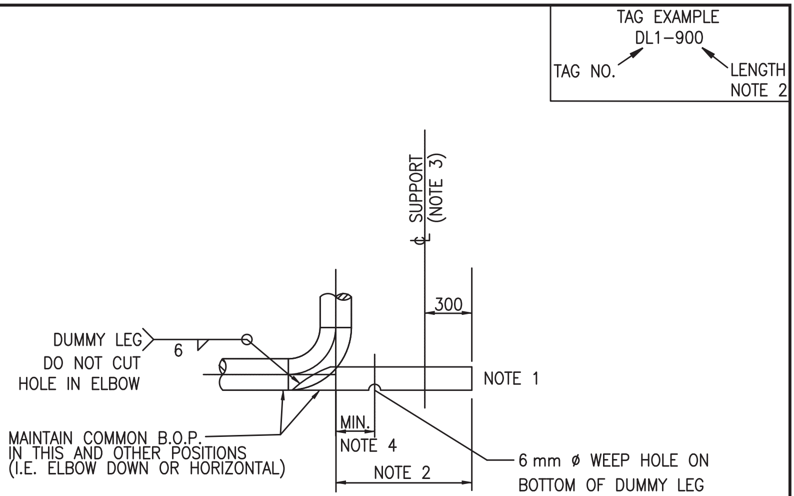
You will find that companies mercilessly plagiarize from each other, and most likely you will recognize standards that you have used before as you move from one company to another. You may even see a standard that you created or helped to create being used by another company.

Examples of standards are shown in Figs. 1.1–1.7.

1.2.2 Charts

There are three charts that are the most important to the piping designers and must be in place:

- Branch connection (can vary by piping class and may be included within the piping classes)
- Line spacing
- Line spanning



PIPE NPS	DUMMY LEG NPS
2	1 1/2 SCH. 80
3	2 SCH. 80
4	3 STD. WT.
6	4 STD. WT.
8	6 STD. WT.
10	6 STD. WT.
12	8 STD. WT.
14	8 STD. WT.
16	10 STD. WT.
18	10 STD. WT.
20	12 STD. WT.
24	12 STD. WT.

NOTES:

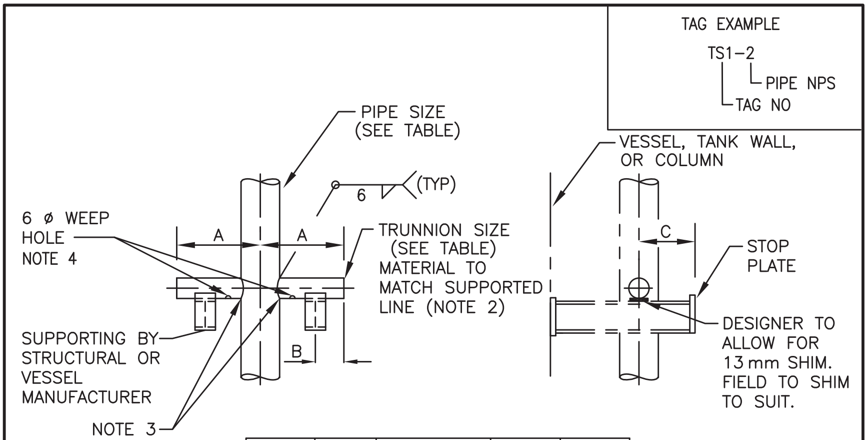
1. DUMMY SUPPORT MATERIAL TO MATCH PIPING CLASS.
2. CENTRELINE OF ELBOW TO END OF DUMMY LEG LENGTH TO BE NOTED ON THE ISOMETRIC.
3. SHOE TO BE ADDED WHERE REQUIRED.
4. MINIMUM EQUALS HALF ELBOW DIAMETER PLUS INSULATION THICKNESS PLUS 20 mm.

Figure 1.1 Dummy leg.

Examples of these are shown in Tables 1.1–1.4.

While line spacing charts and branch connection charts are fairly straightforward, care must be taken with line spanning charts. Line spanning charts will provide layout guidance, but many load factors may affect the posted spans. Final pipe spans must be confirmed during stress analysis.

While not vital, a chart worthy of adding to the above list is that for nozzle projection. Projections (distance from the surface of a vessel or tank to the face of the flanges) vary with nozzle size, flange rating, insulation thickness, and reinforcing pad thickness. The minimum projection



PIPE NPS	DIM A	TRUNNION NPS	DIM B	DIM C
2	230	1 1/2	100	100
3	240	2	100	100
4	260	2	100	150
6	285	3	100	150
8	310	3	100	150
10	340	4	100	200
12	360	4	100	200
14	380	6	100	200
16	400	6	100	200
18	430	8	100	250
20	450	8	100	250
24	500	10	100	250

NOTES

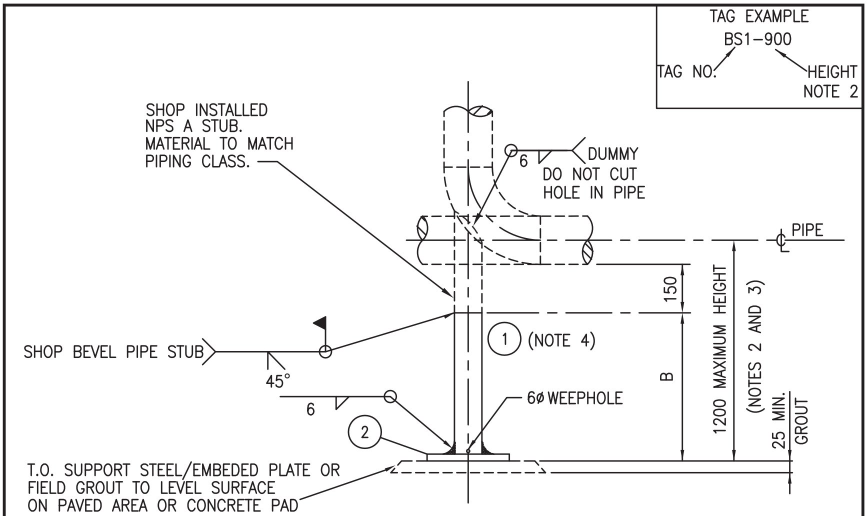
1. DIMENSION "A" TO BE INCREASED BY THE INSULATION THICKNESS.
2. WALL THICKNESS AS PER SPEC. SCH. 40 MINIMUM.
3. ADD RE–PAD WHEN SPECIFIED BY STRESS ENGINEER.
4. WEEP HOLE TO BE MINIMUM DISTANCE FROM PIPE. MINIMUM EQUALS HALF PIPE DIAMETER PLUS INSULATION THICKNESS PLUS 20 mm.

Figure 1.2 Trunnion support.

allows for approximately 3 in. (76 mm) of pipe length between the shell and a weld neck flange. This length is required for welding and removal of stud bolts. An example of a Nozzle Projection Chart is Table 1.5. A nozzle chart is useful for discussion with the mechanical group and study work prior to the receipt of vendor drawings.

1.2.3 Drawing templates and drawing standards

Drawing templates are required for the drawings that are to be created for the project. There are four common drawing templates for four plot sizes depending on drawing type and/or scale factor:



PIPE NPS	NPS A		SHOP FAB B DIM.	C SQ.	T
2	1 1/2	SCH. 80	1100	100	10
3 AND 4	2	SCH. 80	1100	150	10
6 AND 8	4	STD. WT.	1050	200	10
10 AND 12	6	STD. WT.	1000	250	12
14 AND 16	8	STD. WT.	950	300	12
18 AND 20	10	STD. WT.	900	350	16
24	12	STD. WT.	850	400	16
26 AND 36	18	STD. WT.	750	500	20

ITEM No.	DESCRIPTION	MATERIAL	QUANTITY
1	NPS A x B HIGH	A–106 B	1
2	BASE PLT THK. x C x C	G40.21M GR. 300W	1

NOTES:
1. ITEM 1 SUPPORT TO BE CENTERED ON ITEM 2 BASE PLATE.
2. CENTRELINE OF ELBOW/PIPE TO UNDERSIDE OF BASE PLATE TO BE NOTED ON THE ISOMETRIC.
3. HEIGHTS GREATER THAN 1200 ARE TO BE DISCUSSED WITH THE STRESS ENGINEER.
4. FIELD TRIM 'B' DIMENSION TO SUIT FINAL PIPING CENTRELINE ELEVATION.

Figure 1.3 Base support.

- ANSI paper sizes used in the United States and Canada:
  - A size—8½″ × 11″ (e.g., standards).
  - B size—11″ × 17″ (e.g., construction isometrics).
  - D size—22″ × 34″ (e.g., Process Flow Diagrams (PFDs), Piping and Instrumentation Diagrams (P&IDs), and piping arrangements).
  - E size—34″ × 44″ (e.g., plot plans, equipment location plans, and key plans).

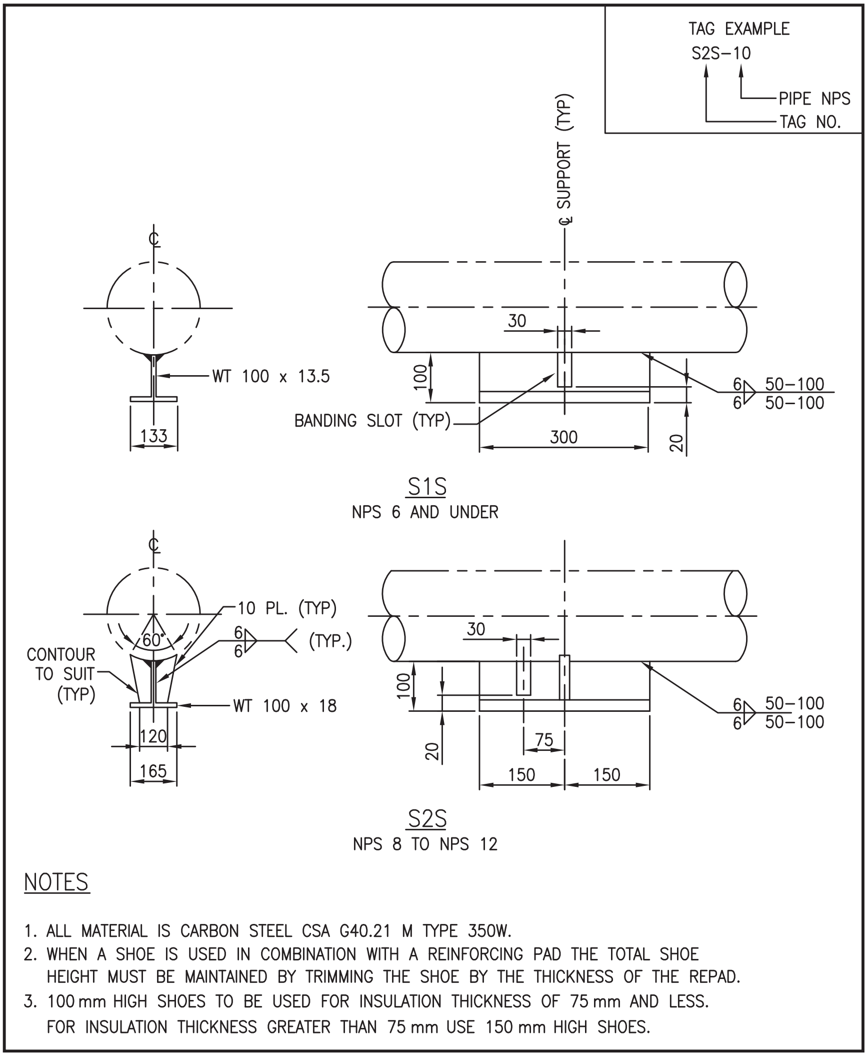


Figure 1.4 Pipe shoe.

- ISO A series paper sizes used in the rest of the world:
  - A4—210 mm × 297 mm (e.g., standards).
  - A3—297 mm × 420 mm (e.g., isometrics).
  - A1—594 mm × 841 mm (e.g., PFDs, P&IDs, and piping arrangements).
  - A0—841 mm × 1189 mm (e.g., plot plans, equipment location plans, and key plans).

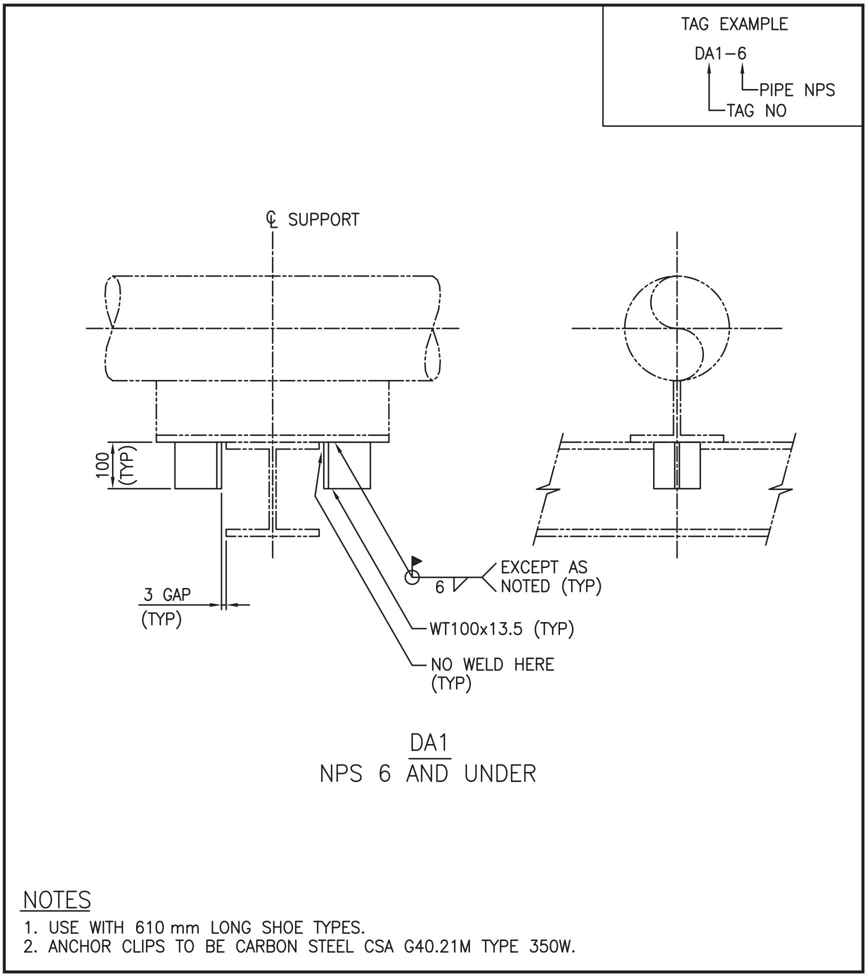


Figure 1.5 Directional anchor NPS 6 and under.

ANSI C (17″ × 22″) and ISO A2 (420 mm × 594 mm) paper sizes are usually reserved for reduced size plots of ANSI D and E, and ISO A1 and A0. This is due to being a convenient handling size while retaining a large enough drawing size for clarity and mark-ups.

It is most likely that the client will have drawing templates for three of the four drawing sizes, ANSI A, D, and E, or ISO A4, A1, and A0, that they will require you to use on their project. For the construction isometric template, ANSI B/ISO A3, the client will most often defer to the engineering company. This is because, unlike the other drawings,

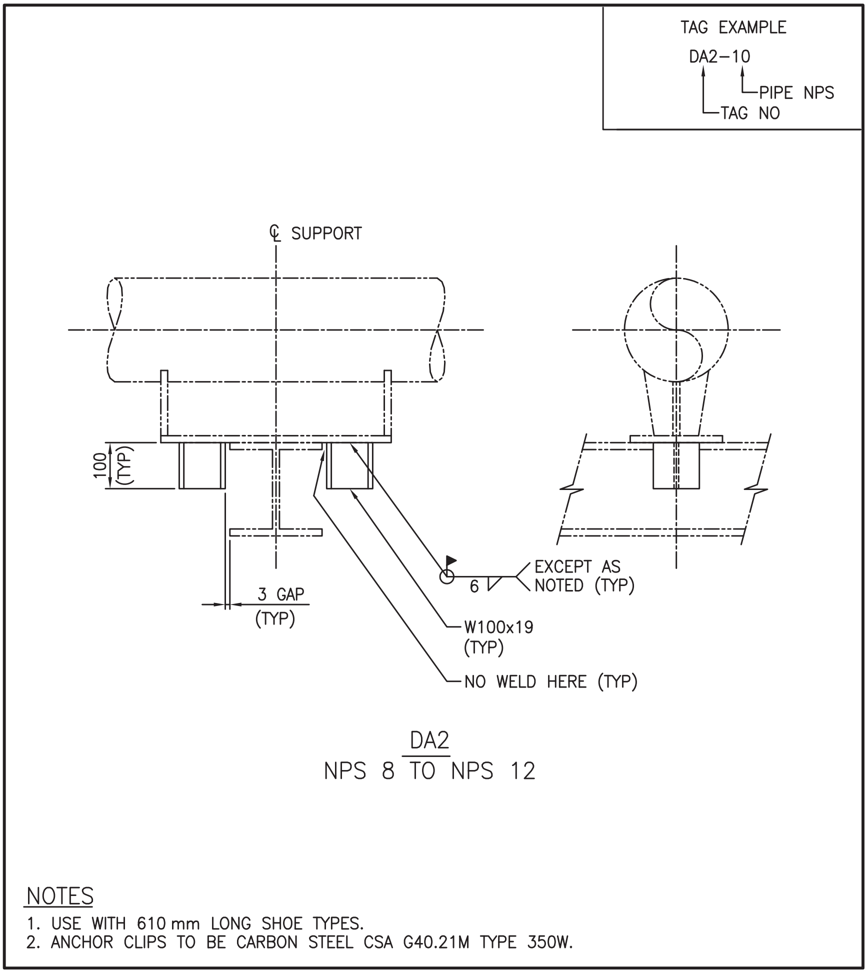


Figure 1.6 Directional anchor NPS 8 to NPS 12.

construction isometrics are not usually issued to future engineering companies to be revised on future projects. After project close-out, these isometrics commonly become for-information-only historical records retained for reference only, negating the need for client drawing template and drawing numbering formats. Additionally, on projects utilizing 3D CAD, engineering companies routinely incorporate a construction isometric template linked to the database for data extraction (e.g., data from the Line Designation Tables, LDT) as part of their CAD set-up.

Drawing templates have predetermined drawing standards as part of their set-up, so that when a drawing is plotted, the text heights, line weights, etc., will be to the correct dimensions.

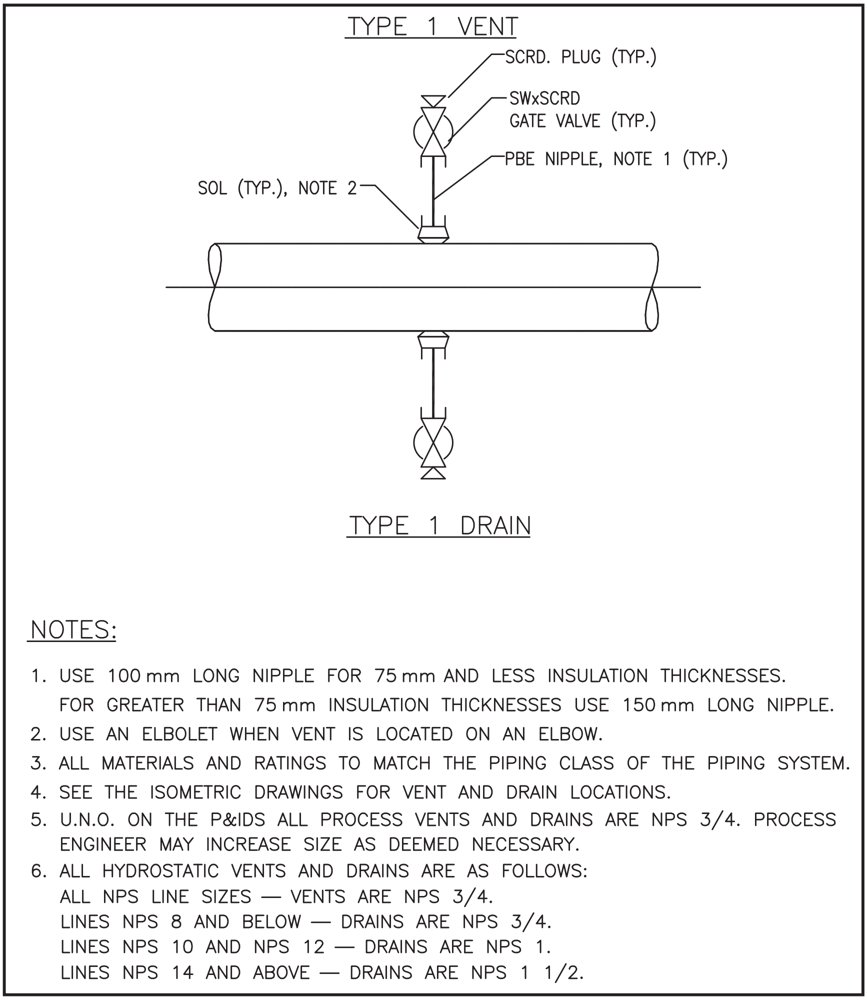


Figure 1.7 Single block vent and drain.

Drawing standards include the following:

- Titleblock with company logo
- Text heights
- Layering system
- Line weights
- Dimension styles

A client requirement to be investigated is the filling in of the title-block. The document management software used by the client may be set up to scrub meta-data from the attributes in the 2D CAD file and for this

Table 1.1 Branch connections process lines

		Branch Pipe Size (NPS)															
		1/2	3/4	1	1 1/2	2	3	4	6	8	10	12	14	16	18	20	24
Run Pipe Size (NPS)	1/2	T															
	3/4	RT	T														
	1	RT	RT	T													
	1 1/2	T&S	RT	RT	T												
	2	Olet	Olet	Olet	T&S	T											
	3	Olet	Olet	Olet	Olet	RT	T										
	4	Olet	Olet	Olet	Olet	WOL	RT	T									
	6	Olet	Olet	Olet	Olet	WOL	RT	RT	T								
	8	Olet	Olet	Olet	Olet	WOL	WOL	RT	RT	T							
	10	Olet	Olet	Olet	Olet	WOL	WOL	RT	RT	RT	T						
	12	Olet	Olet	Olet	Olet	WOL	WOL	WOL	RT	RT	RT	T					
	14	Olet	Olet	Olet	Olet	WOL	WOL	WOL	RT	RT	RT	RT	T				
	16	Olet	Olet	Olet	Olet	WOL	WOL	WOL	RT	RT	RT	RT	RT	T			
	18	Olet	Olet	Olet	Olet	WOL	WOL	WOL	WOL	RT	RT	RT	RT	RT	T		
	20	Olet	Olet	Olet	Olet	WOL	WOL	WOL	WOL	RT	RT	RT	RT	RT	RT	T	
	24	Olet	Olet	Olet	Olet	WOL	WOL	WOL	WOL	WOL	RT	RT	RT	RT	RT	RT	T

Olet = socketweld or threaded end and rating as defined in the applicable piping class

WOL = bevelled end and schedule as defined in the applicable piping class

T = Straight Tee with ends and schedule or rating as defined in the applicable piping class

RT = Reducing Tee with ends and schedule or rating as defined in the applicable piping class

T&S = Straight Tee and Swage with ends and schedule as defined in the applicable piping class

Note: Reducing Tees may be used in place of Olet/WOL if available.

Table 1.2 Branch connections instrument and utility air

Run Pipe Size (NPS)	Branch Pipe Size (NPS): 1/2	3/4	1	1 1/2	2	3	4
1/2	T						
3/4	RT	T					
1	RT	RT	T				
1 1/2	T&S	RT	RT	T			
2	T&S	T&S	RT	RT	T		
3	T&S	T&S	T&S	RT	RT	T	
4	T&S	T&S	T&S	T&S	RT	RT	T

T = Straight Tee with threaded ends

RT = Reducing Tee with threaded ends

T&S = Straight Tee and Swage with threaded ends

reason many clients have strict instruction on exactly how certain information is to be typed in. For instance, drawing titles may have to be arranged on three or four lines of text in a particular order (e.g., Operating Area/Plant Name/Plant Area/Drawing Description) and certain characters and formats may be governed (e.g., date format of DD/MM/YYYY or MM-DD-YYYY).

Other forms of drawing standards that you will require are drawing symbols legend sheets and drafting abbreviations. Primarily, the legend sheets you will require are going to be the PFD and P&ID legend sheets from the client that contain all the approved symbols to be used on the drawings. Drafting abbreviations come from various industry organizations, e.g., ANSI, ASME, and ISA. The most commonly used ones are often summarized as a company standard. See Appendix A for an example of drafting abbreviations used on piping drawings.

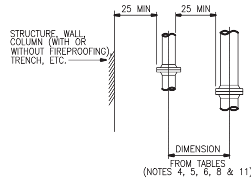
1.2.4 Drawing numbering

Commonly, with the exception of the construction isometrics, clients have drawing numbering requirements. Each client mandates the drawing numbering to be used. File numbering, which ideally should equate to

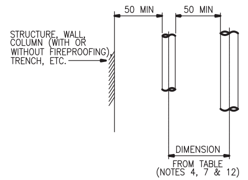
Table 1.3 Line spacing chart

RATING		150#													
	SIZE	1"	1 1/2"	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
150#	1"	115													
	1 1/2"	130	130												
	2"	135	145	155											
	3"	155	165	165	180										
	4"	180	180	180	205	205									
	6"	205	205	205	230	230	255								
	8"	230	230	230	255	255	305	335							
	10"	255	255	280	280	305	335	360	385						
	12"	305	305	305	335	335	360	385	410	435					
	14"	335	335	335	360	360	385	410	435	460	485				
	16"	360	360	360	385	385	435	460	485	510	510	535			
	18"	375	385	385	410	410	435	460	485	535	535	560	585		
	20"	410	410	410	435	435	460	485	535	560	560	585	610	640	
	24"	460	460	485	485	510	535	560	585	610	610	640	665	690	740

RATING		300#													
	SIZE	1"	1 1/2"	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
300#	1"	130													
	1 1/2"	130	130												
	2"	130	155	155											
	3"	155	180	180	180										
	4"	180	180	205	205	230									
	6"	205	230	230	230	255	280								
	8"	255	255	255	280	280	305	335							
	10"	280	280	280	305	305	360	385	410						
	12"	305	335	335	335	360	385	410	435	450					
	14"	360	360	360	385	385	410	435	460	490	510				
	16"	385	385	385	410	410	460	490	510	535	535	560			
	18"	410	410	435	435	460	490	510	535	560	560	585	610		
	20"	435	460	460	460	490	510	535	560	585	610	640	665	690	
	24"	510	510	535	535	560	585	610	640	665	665	690	720	740	790



LINES WITH FLANGES



LINES WITHOUT FLANGES

NOTES:

TO OBTAIN A PRELIMINARY ESTIMATE OF THE PIPEWAY WIDTH REQUIRED FOR A SELECTION OF LINES WITHOUT FLANGES, IN THE SIZE RANGE NPS 2 THRU NPS 8, EITHER OF THE FOLLOWING FACTORS MAY BE USED:

1. IF ALL PIPE SIZES ARE KNOWN, ADD NOMINAL SIZES IN INCHES TOGETHER & MULTIPLY BY 0.34 TO ESTIMATE THE WIDTH IN FEET. (THIS IS THE PREFERRED METHOD.)
2. IF ONLY THE NUMBER OF LINES IS KNOWN, MULTIPLY THIS NUMBER BY 1.43 TO ESTIMATE THE WIDTH IN FEET.

EITHER FACTOR GIVES A PIPEWAY WIDTH WHICH INCLUDES INSULATION FOR 25% OF LINES, ALLOWS 20% OF THE WIDTH FOR THE ADDITION & RE-SIZING OF LINES, & ALLOCATES A FURTHER 20% OF THE WIDTH FOR FUTURE PIPING.

3. LINE SPACING DIMENSIONS LISTED ARE BASED ON 25 mm FLANGE TO PIPE CLEARANCE (ROUNDED OFF TO EVEN DIMENSIONS) WITH FLANGES ON LARGER LINE & ALL LINES BEING ON A 100mm HIGH SHOE.
4. WHERE AN INSULATED & BARE LINE RUN ADJACENT, THE INSULATION THICKNESS IS TO BE ADDED TO THE SPACING DIMENSION.
5. WHERE TWO INSULATED LINES WITH UNINSULATED FLANGES RUN ADJACENT, THE LARGER OF THE TWO INSULATION THICKNESSES IS TO BE ADDED TO THE SPACING DIMENSION.
6. WHERE TWO INSULATED LINES RUN ADJACENT & EITHER ONE OR BOTH LINES HAVE INSULATED FLANGES, TWICE THE LARGER OF THE TWO INSULATION THICKNESSES IS TO BE ADDED TO THE SPACING DIMENSION.
7. WHERE TWO INSULATED LINES WITHOUT FLANGES RUN ADJACENT THE COMBINED INSULATION THICKNESSES ARE TO BE ADDED TO THE SPACING DIMENSION.
8. REVIEW THE 25 mm GAP BETWEEN ADJACENT LINES AT CORNERS, EXPANSION LOOPS, ETC. TO ENSURE ADEQUATE SPACING FOR THERMAL MOVEMENT.
9. INCREASED SPACING MAY BE REQUIRED WHERE ORIFICE FLANGES ARE REQUIRED.
10. INCREASED SPACING MAY BE REQUIRED WHERE PIPE CLAMPS ARE USED. (e.g. ANTI-VIBRATION SERVICE, FRP PIPE SUPPORTS, ETC.)
11. FOR LINES WITH CLASS 900 AND ABOVE FLANGES CALCULATE THE REQUIRED SPACING.
12. DESIGNER MAY USE ONLY WHEN CERTAIN THAT THE POSSIBILITY OF ADDING FLANGES INLINE IN THE FUTURE DOES NOT EXIST. NOT RECOMMENDED FOR THE SPACING OF LINES IN PIPERACKS.

RATING		150#													
	SIZE	1"	1 1/2"	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
300#	1"	130	130	130	155	180	205	230	255	305	330	360	385	410	460
	1 1/2"	130	130	155	155	180	205	230	255	305	330	360	385	410	460
	2"	130	155	155	155	180	205	230	280	305	335	360	385	410	485
	3"	155	180	180	180	205	230	255	280	335	360	385	410	435	485
	4"	180	180	205	205	230	255	280	305	335	360	385	410	435	510
	6"	205	230	230	230	255	280	305	335	360	385	435	435	460	535
	8"	255	255	255	280	280	305	335	360	385	410	460	460	485	560
	10"	280	280	280	305	305	360	385	410	435	435	485	485	535	585
	12"	305	335	335	335	360	385	410	435	460	485	510	535	560	610
	14"	360	360	360	385	385	410	435	460	485	510	535	560	585	640
	16"	385	385	385	410	410	460	485	510	535	535	560	585	610	665
	18"	410	410	435	435	460	485	510	535	560	560	585	610	640	690
	20"	435	460	460	460	485	510	535	560	585	610	640	665	690	740
	24"	510	510	535	535	560	585	610	640	665	665	690	715	740	790

RATING		300#													
	SIZE	1"	1 1/2"	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
600#	1"	130	130	130	155	180	205	255	280	305	360	385	410	435	510
	1 1/2"	130	130	155	180	180	230	255	280	335	360	385	410	460	510
	2"	130	155	155	180	205	230	255	280	335	360	385	435	460	535
	3"	155	180	180	180	205	230	280	305	335	385	410	435	460	535
	4"	205	205	205	230	230	255	280	305	360	385	410	460	490	560
	6"	230	230	255	255	280	305	335	360	385	410	460	490	510	585
	8"	255	280	280	280	305	335	360	385	410	435	490	510	535	610
	10"	305	305	335	335	360	385	410	435	460	460	510	535	560	640
	12"	335	335	360	360	385	410	435	460	490	485	535	560	585	665
	14"	360	360	385	385	410	435	460	485	510	510	535	560	610	665
	16"	410	410	410	435	435	460	485	510	535	560	585	610	640	690
	18"	435	435	435	460	460	485	510	535	560	585	610	640	665	715
	20"	460	460	485	485	510	535	560	585	610	610	640	665	690	740
	24"	535	535	535	560	560	585	610	640	665	690	715	740	765	815

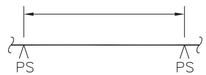
RATING		150#													
	SIZE	1"	1 1/2"	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
600#	1"	130	130	130	155	180	205	230	255	305	335	360	385	410	460
	1 1/2"	130	130	155	155	180	205	230	255	305	335	360	385	410	460
	2"	130	155	155	155	180	205	230	280	305	335	360	385	410	490
	3"	155	180	180	180	205	230	255	280	335	360	390	410	435	490
	4"	205	205	205	230	230	255	280	305	335	360	390	410	435	510
	6"	230	230	255	255	280	305	335	360	390	385	435	435	460	535
	8"	255	280	280	280	305	335	360	385	410	435	460	485	510	560
	10"	305	305	335	335	360	385	410	435	460	460	485	510	535	585
	12"	335	335	360	360	385	410	435	460	490	485	510	535	560	610
	14"	360	360	385	385	410	435	460	485	510	510	535	560	585	640
	16"	410	410	410	435	435	460	485	510	535	560	585	610	640	690
	18"	435	435	435	460	460	490	510	535	560	585	610	640	665	715
	20"	460	460	490	490	485	535	560	585	610	610	640	665	690	740
	24"	535	535	535	560	560	585	610	640	665	690	720	740	765	815

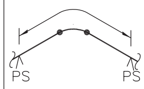
RATING		600#													
	SIZE	1"	1 1/2"	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
600#	1"	130													
	1 1/2"	130	130												
	2"	130	155	155											
	3"	155	180	180	180										
	4"	205	205	205	230	230									
	6"	230	230	255	255	280	305								
	8"	255	280	280	280	305	335	360							
	10"	305	305	335	335	360	410	410	435						
	12"	335	335	360	360	385	410	435	460	485					
	14"	360	360	385	385	410	435	460	485	510	510				
	16"	410	410	410	435	435	460	485	510	535	560	585			
	18"	435	435	435	460	460	485	510	535	560	585	610	640		
	20"	460	460	485	485	510	535	560	585	610	610	640	665	690	
	24"	535	535	535	560	560	585	610	640	665	690	715	740	765	815

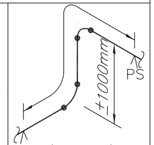
		LINES WITHOUT FLANGES													
	SIZE	1"	1 1/2"	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
LINES WITHOUT FLANGES	1"	85													
	1 1/2"	95	100												
	2"	100	105	115											
	3"	115	120	125	140										
	4"	130	135	140	155	165									
	6"	155	160	165	180	195	220								
	8"	180	185	190	205	220	245	270							
	10"	210	215	220	235	245	275	300	325						
	12"	235	240	245	260	270	300	325	350	375					
	14"	250	255	260	275	285	315	340	365	390	410				
	16"	275	280	285	300	315	340	365	390	420	435	460			
	18"	300	305	310	325	340	365	390	420	445	460	485	510		
	20"	325	330	335	350	365	390	415	445	470	485	510	535	560	
	24"	375	380	385	400	415	440	465	495	520	535	560	585	610	660

Table 1.4 Line spanning chart

PIPE SUPPORT SPACING







PIPE SIZE (NPS)	PIPE O.D. (mm)	PIPE SCHEDULE (NOTES 2, 3, 4)	WALL THICKNESS (mm)	WEIGHT OF WATER-FILLED PIPE SPAN (KILOGRAMS)	ALLOWABLE SPAN (m)	DEFLECTION (mm)	(NOTE 7) FLAT TURN (m)	PS (NOTE 8) ELEVATED TURN (m)
3/4	26.7	160	5.537	–	3.6	15	2.3	2.7
		80	3.912	–	3.0	10	2.0	2.3
1	33.4	160	6.350	21.77	4.8	6	3.1	3.6
		80	4.547	18.14	4.0	13	2.6	3.0
1 1/2	48.3	160	7.137	47.63	5.9	6	3.8	4.4
		80	5.080	38.56	5.2	19	3.4	3.9
2	60.3	80	5.537	61.69	6.1	25	4.0	4.6
		40	3.912	48.53	5.7 (NOTE 5)	15	3.7	4.3
3	88.9	80	7.620	155.13	7.9	6	5.2	6.0
		40	5.486	123.84	7.2	15	4.7	5.4
4	114.3	80	8.560	264.89	8.9	6	5.8	6.7
		40	6.020	207.75	8.1	15	5.3	6.1
6	168.3	80	10.973	633.21	10.7	6	6.9	8.0
		40	7.112	469.47	9.8	15	6.4	7.4
8	219.1	80	12.700	1128.99	12.0	6	7.8	9.0
		40	8.179	832.80	11.2	5	7.3	8.4
		20	6.350	703.52	10.5	4	6.8	7.9
10	273.1	80	15.062	1892.39	13.3	6	8.7	10.0
		40	9.271	1354.88	12.2	5	7.9	9.2
		20	6.350	1054.15	11.1	4	7.2	8.3
12	323.9	80	17.450	2853.09	14.5	6	9.4	10.8
		STD	9.525	1989.47	13.3	15	8.6	10.0
		20	6.350	1451.04	11.5	4	7.5	8.6
14	355.6	80	19.050	3575.67	15.2	6	9.9	11.4
		STD	9.525	2477.97	13.8	15	9.0	10.3
		20	7.925	1989.00	12.5	4	8.1	9.4
16	406.4	80	21.412	4959.58	16.1	6	10.5	12.1
		STD	9.525	3465.45	14.5	15	9.4	10.9
		20	7.925	2536.94	12.9	4	8.4	9.7
18	457	80	23.800	6597.50	17.1	6	11.1	12.8
		STD	9.525	4667.01	15.1	15	9.8	11.3
		20	7.925	3167.89	13.2	3	8.6	9.9
20	508	80	26.187	8521.19	18.0	5	11.7	13.5
		STD	9.525	4333.17	14.2 (NOTE 6)	3	9.2	10.7
24	610	80	30.937	13308.85	19.6	5	12.8	14.7
		STD	9.525	6094.92	14.7 (NOTE 6)	3	9.5	11.0

NOTES:

1. SPANS ARE BASED ON INSULATED CARBON STEEL PIPE (A106–B) FILLED WITH WATER FROM −29°C TO 260°C.
2. XS PIPE AND SCH. 80 HAVE THE SAME WT IN ALL NPS SIZES THRU NPS 8. FROM NPS 10 THRU NPS 24 XS PIPE HAS A WALL THICKNESS 12.7 mm.
3. STD PIPE AND SCH. 40 HAVE THE SAME WT IN ALL NPS SIZES THRU NPS 10. FROM NPS 12 THRU NPS 24 STD PIPE HAS A WALL THICKNESS OF 9.525 mm
4. STD PIPE AND SCH. 20 HAVE THE SAME WT IN NPS 20 NPS AND NPS 24.
5. ALLOWABLE SPAN MAY BE INCREASED TO 6.0 m FOR NPS 2 SCH. 40 ON STRAIGHT RUNS ALONG PIPEWAYS.
6. NPS 20 AND NPS 24 MAY REQUIRE PADS OR SADDLES.
7. 65% OF ALLOWABLE SPAN
8. 75% OF ALLOWABLE SPAN.
9. SEE STRESS GROUP IF VALUES SHOWN ARE EXCEEDED.

Table 1.5 Nozzle projection chart

	NPS	Flange class rating					
		150	300	600	900	1500	2500
Min. outside projection from shell to face-of-flange	3/4	150	150	150	150	150	150
	1	150	150	150	150	150	200
	11/2	150	150	150	150	200	200
	2	150	150	150	200	200	200
	3	175	175	200	200	200	250
	4	175	200	200	200	250	300
	6	200	200	200	250	300	350
	8	200	200	250	250	300	400
	10	225	225	250	300	350	500
	12	225	250	250	300	400	550
	14	250	250	250	350	400	–
	16	250	250	300	350	400	–
	18	250	250	300	350	450	–
	20	275	275	300	350	450	–
	24	300	300	300	350	500	–

All dimensions are in mm.
Dimensions do not include insulation or reinforcing pad thicknesses.

the drawing number, is also mandated in order for the client to be able to accept the drawing files back into the document management system and be able to retrieve them when required. While numbering systems vary by company, most have a hierarchy numbering system using abbreviated identifiers along the following lines:

- Area of operation
- Facility
- Discipline, e.g., mechanical, piping
- Type of drawing, e.g., piping arrangement
- Three- or four-digit sequential drawing number
- Two- or three-digit sequential sheet number

Isometric drawing numbering will require separate investigation. An often used practice is to include the line number as part of the drawing number for easy identification. Sheet numbers identify longer runs where a piping system has been broken into multiple isometric details for clarity, e.g., SHT 1 OF 5, SHT 2 OF 5,. . .. .SHT 5 OF 5.

1.2.5 3D model numbering

What is the model numbering convention to be used for the project? Again, this may be a client or engineering company standard, but it must

be decided right at the beginning of the project. If you are directed to use a company standard, make sure that your client is in agreement. These models will later have to be closed-out and renumbering/renaming can cause considerable work that is likely not included in the budget. As with drawing file numbering, models require a file numbering system that is approved by the client. In today's 3D integrated design world, where all disciplines are referencing the other disciplines' models, and working more-or-less in real time, you and your designers must intimately know the model numbering system. This is in order to correctly name the piping models and identify other disciplines' models that are required to be referenced.

One way that I have seen model numbering done is to follow the Engineering Work Package (EWP) numbering. This makes sense because assembling information is not just the domain of the designers. Often the CAD support group or the material control group will be requested to generate reports of a particular EWP, or a group of EWPs, and a common numbering system for the models and the EWPs will help to locate and compile the information. Common reports are as follows:

- Material Take Off (MTO), either bulk or item specific for
  - pipe and fittings
  - insulation
  - valves
  - shop material (also known as fabrication material)
  - field material (also known as erection material)
- Weld count and diameter inches of welding
- Weights of materials

As all of the reports are generated from the databases that are built as the models are developed, having a direct correlation to the EWP number makes life easier for the downstream people, such as material controllers and purchasers.

1.2.6 Material commodity codes

Material commodity codes are a piping component numbering system used for the identification, ordering, and tracking of materials. Originating in the 3D model material library database, these numbers appear on the MTO reports and the isometric Bills of Material (BOM) and in the documentation used by the purchasers, suppliers, fabricators, and warehousing. These codes are commonly an alpha-numeric string

(e.g., "F" for flange) which uniquely identifies a component. Although ISO 15926 is making inroads, industry standards do not currently exist for material commodity coding of piping components, so companies have to develop their own key element identifiers or engage the services of an outside consultant to develop these for them. So why should this be a concern for the piping lead? If you are using your company piping classes and the material commodity coding is in place, then for the most part you and your designers will have no interest in material commodity codes other than curiosity. However, if material commodity codes are to be used on the project, and development is required because your company does not currently have a commodity coding system, or the client wants you to use their commodity coding system, then you will need to take into consideration the time involved for the development and implementation by the material control group and IT. Development and implementation can impact your ability to start 3D modeling.

As not all projects use material commodity codes, you will have to ascertain whether they are to be used on your project or not. If they are, are they to be to your company's standards or the client's? Will the adoption of a commodity code numbering system cause you any delays?

1.3 SPECIFICATIONS

Many clients and engineering companies will have a set of company specifications for each discipline built on code, safety and insurance requirements, and preferred engineering practices. Most specifications are engineering related, but some are directly related to the layout of the plant. As has already been said, these are related to walkways, platform and ladder requirements, egress and ingress, and equipment spacing, but they often also include other information of importance to the piping designers such as pump and exchanger piping layouts, and transportation requirements for modules and spools. As the lead, you must review these and catalog for your team all of the pertinent specifications and where they may be found, commonly on the company network or a client web based site.

The most obvious and essential specifications to be secured are the piping classes.

1.3.1 Piping classes

The piping classes are one of the most important specifications for the piping designer. These are developed by the piping engineer, and most often have been applied on numerous projects, sometimes for many years. Piping classes are developed around the applicable piping code, and list components and materials manufactured to the standards listed within the code. This allows component use with no further investigation and avoids calculations and material selections being repeated time and time again for the same application. The piping classes list the following:

- ASME code (B31.1 in power plants and B31.3 in process plants)
- Fluid service (process commodities)
- Flange rating
- Corrosion allowance
- Temperature range
- Pressure limits
- Non-Destructive Examination (NDE)
- Heat treatment
- NPS range, and pipe schedule wall thickness (WT) or calc. wall
- End preparation
- Valves
- Listed standards/components and materials accepted by the code for
  - pipe
  - fittings
  - flanges
  - orifice flanges
  - unions
  - plugs
  - nipples
  - spectacle blinds, spades, and spacers
  - olets
  - gaskets
  - bolting

An example of a piping class is Table 1.6.

Piping classes have an abbreviated identifier. An example of this is the following three-digit identifier and Table 1.7:

- Flange rating
- Service
- Pipe material

Components manufactured to standards not listed in the code, or not fabricated to a standard, are not listed within the piping classes. These are known as unlisted or specialty items (SP) and they are listed in the specialty item list. These include such items as strainers and expansion joints. In order to be used within the piping system, specialty items must conform to the engineering and testing requirements set out in the code.

Neither do piping classes take into account out-of-spec items such as a flat face flange needed in a raised face piping system to match with a pump casing flange or Class 300 flanges needed in a Class 150 system to match with the instrumentation.

On 3D CAD projects designers will have to request that these out-of-spec items be added to the piping class material database on a case-by-case basis (given that instruments such as control valves are very commonly specified to a minimum of Class 300 to accommodate the

Table 1.6 Example piping class

PIPING CLASS AAA – CLASS 150 RATING

SERVICE: Sweet Hydrocarbons, Fuel Gas.

PRESSURE LIMIT @ TEMPERATURE:

Temp. °F (°C)	–20 to100 (–29 to 38)	200 (93)	300 (149)	400 (204)	500 (260)
MAWP, psig (kPag)	285 (1965)	260 (1793)	230 (1586)	200 (1379)	170 (1172)

ASME B31.3 LATEST EDITION

Required Corrosion Allowance:	1.6 mm/1/16″
Material Group:	P1 Groups 1 and 2; Carbon Steel
Inspection:	100% Visual Inspection, 100% RT of circumference on 10% of butt welds per welder/welding operator, progressive production basis.
Heat Treatment:	On welds >19mm/¾″ in thickness (ASME B31.3 Table 331.1.1)
Maximum Hardness:	200 Brinell Number

Table 1.6 Continued

Pipe, Flanges and Fittings:

ITEM/CODE	NPS SIZE	RATING	CONNECTION	MATERIAL STANDARD
PIPE: ASME B36.10M	¾ – 1½ ¾ – 1½ 2 – 24	Sch 160 Sch 80 Std.	Thr'd End (TE) Plain End (PE) Bevelled End (BE)	A106 Gr. B A106 Gr. B A106 Gr. B
NIPPLES: ASME B36.10M	½ – 1½	XXS	TE, PE	A106 Gr. B
SWAGES: ASME B16.9	¾ – 1½	XXS	TE, PE	A234 Gr. WPB
FLANGES: ASME B16.5	¾ – 1½ 2 – 24	Class 150 RF Class 150 RF (Std)	Thr'd, SW WN	A105N A105N
ORIFICE FLANGES: ASME B16.36	1 – 1½ 2 – 24	Class 300 RF Class 300 RF (Std)	Thr'd, SO WN	A105N A105N
INSTRUMENT FLANGES: ASME B16.5	¾ – 1½ 2 – 24	Class 300 RF Class 300 RF (Std)	Thr'd, SW WN	A105N A105N
FITTINGS: ASME B16.11 ASME B16.9	¾ – 1½ 2 – 24	3000# Std.	Thr'd, SW BW	A105N A234 Gr. WPB
UNIONS: ASME B16.11	¾ – 1½	3000#	Thr'd, SW	A105N
OLETS: ASME B16.11 ASME B16.9	¾ – 1½ 2 – 24	3000# Std	TOL, SOL WOL	A105N A105N
BLINDS: ASME B16.5	¾ – 12 14 – 24	Class 150 RF Class 150 RF	Spectacle Blinds Spades/Spacers	A516 Gr. 70N A516 Gr. 70N
PLUGS: ASME B16.14	½ – 1½	3000# Solid Hex Head	Thr'd	A105N
BOLTING: ASME B18.2.1			Studs Hex Nuts	A193 Gr. B7 A194 Gr. 2H
GASKETS: ASME B16.20	¾ – 24	Class 150 RF	Spiral Wound 3.2 mm	316 SS, non-asbestos, inner ring

Table 1.6 Continued

Valve Specifications:
(ASME B16.5, B16.10, B16.11, B16.25, B16.34, API 598)

VALVE TYPE	NPS SIZE	RATING	CONNECTION	VALVE CODE (Varies by company)
GATE: API 600, 602	½ – 1 ½ 2 – 12 14 – 24	Class 800 Class 800 Class 800 Class 150 Class 150, C/W Gear Operator	Thr'd SW SW x Thr'd RF RF	Describes valve design, e.g. bolted bonnet, flexible wedge, regular port, OS & Y.
GLOBE: API 600	¾ – 1 ½ 2 – 4 6 – 24	Class 800 Class 800 Class 800 Class 150 Use Gate Valve	Thr'd SW SW x Thr'd RF RF	Describes valve design, e.g. bolted bonnet, stem guided, OS & Y.
BALL: API 608	¾ – 1 ½ 2 – 6 8 – 24	Class 800 Class 800 Class 800 Class 150 Class 150, C/W Gear Operator	Thr'd SW SW x Thr'd RF RF	Describes valve design, e.g. split body, floating ball, regular port.
CHECK: API 594, 600	¾ – 1 ½ 2 – 24	Class 800, Lift Class 800, Lift Class 150, Swing	Thr'd SW RF	Describes valve design, e.g. bolted cap, swing disc.
NEEDLE:	¾ – 1	Class 6000, MNPT x FNPT Class 6000, FNPT x FNPT	Thr'd Thr'd	Describes valve design.

Table 1.6 Continued
Valve Materials (ASTM, NACE, Specified Material)

VALVE TYPE	BODY	BONNET	TRIM	BOLTING STUDS/NUTS
GATE:	A216 WCB or A105	A216 WCB or A105	Stellite – API Trim 8, 13Cr	A193 Gr. B7 A194 Gr. 2H
GLOBE:	A216 WCB or A105	A216 WCB or A105	Stellite – API Trim 8, 13Cr	A193 Gr. B7 A194 Gr. 2H
BALL:	A216 WCB or A105	A216 WCB or A105	PTFE/316SS	A193 Gr. B7 A194 Gr. 2H
CHECK:	A216 WCB or A105	A216 WCB or A105	Stellite – API Trim 8, 13Cr	A193 Gr. B7 A194 Gr. 2H
NEEDLE:	T316SS	Packed T316SS	NACE MR 0175	

NOTES
1. Socket welded piping is preferred over threaded where possible. Use threaded joints at the outlet of vent and drain valves, at outlet of instrument root valves, and to match equipment.
2. Spectacle blinds shall be used up to NPS 12. Spades and spacers shall be used in sizes NPS 14–24.
3. Ball valves have limited maximum temperature (Teflon seats: 200°C, PEEK seats: 220°C).
4. For allowable branch connections refer to Branch Connections Chart.
5. Refer to ASME B16.5 Table 2-2.2 or Table F2-2.2 for Pressure-Temperature Ratings of 316SS Thermowell flanges.

instrument weight with a reduced potential for flange leakage, it is appropriate that all Class 150 specifications databases be prebuilt with optional Class 300 flanges).

As requesting the addition of out-of-spec items can be a source of frustration for both the piping designer making the request and the material controller receiving the request, you will require an approval procedure for adding out-of-spec components into the piping classes libraries. The piping designers' concerns center on the time required for request completion and possible reluctance to add a component. Likewise, material controllers have valid concerns about adding components that appear unnecessary. As this can result in conflict and given that neither of them own the piping classes, it is highly recommended that all

Table 1.7 Piping class identifiers

Flange Rating	Service	Pipe Material
A – 150	A – Sweet Hydrocarbons	A – Carbon Steel A106B
B – 300	B – Sour Hydrocarbons	B – Carbon Steel A333 Gr. 6
C – 600	C – Process Water	C – CS Galvanized
D – 900	D – Process Steam	D – SS 316
E – 1500	E – Chemicals	E – SS 304
F – 2500	F – Acids	F – FRP
	G – Caustics	G – Plastic PVC
	H – Utilities	H – Polypropylene Lined
		J – PTFE Lined

requests be vetted through the piping engineer for approval; the piping engineer is the custodian of the piping classes, and is the appropriate person for the authorization and expedition of changes and additions.

Calculated wall, or "calc. wall" as it is often listed in the piping classes, is another subject to be addressed by yourself and the piping engineer as soon as possible. If you start the modeling with the calculated wall it can later become a problem to update the models once the pipe schedule has been determined. This is particularly true when a piping class encompasses several process commodities and the NPS ranges of pipe vary in calculated WT according to the differing design conditions.

I strongly suggest that you discuss this sooner rather than later with the piping engineer and the material controller. I also strongly suggest that the calculated wall be based on the worst case design conditions for the piping class. The potential for mistakes in design, fabrication, and material control when WT choices exist for a given pipe size can outweigh any cost saving that may be realized on the pipe and fittings themselves. It is also possible that a calculated pipe schedule may prove to be less commercially available than a slightly heavier pipe schedule. Schedule 160, for instance, is usually very available, whereas Schedule 140 usually is not as available.

Finally, the set-up of the piping classes for the use by the designers when creating the 3D models is a joint exercise between the material control group who create the database content and the CAD support group who ensures the functionality. Prior to the start of modeling you

must have these piping classes databases checked against the original (likely in Word format) specifications. The accuracy of all MTO reports and BOM lists on the isometrics rests on the accuracy of the piping class databases and the importance of ensuring the integrity of these databases cannot be overstated.

Having said this, it is also strongly recommended that the piping designers be required to habitually refer back to the original specifications. An impression exists on 3D projects that reference to the original piping classes and branch charts is unnecessary because the choices of available components, including branch fitting choices, have been predetermined and limited per the piping class databases. This is to say that the belief is that the databases provide all the information needed about the allowable piping components (spec driven). However, mistakes in set up and checking do happen, and as a safeguard all your designers should be held accountable to understand the root documents and to verify differing information.

Once the piping classes have been approved they are frozen for the duration of the project. Changes may happen to the piping classes during the project, but these must follow a deviation process.

1.4 PROCEDURES

Projects revolve around procedures, and without these you cannot execute your project. Procedures are the "Highway Code" that keeps everyone on the same page. However, procedures are often either poorly written or not enforced, which is as bad as having no procedure. Read the procedures thoroughly and understand them, because it will be up to you to enforce them later, and possible to expand on them.

Engineering company procedures will commonly include the following:

- Stick files
- Interdiscipline drawing reviews, both internal (engineered drawings) and vendor
- Line numbering
- Stress analysis
- CAD set-up and support
- 3D model reviews
- Checking

- Manhour estimating
- Progress reporting
- Management of change

Client procedures have been developed to standardize the drawing and model deliverables. These include the following:

- Drawings to be as-built
- Project close-out

These last two procedures are usually owned by your client's document management department and enforced by your own company's document management. That does not mean though that you do not have a say. These procedures have areas of overlapping accountabilities between designers and document controllers. Because no procedure is perfect for all situations, the client's document management department is most often conducive to small deviations and are willing to work with you from a designer's input point of view. On smaller projects you may well have direct access to speak with them, whereas on larger projects you will have to request a deviation through your project management team. Deviations to client procedures identified during the initial set-up should be documented in the Project Execution Plan (PEP). You will need to inform your project management team of all deviations to the document management procedures initiated by yourself and agreed to by the client.

The following are brief discussions on all the above-mentioned procedures/activities that you, as a piping lead, must be aware of, and that the piping group has a direct or indirect involvement in. In Chapter Two, CAD and Design Automation in Piping Design, we will discuss in more detail the procedures below that the piping group manage directly or have a major involvement in.

1.4.1 Stick files

Whether electronic computer based or in hard copy paper format, a stick file is the best tool to use for capturing and managing changes. It is a central depository for all mark-ups from all disciplines and ensures that all changes are clearly communicated and surprises are avoided.

The trend in recent years has been to do everything in an electronic computer based environment and shun hard copy paper formats as inefficient and undesirable in the context of project record keeping. This is a perfect example of where the worlds of manual and electronic procedures have collided. While possible to utilize an electronic stick file procedure

using a mark-up tool such as Adobe Reader or Bluebeam Revu, in practice it is still very much human nature to defer to marking up a hard copy print of a drawing due to this still being easier and more familiar. I advocate that a hard copy stick file is still best, scanned prior to back-drafting for record.

A decision will need to be made on either an electronic or a manual stick file procedure.

If electronic is the choice, then you will need to know where the drawings are to be deposited and how they are to be accessed and edited with mark-ups. You will also need to receive alerts when comments are made.

Similarly, if manual is the choice, you will need to have a procedure around mark-ups and notification, and you will need to identify an area where your master stick files will reside. Preferably this will be close by and with reference tables to lay the stick files on. Ideally, you will have room for roller boards. Roller boards, where the drawings are tapped down, work wonderfully to stop people wandering off with your stick files.

1.4.2 Interdiscipline drawing reviews

Drawings are produced in every project. Drawings represent the culmination of the design, and a finalization of all discussions and decisions to date. A review by all disciplines that have had input is required in order to establish that the designs are as expected by all stakeholders. It is your accountability to ensure that the piping drawings are made available for review and comment. Likewise to master stick files, interdiscipline drawing reviews may be by electronic or hard copy methods, either through network access or hard copy circulation. Electronic reviews require a network place where the drawings are stored. Hard copy reviews require a circulation procedure and filing cabinets for storage. Both review methods require a way of sending notifications to the reviewers.

Vendor drawings also require a review procedure. While you are not responsible for initiating vendor drawing reviews, you are responsible to ensure the integrity and availability of the latest vendor drawings for reference and mark-up by your team.

Regardless of the interdiscipline drawing review procedure employed, the document control group play a key role. You will need to liaise with the document control lead for an understanding of their processes and to ensure that your needs are going to be met. In the case of electronic mark-ups, it may also be needed to arrange training for your team on the document control software.

1.4.3 Line numbering

Line numbering is a standard. The elements that make up a line number and the order of placement are standardized by each client or engineering company. The sequencing of the elements may change between companies, but all line numbers contain the following:

- Piping class
- NPS
- Sequential line number
- Insulation thickness and type
- Tracing requirements

Some standards may also include the following:

- Unit number
- Commodity abbreviation of the process fluid

When it comes to the task of assigning line numbers to the P&IDs, a procedure is required. Does a line reduction within a header system constitute the assignment of another line number? Is a pump suction line that splits to a pair of A and B pumps two or three line numbers? You will discover that there are different thoughts on the subject. Line numbering may not be the responsibility of the piping group, and it may fall under the auspices of the process engineers', but you as a piper have a vested interest that requires discussion. The overuse of line numbers can result in piping runs being broken down into a greater number of isometrics.

Whoever does it, and to whatever procedure, line numbering needs to be done sooner rather than later, as modeling cannot begin without line numbers having been assigned.

1.4.4 Stress analysis

How are you going to interface with the stress group? Which lines will be stressed first? How will you track stress analysis? Where will you store the stress mark-ups? And how will the stress requirements be disseminated to the pipers? These are questions that we will investigate in more detail in Chapter Two, CAD and Design Automation in Piping Design. It is a complex matter, and not one to be overlooked. If you do not have a company procedure to fall back on, you will need to develop one.

1.4.5 CAD set-up

CAD support is a major contributor to the success of any project. Ensure that the appropriate company and client CAD procedures are going to be used:

- Maintaining databases
- Plotter and printer set-ups
- Model back-ups, usually nightly
- Project close-out

The above will be of little interest to the designer and should be happening seamlessly in the background. However, there are project set-up requirements that are of particular importance in order for the designer to do his/her work. But, because there are many ways of doing things, the CAD support group will require direction from you, the piping lead, for the following to be input:

- Work areas
- Client or company piping classes
- Client or company piping standards, e.g., shoes, base ell supports, anchors, and guides
- Color coding of pipe, equipment and temporary steel per the client or company standards. For example is pipe to be color coded
  - by piping classes: Class 150, 300, 600, etc.

    or
  - by commodity: sub-sets of water, steam, oil, gas, etc.
- Link for automatic data extraction from the LDT into the isometric titleblocks
- Clash report procedure

Another consideration is the generation of reports and the reports' format. Other groups will rely on reports generated from the databases for such as purchasing and estimating purposes. Establishing the reporting needs is an essential part of the CAD set-up. The databases used for these reports are built during the development of intelligent P&IDs and 3D models, and consist of the following examples:

- LDT
- Equipment Lists
- Instrument Lists
- Specialty Item Lists
- Valve Lists
- Corrosion Coupon Lists
- Car Seal Lists
- Spring Supports List
- Bulk Material Reports
- MTO Reports
- Weld Diameter Inch Reports
- Weights of Materials Reports

A project directory structure is also required where drawings and models are deposited. This structure should ideally be mirrored by each discipline so that finding models is easy for all. As a side note, designers love to copy into their personal drives and work from there on unofficial models. This practice must be discouraged as it can cause obvious communication problems. There is nothing wrong with copying to do some studies, but the results must be imported into the master model as soon as possible, and all work should primarily only be done in the master model.

Which software and version of that software are you using? Lock it in and do not let anyone tell you that an upgrade during your project is an easy matter. The software and version may be mandated by the client, in which case the decision is off of your shoulders, but if it is a company choice do not change once you start. Changing the current version to an untested version during a project inevitably leads to untold grief and extra, unbudgeted hours. No disrespect to the CAD support group, but even if they tell you that it has been tested, do not let your project be the ultimate test case for the newest version, no matter how much they protest that this will solve many of the problems currently encountered. Testing is nebulous, and their testing of some functionality and file conversion on a small scale will not be representative of the full usage by the designers and conversion of dozens or possibly hundreds of models and databases.

Security is another issue to be addressed. Your client may be very interested in this aspect of his/her project, but even if they are not, it is in your own interest to make sure that you are comfortable with the security measures that are in place. Security means access. Who has access to edit the models? Minimally, there should be restrictions on the following:

- Each discipline. A discipline must not be able to edit the other disciplines' models.
- Stages of design. Freeze models when they are ready for checking. Unfreeze but freeze again after the changes required by checking have been made. Designers are perfectionists and if there are no controls stopping them from doing so, they may go back into their models and make changes during checking and even after it has been Issued For Construction (IFC). While keenness can be admired, unmanaged and unchecked changes that surface will cause an embarrassment at the least, and can lead to other costly problems.

Several other decisions that you may also be required to have input into with the CAD support manager, office manager, and project manager are as follows:

- The number of CAD stations you will need.

- The types of software and number of licenses.
- The space and furniture requirements for common areas, e.g., plotters, printers, stick files, filing cabinets, lay down tables.

If manual stick file and interdiscipline drawing reviews are being used, when you meet with the office manager be sure to order all of the stamps you will need, i.e., a date stamp, "RECEIVED," "MASTER STICK FILE," "WORKING COPY," "PIPING COPY," "CHECK PRINT," "SUPERSEDED," and "FOR INFORMATION ONLY." You could also order stamps for "STRESS COPY" and "FOR BID PURPOSES ONLY. NOT TO BE USED FOR CONSTRUCTION," but these can be added to the drawings as blocks at the time of issue.

Designers require lots of support from the CAD support group. You will require a clear line of communication between the two groups for the following:

- General questions about CAD execution and CAD commands
- Copying of databases
- Modeling of specialty items
- Adding of specialty items and out-of-spec components into the piping specifications and material libraries
- Retrieving lost data and corrupted files

Larger engineering companies may well utilize software whereby a request is sent and a ticket number assigned. Smaller companies may well utilize an e-mail request. However this is to be done, make sure that you have a documented procedure that can be distributed to the designers.

1.4.6 3D model reviews

Model reviews are commonly conducted at the 30%, 60%, and 90% stages of design completion, and involve buy-in by all stakeholders up to that stage. Definitions are required for each of these stages so that everyone has the same understanding of what is to be accomplished prior to and during the reviews, and the designers stay focused on the parameters to be established leading up to the reviews. The best way for this to be accomplished is to have written documentation with a model review matrix.

1.4.7 Checking

It goes without saying that checking is a requirement of any project, but how are you going to go about this? What are you going to check? You need a checking procedure to give guidance and ensure consistency.

1.4.8 Manhour estimating

Manhour estimating and manpower planning can be quite a daunting task, and there are books written on this subject alone. Generally speaking, companies employ schedulers for this task, but as a lead you will be required to have input into the piping hours budget and piping schedule. The schedulers will be of valuable assistance in helping you with this task. However, it does not end there. After the piping budget and piping schedule have been established, the task of work allocation—literally the decision on which designers will work in which areas and according to a priority that supports the schedule—rests with the piping lead.

A sometimes overlooked requirement for manhour estimating and manpower planning is to know the deliverables. If these are not clear, do not make assumptions. Get direction from your project management team on the client's expectations. This is to ensure that you have a clearly documented basis for your estimating that can be used later to support a revision to the budgeted hours should the need arise.

1.4.9 Progress reporting

Your project management will expect progress reports. Larger engineering companies will have their own procedures to accomplish this. If you are in a smaller company, chances are that you will need to establish a form of reporting in conjunction with the project management. Reporting is essential, not just because periodic payments from the client may be tied to the progress, but because it is necessary to understand where you are in the project, whether or not you are staying within the budgeted hours, and to identify when you are going off track in order to take corrective action.

1.4.10 Management of change

Change is inevitable in any project, and management of change is crucial to the success of the project. You must manage the trends and scope changes for the piping effort. A trend is an unbudgeted event that increases the number of hours required to complete an activity. For instance, a deviation to a piping class or vendor information that arrives later than planned and causes delays and rework constitutes a trend. A scope change is a modification, deletion, or addition to the original scope that was not budgeted for, such as the addition of a piece of equipment.

In order to recognize trends and scope changes, a clear understanding of the original project scope and budget is required.

Scope changes are quite easy to spot and usually emanate from the client, whereas trends can be contentious and usually have to emanate from you, the piping lead. Are the hours that are being expended normal design development or are they a trend? You are going to find yourself in this debate many times in your career. The simple answer is that there are no simple answers. However, situations such as those below are clues:

- If you have to change your plans and focus due to delayed arrival of information, leading to productivity being lost, this is a trend.
- If you were given information with assurances as to the completeness and accuracy of this information for the level of design, and you have to rework your design because it turned out not to be so, this is a trend.
- If you were required to move ahead with preliminary information into detailed design and later, when firmer information is available, have to rework the design, this is a trend.
- If you or your group has to spend an abnormal amount of time assisting another department or a vendor, this is a trend.

If for whatever reason you find yourself losing productivity and/or reworking a design more than once and are in danger of exceeding the budgeted hours, discuss the situation with your project engineer. A trend may be in order.

You will learn that timing is everything and design developments, such as a line size increase, or scope changes, such as a pump addition, that come during the earlier study stage can be accommodated quite readily without much, if any, schedule impact. But try accommodating the same just before IFC and you will be looking at significant rework, schedule delays, and cost impacts.

The surprising thing, considering its importance, is that managing change is often done poorly or not at all. Formally raising, approving/rejecting, and documenting these will avoid misunderstandings and wasted hours. I have seen more than one project where the lack of documentation caused significant discord between the engineering company and the client. Clients have a tendency to request changes throughout the project and consider them design development, not trends or scope changes. Engineering companies have a tendency to jump to attention and rush in to accommodate the client. The client believes that his/her requests are going to be accommodated without extra cost or schedule

impact while the engineering company assumes that the client realizes otherwise. They are not on the same page, and likely will not be until much later, after further discussions, possibly some hard feelings, and likely after all the changes have already been made.

We must generate change notices to capture the impact that trends or scope changes will have or are having on the piping effort. This documentation allows for a time of assessment to cost and schedule and for a conscious choice to be made on how to proceed. Are the changes necessary? For example, are they safety related, or are they just nice to have? Can something be done about the potential productivity loss related issues?

Your project management will expect change to be recognized, documented, and submitted for approval. As the eyes and ears of the piping group, the piping lead is expected to keep his finger on the pulse, and not jump the gun and allow unapproved design changes nor keep reworking the same area due to someone else's inability to make up his/her mind. You are expected to see change coming, to anticipate the consequences, and to raise flags ahead of time. Do not put yourself in the unenviable position of trying to explain later why you are going over on budget and schedule. You may end up making changes back to the original design and lose credibility as a lead. Only a junior would use the excuse that someone else told them to do it. Do not forget that you are a senior member of the team with a budget that you are responsible for.

It is important that trends and scope changes be addressed as soon as possible, but you will have very little control over how long these will take. There are three options:

- Continue with the design as planned until the change is approved, recognizing that the longer it takes to be approved the more work there may be to undo in the design.
- Incorporate the changes into the design as if they are approved. For this you must get assurances from the project team in writing that the paperwork to proceed is a formality and will be forthcoming.
- Put the design in question on hold until approval is received.

The golden rule is that without an approved trend or scope change, no changes are to be made. This is a very reasonable, necessary, and important requirement for the project, and all companies should have a procedure for submission and approval/rejection. Your company should have forms for trending and scope changes. They will not always have the

same title at each company, but will be along the lines of "Engineering Notice of Trend" and "Scope Change Request."

1.4.11 As-builts

It may seem unnecessary to consider as-builts at the beginning of the project, given that it is one of the last tasks to be completed. However, you will need to establish exactly what your client requires to have as-built in order to complete your manhour estimates. Your client may only require this of critical documents and will define "critical" for you. Critical documents can be defined as documentation that government regulatory bodies and the company deem must be kept current for the continued safe operation of a facility.

While by no means an exhaustive list, the documents generally listed that involve the piping group are as follows:

- P&IDs
- LDT
- Plot plan and equipment location plans
- Underground piping plans
- Heat tracing (commonly hot oil, steam, or glycol)

It is possible that you may also be required to as-built the 3D models and the piping arrangements.

The client procedure must list and give direction in the documents to be as-built.

Depending on whether your company or the client is handling the construction management, the client or company procedures must give direction on

- how the as-built changes will be captured, e.g., redline mark-ups in the field
- how the as-builts are to be turned over to the engineering group
- how the engineering company is to turn the completed as-built documentation over to the client

Internally, at your engineering company, you must plan for the following:

- Reviewing the as-builts, i.e., that the noted changes that occurred during construction were documented and approved
- Drafting and checking of the field collected as-built information
- Sign-off

1.4.12 Project close-out

At the end of the project, a close-out will be required. This generally involves handing over all the models, databases and drawings to your engineering company's document control group for close-out with the client's document control group. Make sure that you have an internal close-out procedure and a close-out procedure from the client, and that you fully understand the requirements of both. If one or both of these has not been provided, you may need to develop them in conjunction with your own people and the client.

1.5 PIPING EXECUTION PLAN

There are two key documents that are the basis for the project: the Design Basis Memorandum (DBM) and the Project Execution Plan (PEP). A Piping Execution Plan and a Design and Drafting Execution Plan will form part of the PEP, and you as the piping lead are expected to be a leading contributor in the writing of these sections. The Piping Execution Plan may be a section unto itself or it may be a subset of the Design and Drafting Execution Plan.

The Piping Execution Plan and the Drafting Execution Plan are where all the decisions that have been made are captured in writing. General decisions on drafting that involve all disciplines, such as CAD software, are captured in the Design and Drafting Execution Plan, and specific piping related decisions are captured in the Piping Execution Plan.

The following is a brief discussion of the DBM and the PEP, as they are the guiding documentation for you and your designers and the basis for everything that is to follow.

1.5.1 Design Basis Memorandum (DBM)

The DBM defines the project scope and describes the technical basis for detailed engineering. The typical content of a DBM includes the following sections:

- Project Overview and Facility Description
- Facility Design Basis, e.g., Specifications and Standards
- Safety Design Basis
- Process Design Basis

- Civil and Structural Design Basis
- Mechanical Design Basis
- Electrical Design Basis
- Instrumentation and Controls Design Basis
- Any additional relevant basis information

1.5.2 Project Execution Plan (PEP)

The PEP describes how the project will be executed and typically contains the following sections:

- Cost Estimate
- Schedule
- Organization Plan
- Project Controls Plan
- Quality Assurance Plan
- Safety and Health Plan
- Regulatory Compliance Plan
- IT Plan
- Contracting and Procurement Plan
- Document Control Plan
- Engineering Execution Plan
- Design and Drafting Execution Plan
- Construction Execution Plan
- Commissioning Plan

Your designers must read and understand these documents because they constitute the official instruction for the project that everyone has to follow. Two key sections in the PEP are the Contracting and Procurement Plan and the Construction Execution Plan.

1.5.3 Contracting and Procurement Plan and Construction Execution Plan

The Contracting and Procurement Plan and the Construction Execution Plan outline the procurement and construction philosophies and are the basis from which many other decisions and planning by the piping lead will stem:

- Modularized and field erected piping splits
- EWP boundaries
- Model boundaries
- Shop and field material splits

- Procurement splits
- EWP drawing packages
- Scopes of Work (SOW)

These documents may be in a preliminary stage when you first start and you may have to help define the contents. Failure to clearly establish the Procurement and Construction Execution Plans at an early stage and starting into detailed design without them can result in material, modeling, and drawing boundaries that may not later match the final desired EWP breakdown. This can lead to confusion for the fabricators and erectors, or added hours to rectify the splits.

1.6 CONCLUSION

You must investigate and secure all of the above, and should any of the above not be readily available, you must raise the flags with your project management team as to where it may be secured from and adopted for the project.

There is a lot to consider, and many questions to be answered, and much will be discussed in more detail in the subsequent chapters.

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CHAPTER TWO

CAD and Design Automation in Piping Design

2.1 INTRODUCTION

For the purposes of this chapter, "design automation" and "CAD" refer to the use of these technological tools in the context of process and plant design and engineering.

Inextricably linked to the role of a piping lead are the tools by which the designs will be executed and the methodologies by which these tools are to be employed. A primary tool in the piping design arsenal is CAD, and it is to this tool that this chapter is dedicated, both in the advantages and disadvantages, so as to provide an awareness of the questions and decisions that may need to be addressed.

A chapter on CAD/design automation for process plant engineering is challenging since software is constantly changing and the size and scope of projects using the technology is wide and varied. Projects can be as small as a relatively simple vendor skid package featuring a few pieces of equipment and minimal piping all the way to a multi-billion-dollar complete process facility.

Since the subject matter of how modern process plant design is performed through the use of 3D CAD can vary enormously from company to company, it is impossible to set out well-defined and universally accepted methodology. In addition, the 3D plant design world is a fragmented place (even considering the relative maturity of the internet and its myriad user support and discussion groups) due to the relative obscurity of the profession and the variety of software that is used. As a result, this chapter will provide observations, discuss generalities, and propose solutions/approaches that hopefully will apply to any modern process plant design effort.

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2.2 OVERVIEW OF TECHNOLOGY

CAD software and other forms of automation have been used for a few decades in the field of piping and process plant design. These software have grown over the years from mainframe specialist utilization (often run concurrently with traditional manual drafting) to exclusively PC-based CAD utilized by all designers. Also over the years CAD software has developed from a purely drafting tool (document centric systems) to a component of an integral system of data linking (data centric systems).

2.2.1 Brief history

A lot of time has passed since Davy Computing's Compaid software was being used in the late 1960s for the creation of piping isometrics for process plants. Davy Computing's software was available for purchase as well as timeshare rental from McDonnell Douglas Computing Services and Multiple Access Limited in St. Louis, Missouri and Montreal, Quebec, respectively. In those days, only the largest projects could afford to take the risk on the new technology, but adapting meant savings in manhours and fewer errors (but also the increased need for training and the use of expensive software and hardware). AutoCAD running on relatively inexpensive Intel-based chips in the late 1980s brought CAD to the mainstream, although at the time this technology was not much more than an electronic pencil for much design work. In the coming years, ever-cheaper and more powerful central processing units, random access memory, physical storage and video card, and display technology led to a revolution in CAD software availability and usefulness.

By the mid-1990s computing power had increased enough to allow 3D piping software to run on workstations (typically Silicon Graphics) instead of mainframes and shortly after such software was ported onto Windows NT, becoming far more mainstream and reducing administration costs. The current oft-repeated meme of "my cell phone has ten times more computing power than the original NASA Moon lander" is at risk of becoming an underestimated cliché of at least one order of magnitude. While mentioning such "amazing" amazingness may now seem sentimental, it does illustrate how far computer technology has developed in such a short time. A 1987 article in *Computer-Aided Engineering Journal*

titled "CAD in process plant engineering" contains this line: "Current PDMS projects have databases around 100 Mbytes."

Relatively affordable 3D CAD has provided amazing abilities for the process plant design industry. The possibilities for informing, educating, and completing previously prohibitively labor-intensive tasks are very impressive. It has become, however, convenient to expect the impossible from the technology. The world's best computer/software technology does not make a better designer; it can only make a good designer better (if implemented properly). As the oft-repeated dictum goes (paraphrased), "automation enables more serious mistakes to be made faster."

The more affordably priced 3D piping software allows smaller companies to compete for larger projects, although the necessity of competent database implementation/maintenance (for piping commodity codes, etc.) and effective user training and discipline must be a prime consideration for management. It goes without saying that management must be "up-to-speed" with current 3D CAD technologies and the inherent real-world capabilities and limitations. Promising that which cannot be accomplished due to ignorance of the software's capacity cannot exonerate management from responsibility. Believing in "well, that feature/function will be fixed by the time we need it" is somewhat short-sighted. On the other hand, the marketplace tends to change quickly enough to leave a lot of doubt in the minds of those making the decisions.

There are many different 3D software packages from simple-to-use to completely data-centric. Often software used is determined by project (similar facilities operated by client requiring data compatibility) or by client preference (owner/operator has standardized on specific software throughout their organization). The software which is chosen can dictate the level and size of project executable. If SmartPlant 3D (SP3D), for example, is chosen then it would not be beneficial to do small riser sites as these will not provide enough income to offset the overall cost of the program. However, CADWorx is an example of a smaller program that can easily adapt to smaller projects, thereby keeping costs lower.

Catalog/database-driven/data-centric design software places components into a 3D model from a preexisting "digital warehouse" (or "catalog") of items as the designer creates or inserts virtual equipment and routes virtual piping. When the items are added to the model they are also added to the overall material list. The main advantages of catalog-driven 3D software (as opposed to 2D programs) are up-to-date material information, improved clash detection and visualization. Key issues when

using this technology are finding and retaining skilled people to operate and maintain the "machinery" as well as software file format incompatibility. Data-centricity essentially adds descriptive information about components in addition to the visual representation of those components.

Most of these programs require a CAD platform such as AutoCAD or MicroStation to install upon; Plant Design Management System (PDMS) and SP3D do not; however, some form of CAD may be required in order to output deliverables such as 2D drawings for component and assembly fabrication and field erection.

Lower cost can be considered to be the AutoCAD and MicroStation based packages such as Bentley AutoPLANT and OpenPlant, Hexagon PPM, Autodesk's own relatively new Plant 3D, PROCAD, and similar software. All these software packages run on Windows operating systems of various vintage. High cost software would be considered to be SmartPlant from Hexagon PPM and PDMS from Aveva.

AutoCAD and MicroStation based programs have the advantage of having a much larger CAD user community that is familiar with the interface and the operating of the software itself, whereas the higher priced programs are more or less exclusive simply because it is difficult for people to experiment with them without already being involved in a large project and employed by a large company which will give them the exposure and training to the software.

The two previously mentioned programs SmartPlant and PDMS are typically used for the so-called downstream "mega-projects" that exist in the billion dollar range and involve many design subcontractors. Some examples of SmartPlant and PDMS projects would be new refinery or offshore platform design and construction, while examples of the AutoCAD/MicroStation-level projects would be smaller refinery upgrade jobs or relatively smaller process piping related facilities and component package systems.

Hexagon PPM has a corporate history extending back to the United States' space program and Aveva's PDMS was originally conceived as a suitably demanding computationally intensive application in order to utilize the processing power of Britain's then newly produced supercomputers.

Also available are some less commonly well-known products such as the data-centric Plant 4D from CEA Systems in the Netherlands, SolidPlant (also from the Netherlands) as well as Smap3D from Germany (both based on SolidWorks) and CADMATIC from Finland. These seem

to be specialized products for niche industries that have not yet broken into the North American process plant design market in a big way.

A major change in the industry was the use of Isogen, software that is still in use today as a standalone program as well as being built into many 3D piping design software suites. Isogen automatically extracts piping isometric detail drawings, bills of materials, and other pertinent data from 3D piping models. This automation reduces considerably the manpower requirements for fabrication deliverables creation and minimizes the risk of data transposition errors caused by human involvement.

2.3 SOFTWARE SUPPORT

One major factor related to operating 3D piping and plant design software effectively and efficiently is the necessity to employ qualified, competent, and motivated support personnel to ensure the smooth operation and prompt fixes for the inevitable problems that will arise during project execution. These resources can be difficult to find, as accredited comprehensive educational courses in this specialty are typically expensive, have high relative knowledge entry requirements and limited geographic availability. An individual who can troubleshoot the average AutoCAD or MicroStation problem will quite often not be qualified to diagnose and correct data-driven 3D piping software issues. Many third-party software vendors do offer intensive courses for existing clients' technical support staff, and some sessions are available over the internet via "webinar" type remote learning. There are no easily available classes or text material that can be accessed by those wishing to learn in their spare time. It is to be noted also that the data-centric systems require a higher degree of CAD administration than the drawing-centric systems.

In any case, when using these database-driven software packages for piping design or in fact plant design, it is incredibly important to ensure that the setup is done properly before any of the design work starts. However, given the realities of plant design it is not always possible to have all of the proper infrastructure in place before the design work starts. Therefore it is critically important to try to anticipate what the project requirements will be as much as is possible before you start your setup. It

is always a losing game to play catch-up after the fact for a CAD/engineering automation support group.

For CAD-related problems, a support ticket-type company "message board" (email or intranet-based) should be implemented where users can describe the issues they are experiencing to CAD support. This communication system should provide users with immediate feedback indicating that the problem has been logged so that their inability to work is noted as a system problem and not their own. When CAD support resolves the problem, it must be noted (at a resource site that the user can see) what the problem was and how it was corrected. In many cases, the writer has seen such logs where the intranet response from CAD support was "Fixed!" indicating that the support person had done their job, but nobody knows how or what was done. This phenomenon can lead to a mutually dependent type relationship between users and support personnel. Needless to say, this is an undesirable and avoidable outcome.

In order for the database generated software to function a catalog must be created. This catalog must describe in full detail which components are available to the CAD operators and how these components will be created within the working design environment. It is very important that at the early stages of a project that those who select components are specific as to which versions or variants are going to be used in the project. Failure to establish this will guarantee confusion and chaos later in the project. Some other issues may be that the products are constantly changing within catalogs and may require some model updates after the data has been already checked. Updating models can prove to be troublesome for some software packages.

An up-to-date, accurate 3D model list is absolutely necessary for all disciplines. The nature of catalog-driven models *requires* that there is no duplication of data; failure to respect this methodology renders the advantage of timely material count untrustworthy.

As much as possible, specific details relating to piping fabrication should be communicated (externally referenced) on the piping isometric deliverable via the use of automatically inserted standard 2D CAD drawings and data.

Database-connected piping and instrumentation diagrams (P&IDs) require considerable up-front groundwork be done before the P&IDs are started. Often, less experienced drafters are assigned the task of flow diagram/P&ID generation and the resulting likely ambiguities in core documents can easily lead to confusion. CAD operators creating P&IDs

from process engineers' sketches (or just modifying preexisting examples) have to be carefully monitored because mistakes, errors, omissions, and misunderstandings at this stage can have a large impact later on in the project, since all piping design originates from P&IDs. At this stage it is useful to employ experienced piping designers on a rotating basis as early stage checkers to monitor the progress of the P&IDs.

Another ongoing issue is the in-house customization of software by engineering firms. This is often done to "fix" an existing bug in the purchased software, to automate certain tasks, or to add some functionality. What can easily happen is that the software from the vendor is updated and the in-house customizing no longer functions, resulting in the engineering firm avoiding upgrades. This can lead to not taking advantage of the "latest and greatest" features and improvements of the software, possibly causing interoperability problems between models that have to be shared internally and/or externally.

Some engineering companies create home-grown "workarounds" or "fixes" to help a project along. One challenge with this can happen when the people who created them have left the company. Any such "fixes" must be fully documented by those who create them, but in practice this is often not done due to time constraints (suffering the fate of many as-built documentation promises). Failure of management to provide the extra manhours for this documentation to be completed *will* result in costly rework and time-wasting finger-pointing later.

2.3.1 Further task automation

One desirable feature of catalog-based CAD is the possibility to perform a global (but careful and judicious) search-and-replace of components that have changed or been modified since the original project start. This can be required due to vendor data being revised (for example, something as innocuous as a one-digit model number change for a component can wreak havoc for a purchasing department or a field inventory count) or minor dimensions being changed.

There are limitations as to what can be automated in this regard, however. Most times a modified component must be erased and then re-created inside the 3D model itself if there are dimensional changes, and this of course requires a fair amount of labor to execute across all instances.

ISO 15926 is an effort to create a standard method of describing process plant-related elements so that descriptive data can be shared between different design and engineering file formats. As the standard is a work-in-progress and there are many complications (motivational, technological, logistical, and political, to name a few) to overcome it remains to be seen if ISO 15926 will ever be implemented effectively in the rapidly changing world of plant design software. The obvious advantages are to the end clients and the actual users of design software, but the challenge of achieving agreement among a myriad of software developers (many of whom may not "buy-in" to the project for economic or other reasons) may prove to be unsurmountable.

The advantages of reaching the goals of ISO 15926, however, are great. It can be claimed that the current state of engineering data storage actually creates work (via data translation tasks/work re-creation), but this notion may prove to be a hindrance to the technology in the long run.

Conversion of models to a more convenient format for review purposes is another example of a task that can be automated, as native file formats can prove to be unwieldy for viewing in the field or with non-specialized computers.

Automated pipe routing (for example, from tank nozzle to pump nozzle via a pipeway) is already in use with software such as ASD's OptiPlant and Bentley's PlantWise. Such software can be very useful in establishing material take-offs early in a project or front end engineering design (FEED) but are less suited for the detail design stage. At these early stages of projects, most detailed information about plant process equipment is rarely known, so precise piping routing is not feasible, and constantly updating information in a tool designed for preliminary material estimates, conceptual layout, and major construction planning is impractical. This does not prevent nonengineering management from sometimes thinking that "the plant has already been designed" when they see the output of these programs. This type of software also requires highly trained as well as experienced piping designers as operators, since the output will be used as the framework for the detail design phase—and any errors introduced at this stage of project planning will carry over into the much more complex and time-consuming phases further on. Fundamental routing and equipment mistakes made early-on in engineering are *very* expensive to correct due to the cascading effect of revisions on downstream tasks.

Until (i.e., likely never) process plant components such as pumps and process vessels are standardized in physical connections and physical sizing and footprint, auto pipe routing software will be mostly used strictly for FEED purposes.

2.4 OTHER CONSIDERATIONS

The previously mentioned article "CAD in process plant engineering" contains the following statement: "However, computer techniques even today tend to mask unreasonable answers, and engineers must retain a firm grasp of basics and cultivate a critical approach to computer answers to trap absurdities."

There should be no delusions that design automation is going away and it is extremely useful, but let us look at some potential negative side effects:

- More easily implemented centralized control in the hands of people who may not appreciate or understand project engineering culture, methodology, or customs.
- Lack of diversity in problem-solving (software capabilities sometime limit potential solutions).
- De-valuing of individuals' established experience, skills, and knowledge (commodification of engineering).
- Silo effect of skillsets, tools, and knowledge of designers (Staedler vs Koh-I-Noor pencils analogy) reducing eligibility for work with different software platforms.
- Nonsimple transference of knowledge from one software platform to another.
- Many fewer entry-level tasks for less experienced people reducing mentoring opportunities.
- Reduced pride in workmanship due to the anonymous nature of deliverable output ("anonymization" of work).
- Knowledge work outsourced to machines which may themselves be offshored to lower cost centers.
- Selling of software to nonengineer executive decision-makers based on "cool factor."

- Administrative only lead versus traditional chief draftsman/technical lead, leading to a flight to the perceived security of management/administration roles.
- Focus on fast track schedules and "fix-in-field" versus careful planning and methodical work processes.

Much has been said about the perceived infallibility of computer models, since, well, "computers don't make mistakes." The people operating them, however, often do. There are many ways software-related issues can occur:

- "Under-trained" operators.
- Incomplete or just plain wrong initial assumptions and misunderstood design criteria.
- An attitude that nontrivial design changes can be easily made and ignoring the concept of "freezing" design in order to minimize cascading chaos effect of seemingly minor modifications.
- Reliance on past models as a resource to design a plant because of the notion that components/designs can easily be re-used (actually, this IS possible, but not without considerable planning and caveats). This time-saving possibility depends on the specialization of the engineering company.
- User "workarounds," sometimes undocumented/unofficial, unintentionally undermining time, or work-saving processes.

2.4.1 Software interoperability

The concept of incompatibility between CAD software has long been an issue for designers and engineers, as this can be an impediment to the easy exchange of engineering data between two different parties. This is an important consideration, since the creators of information or data, whether it be engineering or architectural are not necessarily interested in the computer software complications that may slow them down in performing their primary duties. One challenge here is the file formats from vendors—manufacturers cannot reasonably be expected to create 3D CAD models of all their products in all possible CAD formats.

Inserting ready-made vendor 3D models (if available—for example, a model of an industry standard heat exchanger or pump) into overall plant design models can save time and effort for the engineering firm, since these models will not have to be created by the engineering firm's CAD designers. An added advantage of vendor provided models is that data

originating from the vendor/manufacturer is more likely to be accurate dimensionally than one generated by piping design/drafting staff, as there is less chance of error during information transposition. However, while vendors who can supply 3D CAD models of their components can save a lot of time, if the 3D models that are provided are generic and not specific to the project at hand, this can cause problems down the line if people assume that the standard "out-of-the-box" 3D model is accurate. Careful checking of externally sourced components is always required.

What can also happen is that vendors that do not appreciate the scale of major projects create 3D CAD models using software (such as SolidWorks, Autodesk Inventor, and Solid Edge) that is unsuitable for importation into an overall plant model because it contains far more information than is required for piping layout purposes. An example of this can be a skid manufacturer who creates a 3D model that is so detailed that it occupies 20 or more megabytes of space. In a large plant or process piping facility, a model of this size will cause problems and will have to be modified. Resolution of detail level of supplier-sourced 3D model entities must be considered. Actual manufacturing files (for, as an example, a pump) will be much too large and unnecessarily detailed for inclusion into a process plant 3D model.

Another issue which is frequently encountered is the provision of CAD data which comes from incompatible or not-usable formats from different vendors. What can often happen is that an Engineering, Procurement, Construction (EPC) company will standardize on one CAD system but receives CAD data that is created by different software in an incompatible format. This will require file format conversion (adding nonproductive hours to project) which may cause a loss of functionality as well as introduce increased possibility of human error.

2.4.2 User interface

User interface is the ability of the user to implement the functionality of the software—many advanced features/functions may be present but not enabled or may go unused for a variety of reasons.

Some reasons for suboptimal software feature implementation may be the following:

- Features do not prove to work as expected.
- Feature is too complicated or "fragile" for practical use.
- Feature requires "buy-in" from other reluctant disciplines.

- Feature requires more highly trained employees.
- Feature requires expensive or potentially disruptive corporate infrastructure upgrade.

2.4.3 Over-reliance on software

Exact adherence to instructions is very often critical to the proper operation of software but this mindset is contrary to the very nature of the design process. Design is iterative, unless one is simply customizing a template (in which case, use of the term, "design" to describe the work is debatable). Literal interpretation of instructions written for general purpose can result in a lot of confusion and unintended consequences and can easily defeat the purpose of a tool's implementation.

An apocryphal story about the Six Day War in 1967 is that Egyptian tank crews frequently remained outside their Russian vehicles because the interior of the tanks were too hot (in the desert—who would have thought?). The problem was exacerbated because the crews interpreted the Russian instruction manuals incorrectly. The manuals referred to operating the tank's heater frequently, so they did that—and not making the connection that the armored vehicles instruction manual was written for a climate commonly found in the Soviet Union. How is that for not thinking things through and not asking for clarification? But in the software world, asking questions is often frowned-upon perhaps because no one actually knows the answer or answering the question may lead to inconvenient other questions or explaining things may just take too much time. "Just because" is often the response given.

Professional commercial software tends to have an authoritative air about it since it is written by a group of subject matter experts in that field. This can often lull the users into a sense of complacency and confidence when they could be challenging the software's output because of the phenomenon of garbage-in, garbage-out (GIGO). In many ways the use of software (since the perception is that it has been created by experts) has instilled a sense of trust in something intangible. But this has created in many ways a nonquestioning attitude toward whatever the output of the software may be (black-box magic).

This goes back to the concept of leadership. Even a technically competent leader will have a hard time challenging the output of software unless he knows its workings inside and out and also knows the variables that were entered in order to generate the results. This phenomenon has

resulted in many project leads only concerning themselves with budget and schedule, largely abandoning the technical side of the role.

One of the main concerns with engineering today is over-reliance on software. It has become far too easy to rely on the output of a machine as opposed to thinking for yourself. As we know, many students prefer to take shortcuts and shortcuts are not something that should be done in engineering because of the high stakes of uncaught errors in this business.

This can be extremely dangerous, as any human endeavor necessarily requires the critical thinking and input of the people that are local and addressing the concern that is immediate to them. To put trust in some faraway programmers' ability to understand immediate concerns and said programmers' ability to understand what is going on locally is problematic.

Computers and software can encourage a certain laziness and attitude toward things that should deserve much more careful attention to detail. While it is very interesting to work in computer science and develop software for use by the masses, it is incredibly important to understand that not all people using your software will fully understand the ramifications of using default settings and obtaining results that look pretty, but only appear to be correct and valid.

2.4.4 Software upgrades

Many users of CAD programs are concerned about the seemingly endless upgrade cycle in which they are forced to purchase new versions of software in order to remain compatible with others that may have to use their digital files. This is a very legitimate concern as many companies will purchase a software package and customize it only to find that upgrading to a later version, their in-house customized software tools have been rendered ineffective or upgrading actually breaks their workflows.

Many "high-end" 3D CAD software companies seem to beta test their offerings perpetually, forcing the client into a seemingly never-ending co-operation agreement.

Time will tell which direction computing and software will take in the engineering world. The goal of software development is to make things easier to accomplish not to make them more complicated simply for the benefit of software developers.

2.4.5 Offshoring

Reliable internet service in the developing world, sophisticated hub-and-spoke networked "expert system" engineering design software and affordable, powerful computer hardware have combined to diminish process plant project work execution in the western world.

We now appear to have the commodification of knowledge in the sense that knowledge, skill, and information is being stored in software rather than brains. Decision-making, nonengineer executives often conclude that the need for experienced personnel is greatly diminished because of this.

But of course in the end we find ourselves again looking at the loss of local project execution capabilities and institutional knowledge loss via

1. task replacement by automated systems and outsourcing of most remaining work, resulting in
2. elimination of entry and mid-level employment opportunities, causing
3. less qualified and less experienced individuals attaining higher levels of critical decision-making.

Offshoring or outsourcing has its place, for instance additional staffing requirements and division of labor in a tight market and/or tight schedule situation, but to rely solely on this as an execution strategy depletes the local market of expertise and denies upcoming economies the advantages of skilled mentorship. Lack of expertise may also result in less than anticipated cost savings and schedule overruns for the client.

As the piping lead, you may not only have to plan the work according to known procedures, but may also have to be a diplomat concerned with the time zone and the cultural and experience differences of a divided piping design execution plan.

2.4.6 Model reviews

Formal design review sessions which may include the client are generally conducted at specific completion points during a project's progress. It is recommended that these sessions be limited to as few project participants (those directly affected by the session) as practical, as increased attendance inevitably leads to complications and less effective use of professionals' valuable time. It is suggested that a project design coordinator be present to interpret any design changes and evaluate the potential impact of the said changes—this role will represent disciplines not present at the meeting and the position requires someone with a great deal of experience

and broad knowledge of plant design. Consideration should be given to "webcasting" design reviews to interested parties, where they can peripherally "listen-in" to the activity while engaged in other tasks. This has the advantage of keeping meeting attendance low while enabling interested parties to monitor the discussion and be able to quickly text message the design review moderator with any important questions and/or concerns.

Key people for design review sessions:

- Design Coordinator/Mediator (cross-discipline, experienced plant designer familiar with project, able to effectively interact with Civil, E&I, and Management).
- CAD Support (not present in meeting, but needed for proper hardware setup, live database functionality, premeeting testing, and fallback solution).
- Design Review Moderator/Organizer (initiates meeting/invites attendees, takes minutes and issues minutes to concerned parties, pushes meeting along, "Boss" of meeting).
- Visualization Software "Pilot" (must be an experienced 3D designer—preferably a piper—intimately familiar with the area being reviewed. Does digital capture of needed design changes and files them to appropriate network drive).

2.5 TRAINING

Training for a 3D environment is also a major issue. Poor training or lack of any training is a recipe for disaster. Unless a client is willing to foot the bill for new software and training, many smaller engineering firms may be unable to bid for contracts where the client requires that a specific software package be used (for example, to maintain file format standards across their organization).

In theory, the end client should only be concerned with being able to access the database and view the 3D design models and this can be easily accomplished with many 3D viewing programs, unless

- they have their own in-house engineering group that may subsequently wish to modify the models;
- they will be sending the models to another engineering company for use on operations and/or expansion projects;

- they incorporate the data into other systems for plant lifecycle management.

An important thing to note is that many designers these days have only point-and-click knowledge of the finer details of piping, so real-world training is important. Some younger designers today are being mentored by more senior people who have never set foot in a process piping facility. Much care has to be taken to ensure that new designers do not have "digital-only" experience, especially for those who may have more fascination for the sophisticated tools at their disposal than they do for what they are actually designing. Fancy-looking, interactive 3D models can easily provide the illusion of technical achievement but a designer has to be able to see through the shiny bits.

Another consideration for 3D CAD for plant design is the availability of competent operators. Some of these systems have a steep learning curve and are complex to understand and operate effectively, so at times it may be difficult to find competent operators for the software, not to mention people who are familiar with the domain of piping design itself.

The more complex a computerized design data system becomes, the more it becomes a victim to its own promises. In order to have the ideal design data system, the users must function as a subset of the machine. In a creative process such as process plant design (which typically takes months, if not years, to complete), this is impossible. While 3D CAD is an excellent tool for visualizing proposed designs it does not take the place of proper design. Computers are simply a tool just like a pencil and as such must be used properly.

Complicated 3D software does take away a certain amount of knowledge required by the designer but it does not replace the knowledge required to create an efficient design.

Overall, piping designers are better off reading specifications standards and procedures before becoming familiar with 3D software operation, as it is all too easy to assume that the computer and other software will do the work for you.

First of all, operators of the software have to be fully trained as to how to place components and do all the things that a regular drafters could do with a pencil. If the operators are not familiar with how the software operates, this will require a lot more CAD support time which eats into budgets. CAD support should exist to fix problems that happen with the can software, not to train the operators on how to use the software.

Of course 3D plant design software is always evolving, so there is always the possibility of a future in which everything will work perfectly with a point-and-click approach to training, as opposed to the current point-and-click backed-up with technical understanding. Present reality is far from this future state, but quite often you will find that people who do not understand how the software functions firmly believe that we are already there, and have unrealistic expectations as to how it works. This can prove to be a problem unless the limitations and the requirements of the 3D software are made clear to all participants before the project starts.

2.5.1 Online forums

A phenomenon of the internet era and an indictment of the lack of training is the flourishing of online forums for advice. Most of the first internet technical discussion forums were unsurprisingly related to software and hardware issues. Online advice received for solutions to these types of problems are relatively simple to test and replicate, unlike the true test of most process piping installations—actual operation in the field many, many months down the road.

Within such internet discussion environments people can seek answers and group collaboration on technical issues and problems, taking advantage of the so-called "wisdom of crowds." Usually such discussion is engaged in by individuals of similar knowledge, experience, and skills, but it is often the case nowadays that more naïve questions are being raised.

This is not referring to known online forums where professionals fine tune methods and propose improvements, rather the phenomenon raised here is the asking of extremely detailed (and/or open-ended) technical questions (often omitting key elements) about complex matters that display an obvious lack of fundamental knowledge of the discipline. This causes interested readers to have to post their own queries to ask for clarification, often kicking off a flurry of forum messages speculating on answers to a badly defined question. As might be expected, the advice gained from anonymous online technical discussion forums can easily be worth exactly what you have paid for it, and possibly even less if it causes problems that would not otherwise have occurred. If a neophyte who is newly assigned with completing tasks he/she is unqualified to perform is unable to evaluate the suitability of proposed solutions, things can get out of hand very quickly.

As a piping lead you should consider that a lack of training will drive your designers to these quarters, for what may be less than adequate or poorly interpreted advice that will be enacted on your project.

2.5.2 Engineering educational opportunities

Some examples of the educational possibilities of 3D interactive software (for those who are interested in learning) that could be real-time and graphically visually responsive:

- Process simulations enabling students to experiment with pressure, temperature, flow and fluid changes and how this affects the piping.
- Examples of piping stress reactions under varying conditions.
- Theoretical what-if scenarios resulting from seemingly minor design changes.
- The physical realities of plant operation/maintenance.
- Practical construction techniques (what is/is not feasible in the field/shop).

2.6 EMERGING CAD TECHNOLOGIES

CAD technology is always on the move and there are a number that, if not mainstream already, are emerging as the path forward for the future. Each requires the full understanding and engagement of the piping lead for a successful and value added implementation at a project level.

2.6.1 3D scanning

3D scanning is already commonly being used in the plant design industry to document facilities as-built, to perform site inspections for brownfield/revamp projects prior to and during the design process as well as for dimensional control of piping spools and of modules at fabrication shops. The piping spools and module piping are 3D scanned and then compared to the 3D model to ensure that they have been fabricated according to the piping arrangements and isometrics in order to minimize field fitting errors during erection on site.

2.6.2 3D printing

3D printing, while a fascinating technology, would seem to have limited applications in the plant design and construction process. Possibly there is a potential to provide 3D print scaled major plant components, such as pipe racks, equipment, and major structures, after they have been modeled for the purposes of studying and documenting facility or unit layout options during feed stages by personnel untrained in or for whom the use of 3D software is unavailable (i.e., viewing of the plant 3D model in an on screen environment).

2.6.3 Virtual reality

Virtual reality is being touted as the next frontier for operations training and design review but the technology is not yet commonplace and has special hardware requirements. Virtual, live walk-throughs in order to determine accessibility for operations and maintenance are obvious applications for the technology, while its use during design stages is less practical.

2.7 CHALLENGES

The ideal situation for engineers and designers using software would be one in which users could choose their own preferred program but also be able to share files easily with everyone else. A worthwhile goal would also be to standardize program behavior as much as possible to allow the user to select their preferred input and execute commands method of operation. This feature would greatly eliminate the vendor lock-in and silo effect currently seen in many projects.

Access to certain software packages for evaluation can be limited due to database or hardware requirements. It is very rare to see published comprehensive unbiased, informed opinions on and comparisons of various plant design software packages. Often these reports are prepared in-house for internal viewing only and may in fact reflect inherent biases and preferences (preferring Option X because of past experience with Option X) from those specialists who generate the reports. There are currently very limited opportunities for potential clients to view 3D design

software in action prior to implementation so as to be able to compare their choices.

The choice of plant/piping design software may be dictated by various other factors:

1. Client preference, possibly due to file compatibility issues, model integration, or familiarity of staff with existing software.
2. Whatever software the EPC firm has specialized in (if 1) it is not a concern.
3. Availability of skilled "operators" and/or technical support personnel.
4. Actual cost of software.

Ideally, the various 3D CAD software vendors' offerings would be subject to independent third-party testing and evaluation. Current industry publications and periodicals do not have the time, funding, or skilled personnel to accomplish this. This third-party testing and evaluation would enable prospective users to objectively determine which options are best for their needs and introduce the ability to directly compare the offerings from different companies. Such an ongoing project would be a substantial undertaking but the advantages of doing so should be apparent for clients, EPC firms, and users. It could also provide a source of valuable information for future feature offerings from software programmers—feedback from actual users who have experience with multiple platforms.

Of course, this would require various vendors to accept the determinations and findings of the Technology Evaluation Group—something which they may be reluctant to implement if received only from a small cross section of industry.

In summary, the choices of CAD software and the resultant required development of workflows; the required experience of CAD support; the required experience of designers; the training (or lack thereof) that is provided; and the degree of outsourcing, are all challenging factors that, left unaddressed, will have profound effects on your ability as a piping lead to deliver an on-time and on-budget quality product.

One last thought, since employers believe that fewer workers are required to execute given tasks using the CAD software of choice, employers also believe that they should limit their consideration of candidates for project roles to those well versed in the preferred or mandated software. The flaw in this thinking is that an experienced piping designer versed in one 3D CAD software can be taught how to be functional in the use of an unfamiliar 3D CAD software in a matter of weeks (if the software has a familiar CAD base, such as Bentley AutoPLANT and

Hexagon PPM, both of which are AutoCAD based, then the learning curve is shortened to days), whereas an inexperienced piping designer, however, versed in the software, can only be taught the skills of piping design through many years of exposure to different design requirements on many projects, coupled with the mentorship of knowledgeable piping leads. Selection of piping designers based solely on their experience with a particular CAD software will not only limit your choice of experienced personnel, but may well eliminate highly qualified personnel that would otherwise bring a great deal of knowledge and capability to the benefit of the project.

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CHAPTER THREE

Procedures

3.1 INTRODUCTION

In this chapter we will be discussing the key procedures that are required. You must have the means to monitor the progress of your project and capture the changes. You cannot possibly manage the work if you do not have a clear, concise plan to do so.

In the first edition of this book it was stated that, while of a manual nature involving a paper trail, the procedures presented were still relevant in a computerized environment due to paper being a wonderful medium for communication and record keeping. This is still true 7 years later, but to a lesser degree given the adoption of the wider offerings of tools and applications by software vendors. Document management software and mark-up tools such as Adobe Reader or Bluebeam Revu for instance, when implemented with forethought, are effective replacements for the more traditional hand marking-up of hard copy printed drawings circulated for review and comment. A consequence however has been that many aspects of procedures once prescribed by the piping and other discipline leads are now more so within the domain of the document control group to manage.

Primarily these are the storage of superseded drawings and accessibility for reference and mark-up of

- master stick files
- interdiscipline drawing reviews (IDRs)
- vendor drawings

But may also include the management of

- 2D and 3D CAD files
- stress sketches
- model review comments

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Unlike manual procedures which can be fairly consistently applied from company to company, the choices of available software and functionalities make it impossible to describe a one scenario approach and the workflows that would fit all. Therefore the following procedures are offered as originally presented for those working in companies that still employ the more manual methods and to serve as a guide for those working in companies employing a more software-driven approach. The procedures are still relevant for the latter case in that they provide a workflow for the piping lead to discuss with the document control lead and possibly a business analyst.

Many projects have failed to realize the benefits of technology due to a belief that the implementation of a new technology in itself will provide project execution excellence. In order to be successful, a recognition and incorporation of the business needs is required. Bridging the gap between technology and business needs for stakeholders is where a business analyst enters the picture.

In this context, you may choose to follow the procedures as presented, make your own modifications to suit your needs, or develop your own procedures based on the outlined principles. The important thing to remember is that a procedure ensuring the integrity of information is required. The tracking of the progress and the communications between the disciplines are made more efficient, and the possibility of making mistakes is reduced when everyone follows a procedure.

3.2 MASTER STICK FILES, WORKING COPIES, AND INTERDISCIPLINE DRAWING REVIEWS (IDRs)

Stick files, working copies, and IDRs are closely interrelated. The use of stick files is backed up with working copies, and the IDRs are a periodic reality check of where the project is in production.

These procedures extol the virtues of a "paper trail" that has somewhat fallen by the wayside with the advent of CAD and document management software. Consider how the procedures are replicated using a more software-driven approach. With careful analysis and an understanding of the logic behind them, a successful electronic substitute is possible. Conversely, and this has been my experience, a middle ground approach

whereby manual procedures are not totally abandoned, but rather are supplemented using pdf files and scanning of drawings works best.

During the manual drafting days when drawings were filed in drawers, designers did not pull the drawings out every day to update the latest comments from an engineer. Collecting multiple mark-ups on multiple copies of the same drawing was a recipe for things to get lost. Consequently, a master stick file was used as a depository for all comments to be captured on until the right time to update the drawings was decided.

With CAD and electronic files on a network, anyone can run as many plots as they want, and designers can jump into and out of many drawings in a given day. A tendency has developed toward printing copies, marking up and giving them to the designer for drafting, sometimes on a daily basis. Yet, the same questions that needed to be answered and controlled years ago are still in need of the same today. What was changed? Who made the changes? When did they make the changes? Why did they make the changes? And, who approved the changes?

The use of 3D CAD over 2D CAD does not help with these questions. Some would argue that everything is in the model and approved during model reviews. While model reviews are an important aspect of 3D design and the printed model review comments/screenshots certainly leave a paper trail, the reality is that all questions are not answered, nor are they apparent when viewing the models. Having a design change captured in a model does not explain why the change was made. The end product is still a drawing, and managing the drawings is still the best way of controlling your project, for many reasons that will be explained later.

There was a time when all drawings followed the master stick file/ IDR procedure from the beginning to the end of the project. Now this primarily applies to the P&IDs, plot plans, equipment location plans, and key plans. With the advent of 3D CAD, piping arrangements and isometrics are now generated toward the end of the project, and they will no longer follow this path until they are ready for checking. 3D models have become the communication tool between the disciplines for change during the design stage. For instance, the piping group often places "temporary steel" in the 3D models for the structural designers to follow and no longer mark up a stick file. However, the piping arrangements and isometrics must be circulated as an IDR at the checking stage and it is during this time that the stick files can be created. Beyond Issued For Construction (IFC) the stick files are required during construction for

reference and to capture the resolutions/changes made when answering questions from the fabrication and construction contractors.

3.2.1 Master stick files

The benefits of master stick files are as follows:

- Provides one location for the capturing and recording of changes (what/who/when/why), unlike verbal instruction, e-mails, marked-up bootleg copies of drawings, and post-it notes which are difficult, if not impossible to track.
- All team members know where to go to get the latest information. The latest copy of a drawing being the one on the stick file and not, if people are following the procedure, a mark-up sitting in someone's office or the electronic CAD file on the network.
- Consolidation of effort. All team members can see what the others are planning, how they are being impacted, and how they may be impacting others.
- Planned changes are apparent and can be vetted before implementation.
- Provides for a managed drawing update. Instead of engineers showing up with mark-ups at indiscriminate times and interrupting the workflow, comments are captured on an ongoing basis until the project engineer and the piping lead decide an update is in order.
- Provides a historical and permanent record of changes throughout the life of the project.

3.2.1.1 Storing master stick files

Stick files are an assembled collection of the project drawings. Each drafting discipline must maintain their drawings in their area and divide them according to the drawing type. For the Piping Group these are primarily the

- P&IDs
- Line Designation Tables (LDT)
- Plot plans, equipment location plans, and key plans
- Piping arrangements
- Isometrics

A note about the P&IDs: depending on your company's size and/or the structure of the engineering departments, you may not have custody of the P&IDs until later in the project. In many companies the process group has their own drafting support until after Issued For Engineering (IFE). If the responsibility for the drafting comes under the piping lead,

or once the custody has been transferred to the piping group, then you should manage them in a stick file. Hopefully your process group, and the other departments for that matter, will also do so.

The master stick files can be stored in a number of different ways:

- Full size drawings held in the traditional stick file clamp and hanging arrangement
- Full or reduced size drawings taped to a roller board
- Reduced size drawings maintained in oversize three or four ring binders

I like to place P&IDs and plot plans, etc., in hanging stick files or on a roller board, and piping arrangements in hanging stick files and isometrics in the oversize three (or four) ring binders. I also prefer the full size drawings, as they have lots of room for mark-ups and are to scale in the case of scaled drawings.

3.2.1.2 Managing master stick files

These project masters are always in the custody of the piping lead and managed in the following ways (refer also to Fig. 3.1):

- Each stick file has a cover sheet and a drawing index.

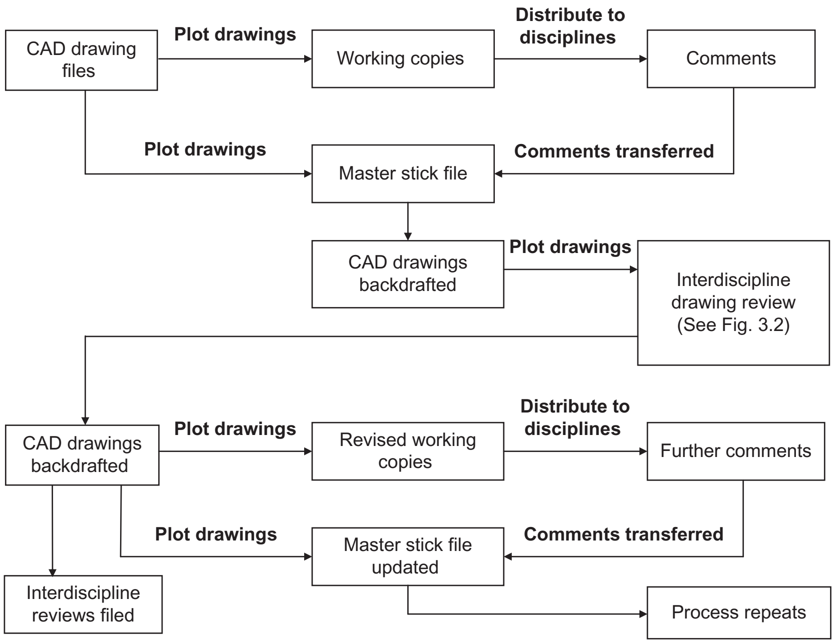

Figure 3.1 Stick file flowchart.

- All the drawings will be stamped "MASTER STICK FILE" and dated.
- Drawings are organized in numerical order.
- The stick files are not to be removed from the drafting area without the piping lead's approval.

Be very guarded against letting your stick files leave the area. One, because they may not come back, and two, because while they are gone someone else may come to do a mark-up and you would have to send them on a search mission, which is a good way to lose their goodwill to follow your procedure.

- The piping lead must be informed of all changes.
- A stick file log is created (spreadsheet) to be filled in by everyone who marks up changes on the stick file. The log can reside on the front of the stick file or in a separate binder close by. The log requires the following columns:
  - Printed Name
  - Signature
  - Date
  - Drawing Number
  - Revision Number
  - Reason For Mark-Up.
- All mark-ups must be legible. Changes are to be signed and dated.
- All project team members must mark up the stick file with any changes/additions, including holds, which can affect the ongoing engineering work. Preferably you will have them do their mark-ups in a discipline color code. The color coding helps to establish who did the mark-up when the author forgets to sign or the signature is illegible. See Table 3.1.
- Questions on stick files are not allowed. Questions must be discussed with the appropriate party and the resolution marked-up. This is so that when the time comes to do the backdrafting, the drafter is not spending piping hours chasing others to get the answers.
- The piping lead will have the comments on the stick file drawings backdrafted, either prior to a scheduled IDR or by monitoring the mark-ups and periodically calling for an update. Changes that have an impact on cost and/or schedule will be discussed with the project engineer prior to backdrafting. Trends and scope changes must be approved prior to the work being carried out.
- Further mark-ups are not allowed on the stick file during the backdrafting exercise as this just interrupts the backdrafting effort. Request that new mark-ups be held until the IDR set is issued.

Table 3.1 Discipline mark-up color codes

	STICK FILES AND INTERDISCIPLINES (Note 1)	CHECK PRINTS (Note 3)
RED	MARK-UPS BY PIPING DESIGN	CHECKER MARKING REQUIRED CHANGES AND ADDITIONS
YELLOW	BACKDRAFTER HIGHLIGHTS BACKDRAFTED COMMENTS	CHECKER INDICATING CORRECT INFORMATION
FLESH		CHECKER MARKING ITEMS TO BE DELETED (Note 2)
BLACK	MARK-UPS BY CIVIL/ STRUCTURAL DESIGN AND ENGINEERING	CHECKER'S NOTES TO BACKDRAFTER
BLUE	MARK-UPS BY ELECTRICAL DESIGN AND ENGINEERING	CHECK MARK BY BACKDRAFTER INDICATING CHECKER'S MARK-UPS INCORPORATED ON CAD FILE
GREEN	MARK-UPS BY INSTRUMENTATION AND CONTROLS ENGINEERING	CHECK MARK BY CHECKER INDICATING BACKDRAFTER INCORPORATED THE INFORMATION CORRECTLY
BROWN	MARK-UPS BY MECHANICAL AND STRESS ENGINEERING	
PURPLE	MARK-UPS BY PROCESS ENGINEERING	
ORANGE	MARK-UPS BY PROJECT ENGINEERING	

Notes:
1. Sign and date mark-ups.
2. Do not obliterate the existing information to be removed.
3. Checker and backdrafter to sign and date checkprints.

- When the stick file is updated the previous revisions will be stamped "SUPERSEDED."
- Superseded stick file copies will be filed and retained for the duration of the project.

3.2.2 Working copies

- Provide a personal copy to record on.
- Reflect the status and decisions to date from last interdiscipline drawing review.

3.2.2.1 Managing working copies

Working copies are issued to the project team members to ensure that everyone has copies of the latest drawings to refer to:

- Working copies will be ANSI B (11″ × 17″) or ISO A3 (297 mm × 420 mm), stamped "WORKING COPY" and dated.
- The piping lead will issue the first set of working copies to the team members as soon as the drawings are ready for general distribution. The project engineer and the piping lead will agree which team members are to receive working copies. As a minimum this would be the same individuals who are to be included on the IDR. Subsequent issues of working copies by the piping lead will be after a stick file drawing update or after an IDR.
- Team members must periodically refer to the stick file and update their working copies by recording all comments. A cautionary note: comments on the stick file involving a trend or a scope change can only be acted upon once approved.

3.2.3 Interdiscipline drawing reviews

The benefits of IDRs are as follows:

- Ensures that all team members have signed-off on the design to date.
- Ensures trends and scope changes are addressed in a timely and orderly manner.

Interdiscipline reviews (also known as Squad Checks) are conducted to ensure that all disciplines are aware of the developments and have opportunity to comment on those aspects that affect their work. Also, parties that have direct input into the design are satisfied that their communications have been understood and incorporated correctly, and that the drawings reflect the latest available information. The IDR ensures that all team members sign-off periodically during design development.

IDRs may be conducted at any time at the discretion of the project engineer, but as minimum reviews will be conducted prior to a major issue, i.e.,

- Issued For Review (IFR)
- Issued For Approval (IFA)
- Issued For Hazop (IFH)—P&IDs and Plot Plans
- Issued For Engineering (IFE) also known as Issued For Design (IFD)
- Issued For Construction (IFC)

By agreement between the project engineer and the lead discipline engineer, the IDR will be conducted in one of two ways:

- a review meeting with all parties present
  or
- mark-up of a review set of drawings located in a central area by a set deadline.

Commonly this will depend on the urgency to complete the review.

Note that some companies choose to circulate the IDR from one reviewer to the next rather than place them in a central review area; however, the net result is the same.

3.2.3.1 Managing interdiscipline drawing reviews

The project engineer is ultimately responsible for ensuring the timely review of the documents and drawings and the completion of reviews, but the success of the reviews depends upon a joint effort of the project engineer, discipline engineer, and piping lead, each following the below prescribed point form steps in a chronological order.

Referring to the attached flowchart, Fig. 3.2A, B, the drawings are prepared for the review.

- The project engineer, discipline engineer, and piping lead:
  - Agree to the issue date and the drawings that are to be included in the IDR.
  - Inform the team members that an IDR is imminent. Team members are given an appropriate amount of time to get any last minute comments marked-up on the master stick file.
- The piping lead:
  - Has the drawings revised and checked to the mark-ups on the master stick file.
  - Assembles one full size set for review.
  - Stamps the full size set with the interdiscipline drawing review stamp, Fig. 3.3, and forwards the set to the project engineer.
- The project engineer:

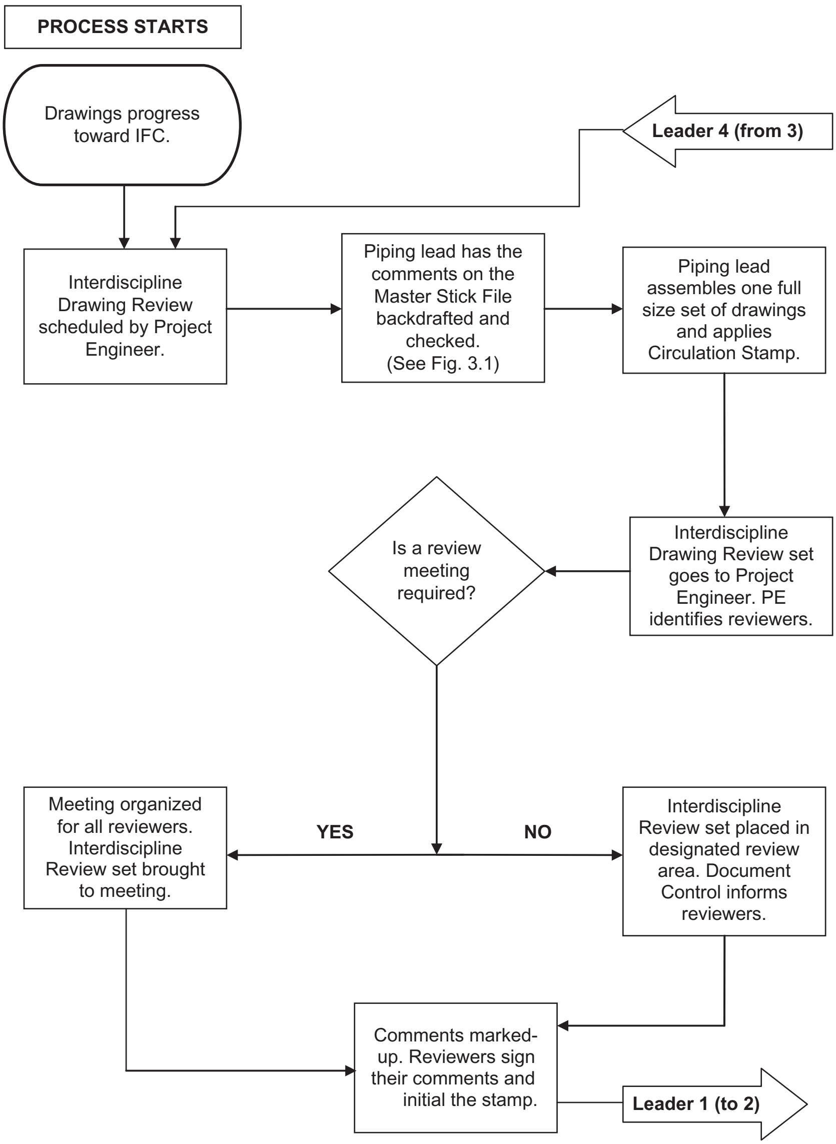

Figure 3.2 Interdiscipline drawing review flowchart.

- Decides who is required to review the drawings. (Table 3.2 is a suggested matrix of the types of drawings to be reviewed and who should review them. The final decision on the drawings to be reviewed and those required to review them rests with the project manager, project engineers, and the lead discipline engineers.)
- Fills-in the interdiscipline review stamp.

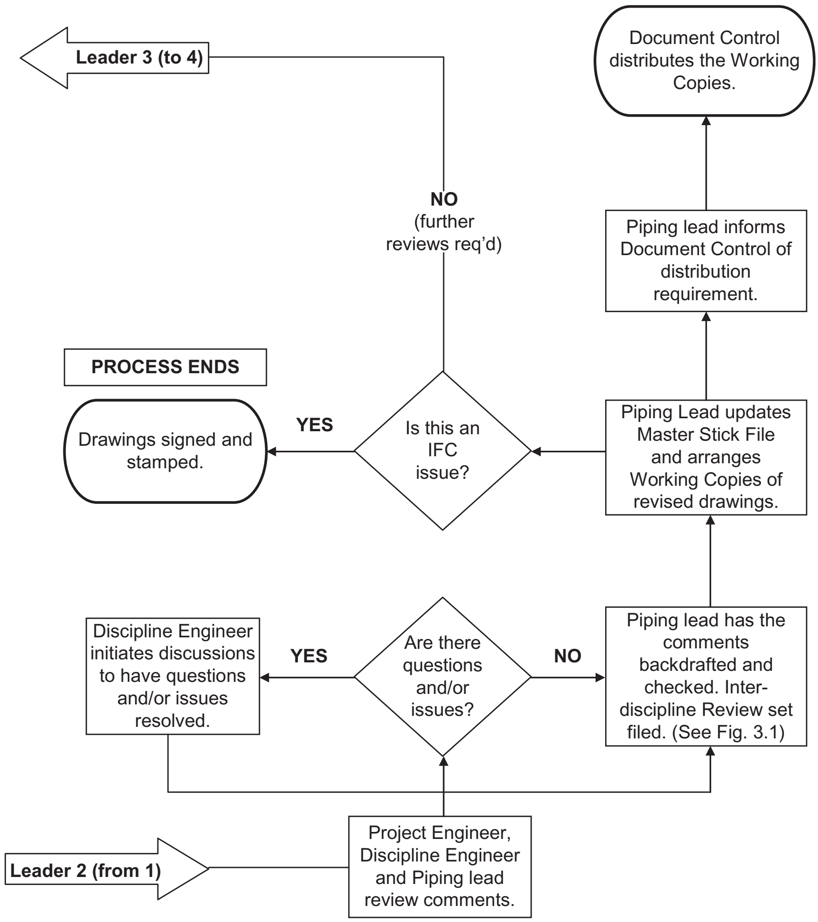

Figure 3.2 (Continued)

- Crosses off the departments that are not required to review the drawings.
- If deemed necessary, prioritizes the order of the reviewers in the CIRC. (circulation order) column, i.e., first, second, third, etc. Note: The project engineer, the "Issuer," will always be the first and the last reviewer. The discipline engineer should always be the second to last reviewer.
- Notes the date that the review must be completed by, and who the mark-ups are to be returned to.
- Informs document control to place the full size set of drawings in the designated review area and to notify the reviewers or organizes a review meeting. Note that if there is to be a meeting, it is a good idea to bring along the master stick file for reference.

COMPANY NAME Inter discipline Drawing Review			
CIRC.	DEPARTMENT	INITIAL	DATE
	Issuer		
	Process		
	Mechanical		
	Piping Stress		
	Piping		
	Civil		
	Structural		
	Electrical		
	Instrumentation		
	Controls		
	Construction		
	Operations Sponsor		
	Project Engineer		
Mark-ups to be in Discipline Colour Code			
Reviews to be completed by:		Return to:	

Figure 3.3 Interdiscipline drawing review stamp.

- The reviewers:
  - Review that their comments placed on the master stick file have been correctly incorporated into the IDR set of drawings.
  - Add new comments.
  - Sign and date the interdisciplinary review stamp on each drawing.
  - Mark-up per the discipline color code.
  - Mark-ups must be legible and signed. If the signature is not discernible, then the reviewer should also print his/her name using block capitals.
  - All comments must be marked up on the IDR set. It is not allowed to staple the working copy to this set.
  - Discuss questions with the appropriate reviewer(s) and reach a resolution. Involve the project engineer, design engineer, and piping lead if necessary.
- The project engineer, discipline engineer, and piping lead:
  - Review the comments.
  - Resolve any unresolved issues or questions. It is incumbent upon these individuals to resolve any issues, as it is not appropriate to have a designer tackle unclear or conflicting instruction during backdrafting.

Table 3.2 Interdiscipline drawing review matrix

LEGEND: R = Responsible for final drawing S = Must review and sign-off the drawing I = Issued for information only	PROJECT MANAGER	PROJECT ENGINEER	PROCESS	MECHANICAL / PIPING	PIPING STRESS	CIVIL / STRUCTURAL	ELECTRICAL	INSTRUMENTATION	CONTROLS	CONSTRUCTION	OPERATIONS SPONSOR		
PROCESS:													
Process Flow Diagrams (PFD)	S	S	R	I			I	S	S		S		
Piping and Instrumentation Diagrams (P&ID)	S	S	R	S	I		S	S	S		S		
Line Lists	S	S	R	S	I		I	I	I		I		
MECHANICAL / PIPING:													
Plot Plan	S	S	S	R	I	S	S	S	S	S	S		
Piping Plans, Sections and Details		S	S	R	S	S	S	S	S	S	S		
Piping Isometrics				R	S					S			
Underground Piping Plans		S	S	R	S	S				S	S		
CIVIL:													
Grading Plans and Details	I	S		S		R				S			
STRUCTURAL:													
Structural Plans, Sections and Details		S		S		R	S			S			
Foundation Details		S		S		R				S			
Piling Plans				S		R				I			
Building Floor Plans and Elevations		S		S		R	S			I	S		
ELECTRICAL / I&C:													
Area Classification and Grounding Layout	S	S		S			R	S	S		S		
Cable Tray Layouts				S		S	R			S			
Electrical and Instrumentation Location Layouts				S			R	S	S		S		
Single Line Diagrams		S					R						
Alarm and Shutdown Keys	S	S	S				S	I	R		S		

- Discuss comments affecting cost and/or schedule. The project engineer either approves or rejects the comments. Rejected mark-ups are communicated back to the originating reviewer.

- The piping lead:
  - Has the comments backdrafted immediately.
  - Updates the master stick file.
  - Issues each team member with an updated working copy.
  - Files the IDR set for the duration of the project. At the project closeout these will be archived with other project documentation.

- The reviewers:
  - Review the newly issued working copies to ensure the comments placed on the IDR set have been correctly interpreted. Inform the piping lead of any errors and mark these up again on the newly updated master stick file.

3.3 VENDOR DRAWING REVIEWS

Vendor document control is a complex procedure starting with the engineering company data sheets, followed by the requisitions, purchase orders, and ending with the certified as-builts and vendor data books. As it is not the purpose of this book to get into the details of the procedures of other departments, except in context with the responsibilities of the piping lead, we will limit our discussion on this subject.

The vendor drawing review procedure is just like the IDR procedure and requires the same input from the project and discipline engineers in conjunction with management by the document control group. Unlike the IDR where the piping lead is key to the creation, integrity, and moving the piping discipline drawings through the system, the lead's role for the vendor drawings is one of managing them once they come into the piping group. Fig. 3.4 is a simplified flowchart of the vendor document review procedure.

As per the piping drawings, a master stick file is required for all disciplines to mark up their comments on during the period of time a drawing has been returned to the vendor and the vendor resubmits the drawing with the required changes. There are systems in place in the piping group to govern the integrity of all documentation handled. Specifically the piping lead will manage the mechanical vendor drawings in the following ways:

- Create a storage place for the master stick file copies in the piping area. Usually this is going to be in a filing cabinet with file folders, each of which will have a tab with the equipment number. Because vendor drawings come in a variety of sizes, even from the same vendor for a given piece of equipment, this is by far the best way.
- When vendor drawings are circulated for review, ensure that the applicable piping members complete their reviews in a timely manner.

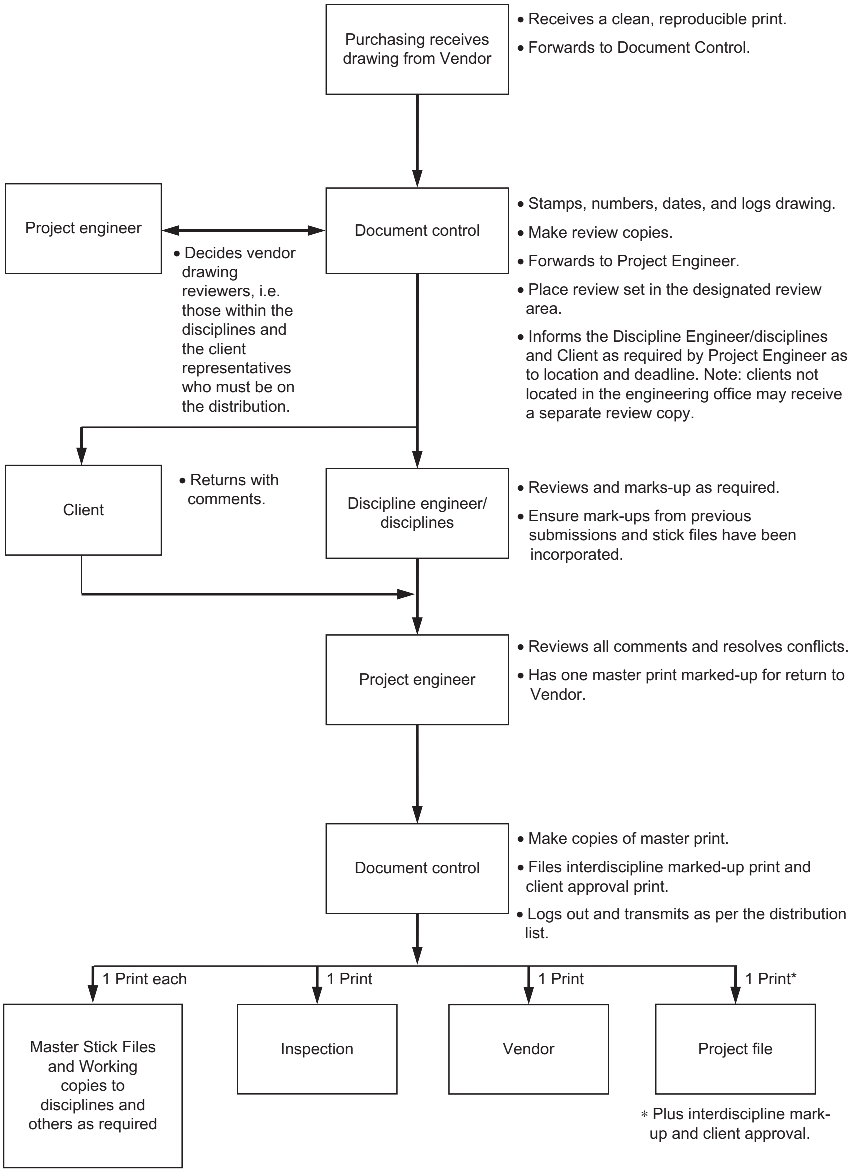

Figure 3.4 Vendor document review flowchart.

- Review the mark-ups from all team members. Mark-ups may be new information, previous mark-ups not incorporated by the vendor, and mark-ups from the stick files not yet communicated to the vendor.
- Discuss issues with the project engineer.

- Act as agent for the project engineer to have one clean mark-up created from the vendor review copy for return to vendor.
- Return the clean mark-up and marked-up review copy to document control.
- Maintain the master stick file by filing the latest master stick file copy and superseding the previous stick file copy.
- Secure working copies for the applicable piping team members.
- Bring mark-ups on the master stick to the attention of the project engineer. For instance, if a nozzle is moved there is no point in waiting until the next vendor submission to capture this change. It must be discussed with the vendor as soon as possible.

3.4 LINE NUMBERING

Line numbers are required for the registration of piping systems with local authorities; for fabrication and installation tracking; and for line identification in quality assurance documentation, e.g., hydrotest and x-ray reports. Once the P&IDs have been developed to a reasonable stage of completion, line numbers should be assigned. This needs to happen prior to the start of 3D modeling. Some companies will leave this task to the process group. I believe that it is the best one handled by the piping lead. Generally speaking, a piping lead will have a better understanding of the piping layout, isometric production, and construction requirements. This information, commonly understood by the piping lead, is valuable when assigning line numbers. Consistency of approach to line numbering is a requirement in order to

- Minimize the quantity of line numbers;
- Ensure that the grouping of lines in the LDT is by commodity and system;
- Assist construction. Line numbers are used for isometric drawing numbers, and therefore there is a direct relationship between line numbering and the order of arrangement of isometrics in the Engineering Work Packages (EWPs). By using a structured approach to line numbering, the isometrics will be arranged such that the associated lines to be welded together will be grouped together;
- Avoid unnecessary and unwanted breaks in the isometrics. The software that automatically generates isometrics will make a break at all

line number changes unless manually overridden. This may result in extra isometrics and can lead to extra field welds. Spooling fabricators often interpret all breaks between isometrics to mean a field weld location.

3.4.1 Line numbering rules

The following rules will help achieve the needed consistency:

- Rule 1—Assign numbers in the direction of flow, working through each P&ID until all lines, including branches, are numbered. Do not forget the numbering of all miscellaneous lines at each piece of equipment (drain lines, vent lines, etc.). Note: piping used for instrumentation (level transmitters, bridles, etc.) with volumes of 0.5 m^3 (500 cc) or more may require a line number for registration. Start with the main process feed line, following the primary process. Secondary processes should be completed next. Utility lines should be numbered next, completing one utility system at a time. Never re-use deleted line numbers after the first official issue of the P&IDs.
- Rule 2—Use one number for a line that runs from one piece of equipment to another in the direction of flow. The number may include one line size or more. List the different header NPS pipe sizes separately on the LDT. Refer to Figs. 3.5 and 3.6.
- Rule 3—Assign a new number whenever the pipe specification changes along the length of a line. Refer to Figs. 3.7 and 3.8A, B.
- Rule 4—If the line class changes downstream of a control valve to a lower line class, carry the higher line class and number through to include the bypass valve and the block valve after the control valve. Refer to Fig. 3.8B.
- Rule 5—Sub-headers and branch lines to or from main headers will change number. Refer to Figs. 3.5 and 3.7.

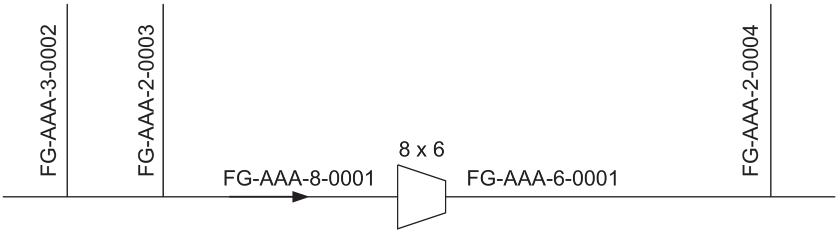

Figure 3.5 Header with line reduction.

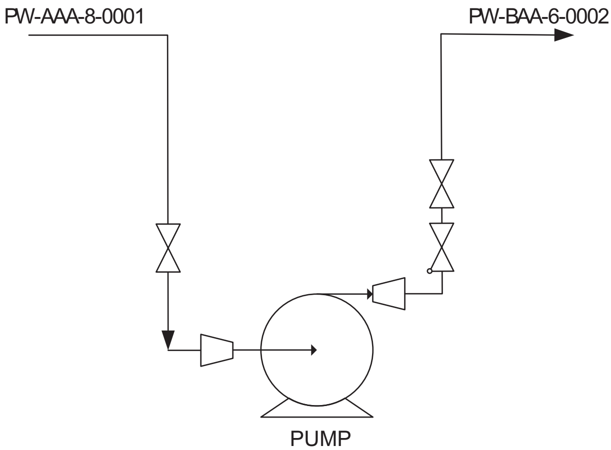

Figure 3.6 Inlet or suction and outlet or discharge for single piece of equipment.

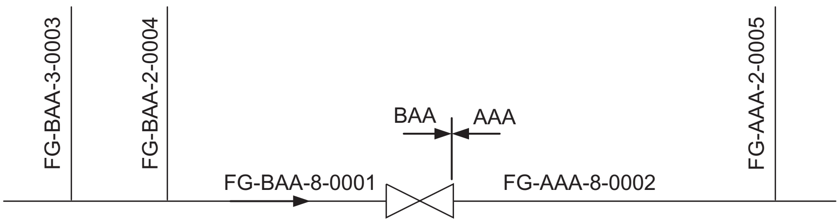

Figure 3.7 Header with spec. break.

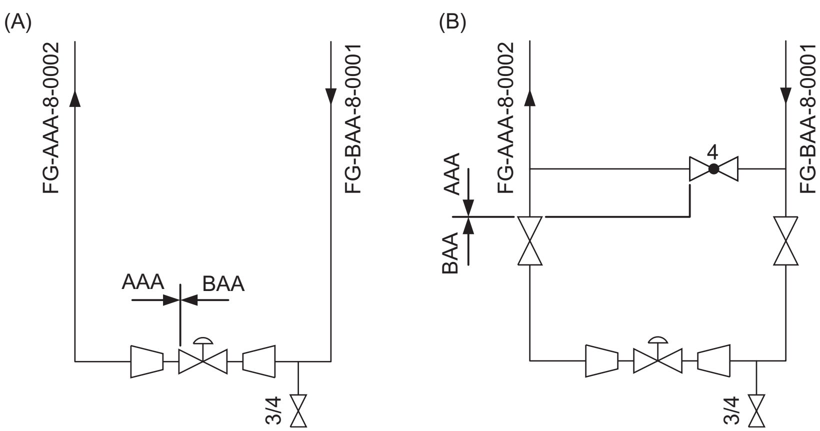

Figure 3.8 (A) Control valve without bypass with spec. break. (B) Control valve with bypass and spec. break.

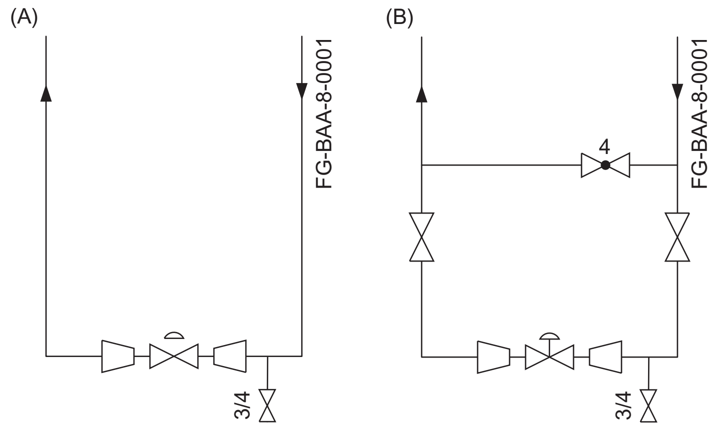

Figure 3.9 (A) Control valve without bypass or spec. break. (B) Control valve with bypass without spec. break.

- Rule 6—Vents, drains, sample connections, and other very short connections are an integral part of the line and will carry the same number as that line. The size must be noted on the P&ID. Refer to Fig. 3.9A, B.
- Rule 7—Lines to relief valves shall be assigned a line number. Lines running from a relief valve to a collection header or to atmosphere will be assigned a separate line number. Refer to Figs. 3.10 and 3.11.
- Rule 8—Long by-passes around vessels or other equipment shall be assigned a separate line number. Short by-passes between lines, such as those at control valve stations and relief valves, are not given a separate line number. Refer to Figs. 3.8B, 3.9B, 3.10B, 3.11B and 3.12B.
- Rule 9—Refer to Fig. 3.12 when assigning numbers to relief valves on equipment.
- Rule 10—Where pumps, exchangers, and similar equipment are piped in parallel, the incoming line number shall be continued through to the "A" designated equipment. The outgoing line shall be assigned a new number. Refer to Fig. 3.13.
- Rule 11—Header and manifold piping for aerial coolers shall be numbered as shown in Fig. 3.14.
- Rule 12—In multi-unit plants, the line numbers often include a unit identifier, e.g., Unit 2, line number 2001. In these cases the line number should be maintained from the start to the termination, regardless of the number of units through which it passes. Branch lines are numbered according to the unit that they serve.

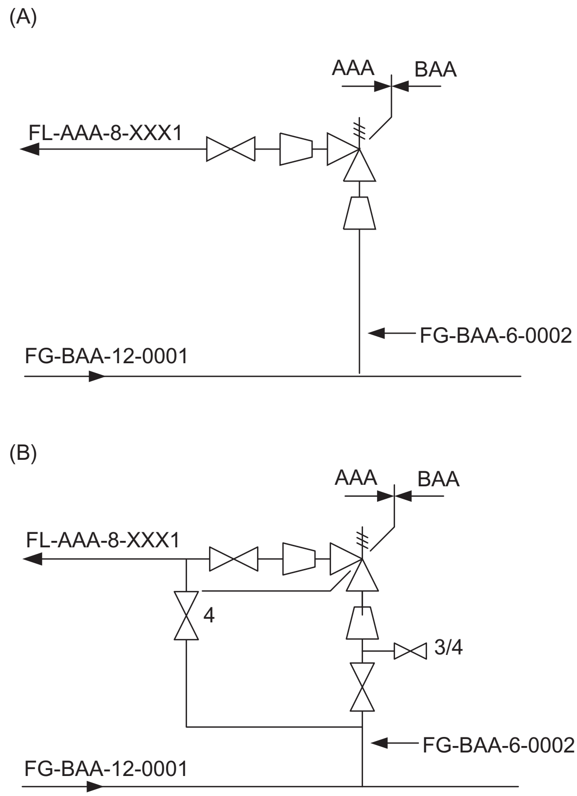

Figure 3.10 (A) Single PSV without bypass. (B) Single PSV with bypass.

3.5 STRESS ANALYSIS

It goes without saying that stress analysis is an integral part of the overall piping design effort, but what is stress analysis? It is a term applied to the calculations that address piping loads resulting from gravity, temperature, pressure, fluid flow, seismic activity, wind, and other environmental conditions. The purpose is to ensure the safety of piping and piping components; the safety of connecting equipment and supporting structures; and, most importantly, the safety of personnel. Codes establish the minimum scope of stress analysis to ensure stress limits are not exceeded. But that is not the sum of it. Because this is an extremely important component of piping design there are requirements that this activity must be documented and the paperwork be archived. We need to

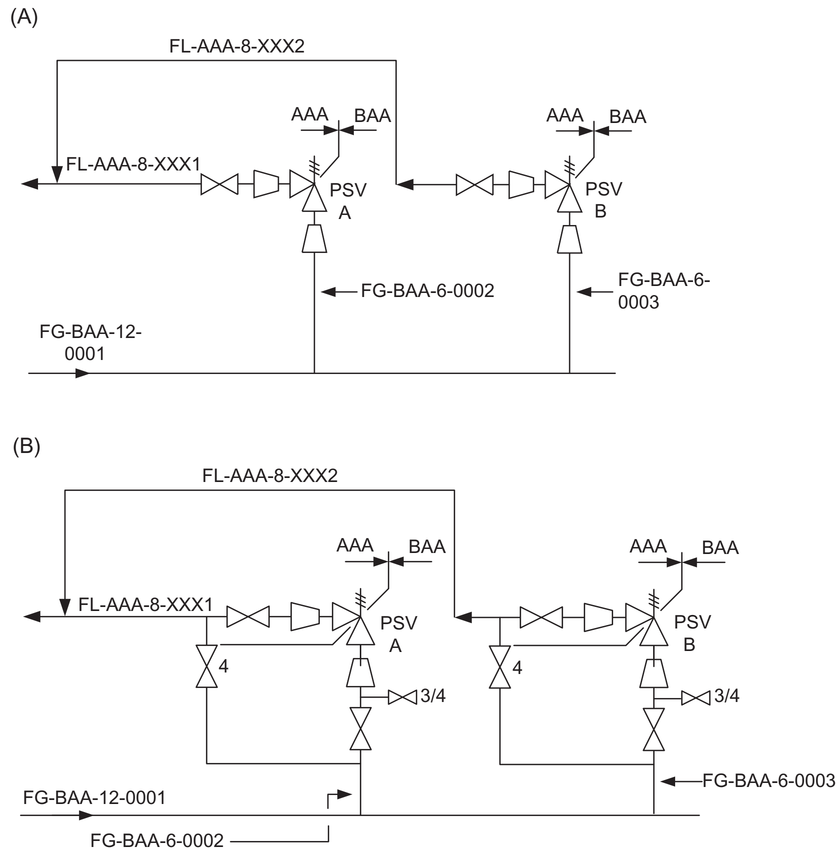

Figure 3.11 (A) Multiple PSV without bypass. (B) Multiple PSV with bypass.

manage the effort appropriately to ensure that the stress analysis is carried out in an efficient manner.

Piping stress analysis is highly interrelated with piping layout and support design. Establishing stress analysis requirements and monitoring the progress throughout the project avoids poor timing and reworking, and minimizes the possibility that something is missed.

3.5.1 The stress analysis procedure

Your procedure must provide checks and balances. It is necessary that the stress analysis for all lines be considered at the beginning and throughout the life of a project, that the stress engineer's requirements are incorporated into the layouts, and that the history of this activity can be

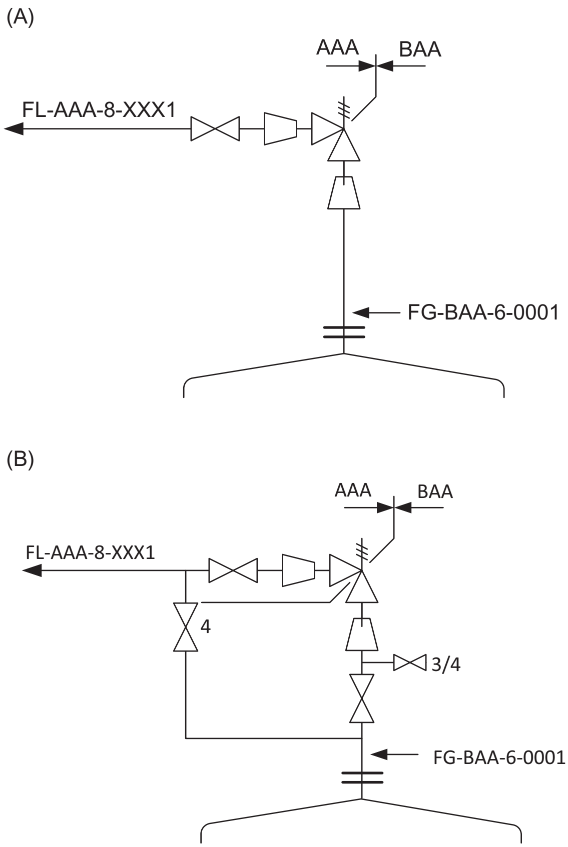

Figure 3.12 (A) Single PSV without bypass on vessel. (B) Single PSV with bypass on vessel.

recreated. This requires the stress group to be involved in the piping layouts at the earliest possible opportunity, and that the flow of information between the two groups will be monitored.

What are these requirements and why?

- Engage the stress group prior to starting the piping layouts to establish the stress analysis criteria, i.e., methods of calculation: visual, manual calculations, or computer analysis. Preferably, as a minimum you will have IFE P&IDs and LDTs to work with, but you may have to begin this exercise with IFA level documents. This establishes a level of priority. The lines indicated as requiring a computer analysis (Critical Lines) are the high priority lines, those that will require the most attention and the routings of which are most likely to be problematic.

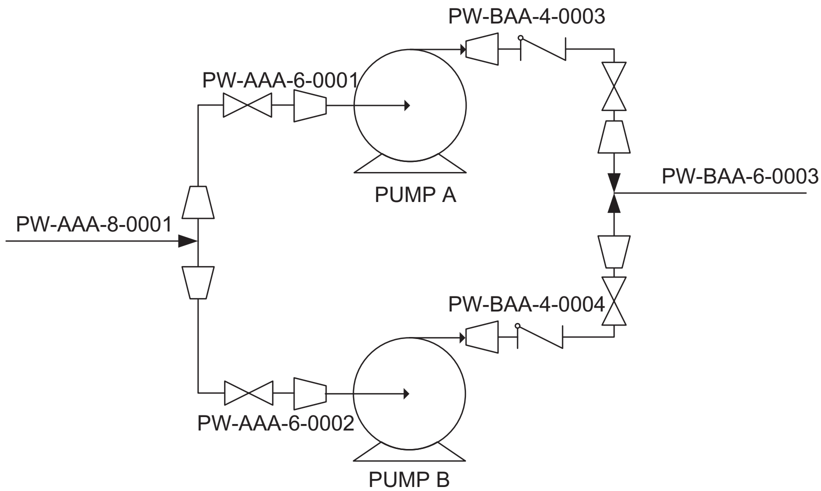

Figure 3.13 Inlet or suction and outlet or discharge for multiple equipment in parallel.

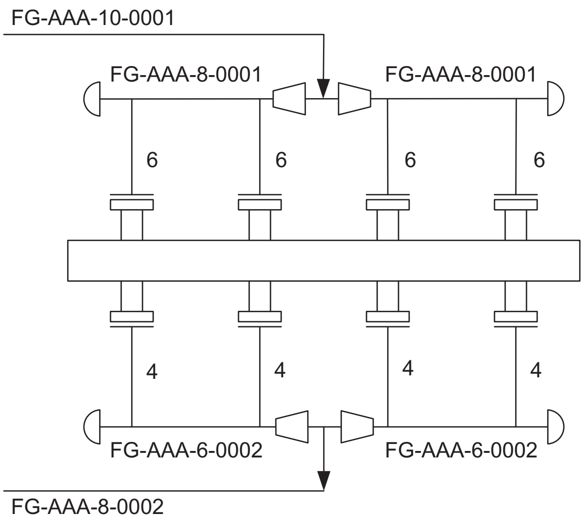

Figure 3.14 Inlet and outlet for aerial coolers.

These are the lines to be laid out first and submitted for stress analysis, commonly during the study stage of the design. Early review of these lines will save rework and/or costly changes later. Refer to Table 3.3.

- Identify the method of analysis in the LDT. This gives one location for reference for all interested parties. Refer to Fig. 3.15.

Table 3.3 Stress analysis initial determination matrix

NPS	Design Temperature (°C)											
	50	75	100	125	150	175	200	225	250	275	300	325
1	V	V	V	V	V	V	V	M	M	M	M	C
1½	V	V	V	V	V	V	V	M	M	M	C	C
2	V	V	V	V	V	V	M	M	M	C	C	C
3	V	V	V	V	V	M	M	M	C	C	C	C
4	V	V	V	V	M	M	M	C	C	C	C	C
6	V	V	V	M	M	M	C	C	C	C	C	C
8	V	V	M	M	M	M	C	C	C	C	C	C
10	V	M	M	M	M	C	C	C	C	C	C	C
12	M	M	M	M	M	C	C	C	C	C	C	C
14	M	M	M	M	C	C	C	C	C	C	C	C
16	M	M	M	M	C	C	C	C	C	C	C	C
18	M	M	M	C	C	C	C	C	C	C	C	C
20 +	M	M	M	C	C	C	C	C	C	C	C	C

NOTES:

Using the table above:

1. If a design temperature falls between two table design temperatures, use the higher of the two table design temperatures for determining the level of stress analysis.
2. A "V" in the table indicates that analysis may be possible by visual inspection of the piping arrangements. Indicate "V" on the Line Designation Table. A stress isometric is not required.
3. An "M" in the table indicates that analysis may be performed by manual or hand calculation methods. Indicate "M" on the Line Designation Table. A stress isometric will be required if requested by the stress group.
4. A "C" in the table indicates that analysis will be performed by computer program methods. Indicate "C" on the Line Designation Table. A stress isometric is required.

Other lines that may require analysis by computer program methods, even if not indicated as such by the above table, are:

1. All lines subject to vibration or pulsation.
2. All lines subject to severe cyclic service.
3. All lines connected to sensitive equipment such as:
   a. Centrifugal and reciprocating, compressors and pumps, with the exception of auxiliary piping.
   b. Steam lines to and from turbines.
   c. All air-cooled heat exchanger piping systems connecting to exchangers with four or more header box nozzles.
4. All lines to and from reactors.
5. All lines subject to steam purging (min. t = > 180 C)
6. All lines Cat. "M"
7. All lines subject to dynamic forces, e.g. pressure relief systems.
8. All jacketed piping.
9. Branch line tie-ins of large branch piping.
10. All underground lines where pressure > 1000 psi or > 70 C
11. All thin-walled piping NPS 18 or larger, having an outside diameter divided by wall thickness ratio of more than 90.

LINE DESIGNATION		REFERENCE	OPERATING CONDITIONS		DESIGN CONDITIONS							
						CODE		TEST		UPSET		EXPAN
ORIGIN	TERMINATION	P&ID DRAWING NUMBER	PRESS. kPa (GAUGE)	TEMP °C	STRESS ANALYSIS	PRESS kPa(g)	TEMP °C	PRESS kPa(g)	MEDIUM	PRESS kPa(g)	TEMP °C	TEMP °C

Indicates the method of stress analysis employed:
V = Visual
M = Manual
C = Computer ("Critical Lines", the minimum lines requiring a formal stress analysis. All other lines are to be reviewed during detailed design to determine if a formal stress analysis is necessary.)

Figure 3.15 Stress analysis method listed in LDT.

- Establish the method for the flow of information from the piping group to the stress group and back. This will be by hard copy stress isometrics and may also be accompanied by the required file format for importation into the stress analysis software. Stress isometrics are submitted for each of the computer analyzed lines because formal stress analysis is done line by line. The hard copies of the isometrics provide the best record of the progress and convenience for mark-ups. These mark-ups will become a document of record. Lines may go through several revisions before approval. It is important to know the status of all lines at any given moment, i.e., lines are in a state of flux; while some are approved, others are awaiting submission or resubmission to stress, and others are still being analyzed by stress and are awaiting return to piping. The piping checker and signing engineer must have a means to satisfy themselves that they have checked the piping arrangements and the isometrics against the final approved information. It may also be necessary to recreate the stress analysis history of a given line or lines at a later date. Refer to Fig. 3.16.
- Monitor the flow of information. Set up a stress log to track the submissions and resubmissions of stress isometrics to stress, and stress isometrics returned from stress. Refer to Fig. 3.17.
- Store the stress isometrics. Each plant area needs two stress binders titled: "SUBMITTED TO STRESS" and "RETURNED FROM STRESS." These are to be maintained in a common area where they are accessible to the designers, checkers, and engineers. As with the stick files, they must not leave the area.
- Due to the importance of this information, and because on larger projects it will become a full time job, I strongly suggest that there be a designated stress coordinator working on behalf of the piping lead. This individual is to be a single point of contact for moving stress isometrics to/from the stress group, keeping the stress log and binders up to date, and arranging working copies for the designers and checkers. If you leave it to each individual to do this, you will find very quickly that the tasks are not completed and that information will go missing. Refer to Fig. 3.16 and Section 3.5.2.

3.5.2 Stress analysis procedure notes

3.5.2.1 Set-up

- Note 1-1—piping lead:
  - Assembles a Control Set of P&IDs, LDTs and forwards the package to the stress engineer.

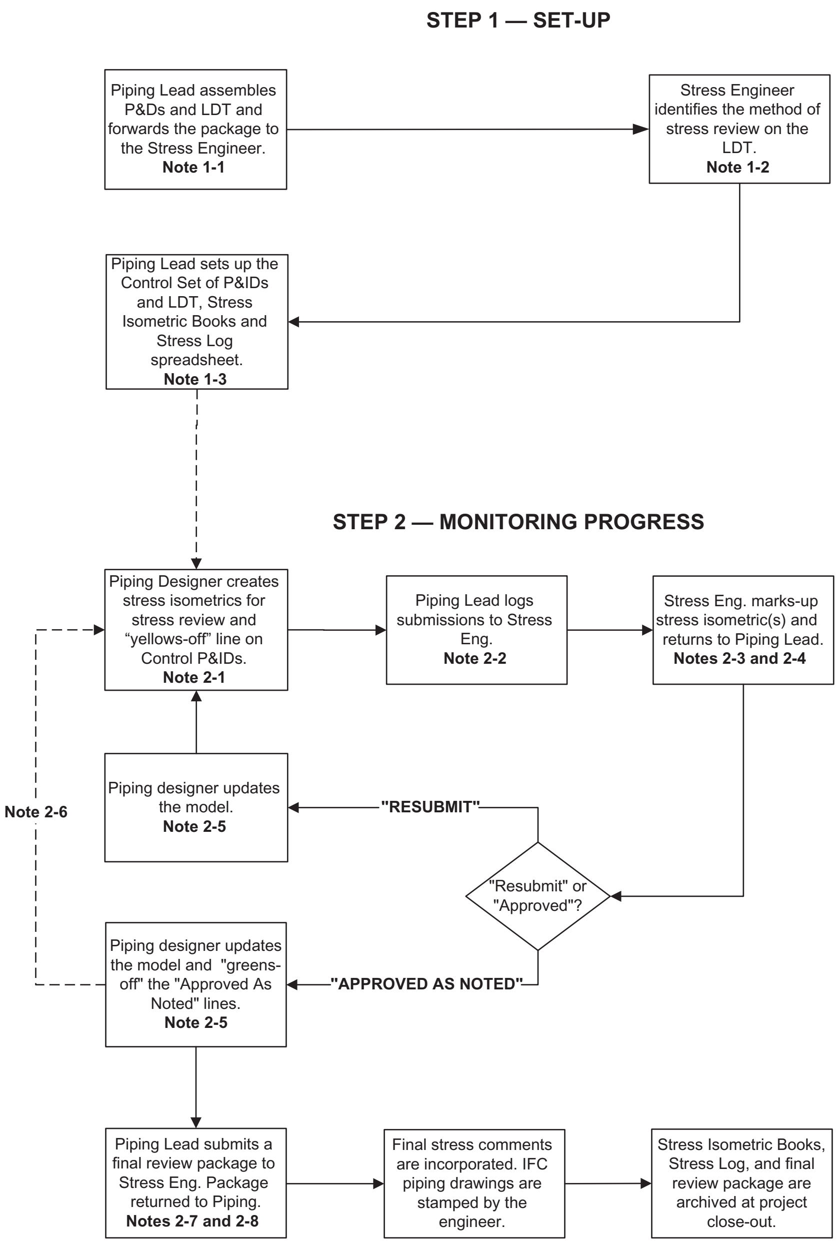

Figure 3.16 Stress analysis flowchart.

STRESS ISOMETRIC NUMBER	LINE NUMBER(S) ON STRESS ISOMETRIC	REFERENCES		DRAWN BY		SENT TO STRESS	RETURN FROM STRESS	SENT TO STRESS	RETURN FROM STRESS	SENT TO STRESS	RETURN FROM STRESS	APPROVED	REMARKS
		P&ID No.	MODEL No.										
					REV								
					DATE								
					REV								
					DATE								
					REV								
					DATE								
					REV								
					DATE								
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Figure 3.17 Stress log.

- Note 1-2—stress engineer:
  - Identifies the stress review requirements in the LDT using Table 3.3 Stress Analysis Initial Determination Matrix, P&IDs, and his/her own judgement.
  - Returns the package to the piping lead.
- Note 1-3—piping lead:
  - Sets up a "SUBMITTED TO STRESS" stress isometric book and a "RETURNED FROM STRESS" stress isometric book.
  - Stores the control set of the P&IDs and LDTs in the design area.
  - Places the stress log spreadsheet into the project directory stress folder.

3.5.2.2 Monitoring progress

- Note 2-1—piping designer:
  - Identifies the lines for which he/she are responsible to create stress isometrics—by reference to the control set of P&IDs and LDTs.
  - Routes lines and submits stress isometrics on an ongoing basis.
  - Creates an electronic stress isometric drawing file and stress software importation file (assuming compatible software, otherwise this will not be possible) for each stress isometric and places them in the project directory stress folder. Use line number for isometric number and revisions starting at Rev. A. See Fig. 3.18.
  - Prints two hard copies of each stress isometric, stamped and dated: one "PIPING COPY" and one "STRESS COPY." (Note that the stress copy stamp is to include two boxes for the stress engineer's use: "APPROVED AS NOTED" and "RESUBMIT.")
  - Issues both to the piping lead.
  - "Yellow-off" on the control P&IDs. This serves as a visual aid to indicate stress progress of lines IFA.
  - If more than one person is involved in a system, then each of the piping designers "yellows-off" their portion and indicates a demarcation, and initials on their side of the demarcation.
  - Ceases work on the piping system while it is being reviewed by the stress engineer.
- Note 2-2—piping lead:
  - Fills-in the stress log.
  - Files the piping copy in numerical order in the "SUBMITTED TO STRESS" book.
  - Issues the stress copy to the stress engineer.

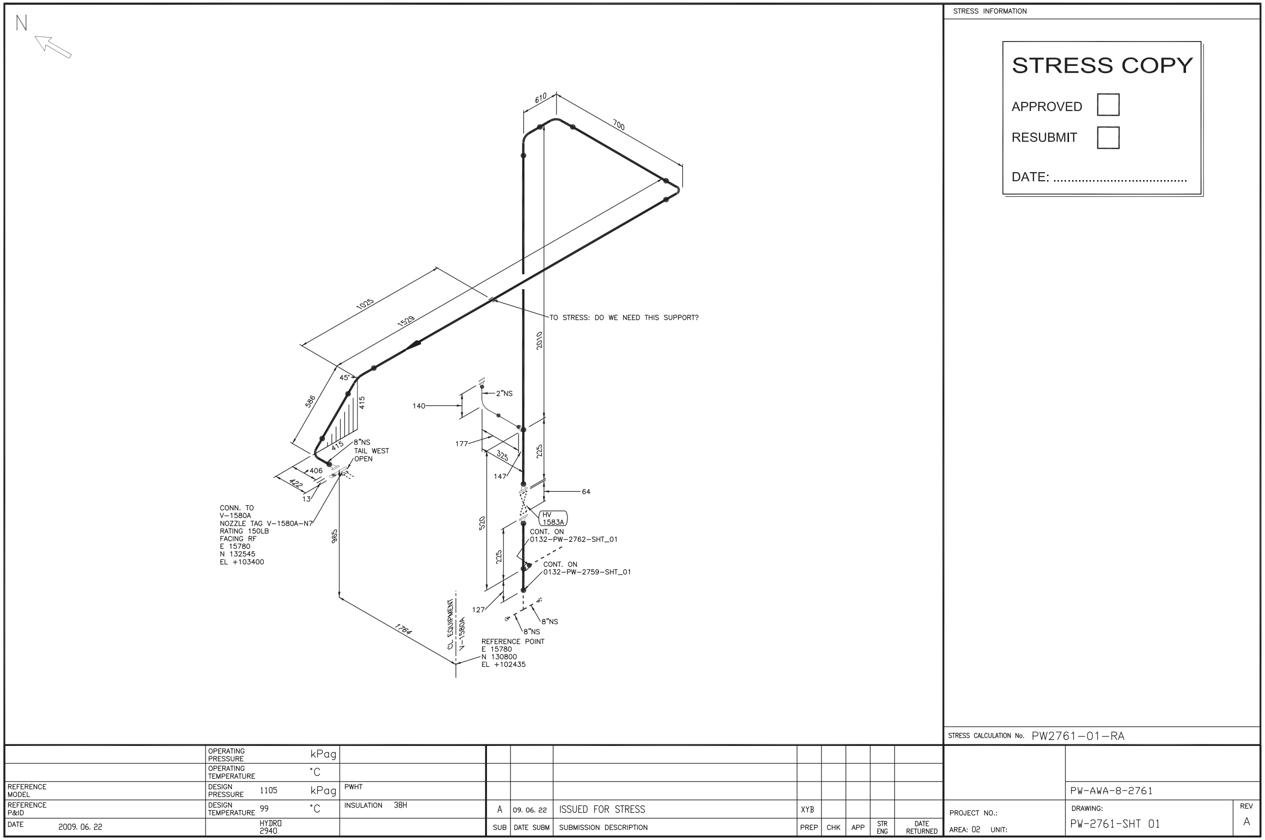

Figure 3.18 Stress isometric.

    - For resubmitted stress isometrics, the previous revision returned from stress (in the "RETURNED FROM STRESS" book) is stamped "SUPERSEDED."
- Note 2-3—stress engineer:
    - Imports the importation file into the stress software.
    - Discusses piping configuration issues with the designer. Resolutions are noted on the stress isometric by the stress engineer.
    - Marks up configuration changes, loads, movements, and tag numbers of pipe supports, anchors, guides, etc.
    - Signs and dates, and marks "APPROVED AS NOTED" or "RESUBMIT" box.
    - Makes a copy for his/her records and returns marked-up isometric to the piping lead.
- Note 2-4—piping lead:
    - Fills-in the stress log spreadsheet.
    - Makes a working copy for the structural lead and the piping designer (stamped "WORKING COPY"), and forwards these copies to them.
    - Files the original into the "RETURNED FROM STRESS" book.
    - Stamps "SUPERSEDED" on the piping copy in the "SUBMITTED TO STRESS" book.

    I recommend removing these from the stress book and storing them separately. In this way you can easily identify which stress isos are still with the stress group.
- Note 2-5—piping designer:
    - Updates the model as per the stress comments.
    - Discusses design issues with the stress engineer. Small changes are marked-up on the master returned copy and initialed by the stress engineer. For example, moving an anchor or a support.
    - Resubmits a revised stress isometric and stress software importation file, if requested.
    - For "APPROVED AS NOTED" lines only, "greens-off" on the control P&IDs over the yellow highlight. This serves as a visual aid to indicate that the piping configurations have been approved.
    - Discusses "V" and "M" designated lines with the stress engineer to get a verbal okay, and provides stress isometrics as requested. Not all lines requiring computer analysis are identified from the minimum requirements and are identified later during design development.

- Note 2-6—piping designer:
  - If it is required to resubmit a revised stress isometric of a greened-off line, then a red cloud is placed around the line on the P&ID with the comment "RESUBMITTED."
  - "Greens-off" the red cloud after re-approval.
- Note 2-7—piping lead:
  - Issues a set of piping arrangement and construction isometric drawings to the stress engineer for the final review at the drawing checking stage.
- Note 2-8—stress engineer:
  - Confirms that stress comments have been incorporated by piping, and reviews lines that were not previously reviewed ("V" and "M" categories).
  - Marks up any comments.
  - Returns package to the piping lead.

If all of this sounds like a lot of work, let me assure you, it is. But finding out later in the project that lines have been missed can cause very costly delays and rework. There are no easy answers to this.

I worked on a project where we tried importing and exporting from the 3D models to the stress software and back to the 3D models. Compatible 3D and stress software have the capability for import and export, but the procedure for managing the electronic transfer of the converted files through project folders proved to be cumbersome. Lost files, misplaced files, and incorrectly named files made keeping track of the progress and getting accurate status reports very difficult and very time consuming to manage.

The immediately visual sense that you get from reviewing the control sets of P&IDs and stress isometric books and the stress log is very valuable. However, you do have to keep the P&IDs up to date with the latest revision issues. Hopefully you will not be receiving frequent changes to the P&IDs after IFC, but if you are, the upside is that you have a great tool for estimating the impact of those changes, and to present an argument against making the changes when you are well into the design. The stick file procedure and this procedure complement each other. Comments on the stick files, in particular changes to optimize line sizes, may prove to have been marked up too late when compared with the progress on the stress control set of P&IDs.

You may find that your stress engineer wants to review everything by computer analysis and wants a stress isometric for all lines. Many stress engineers feel that this is the best way to ensure that everything is

covered. There is merit to this when you consider that for V and M designated lines the stress engineer will need time to become familiar with the layout by reviewing the piping arrangements and isometrics. They may make dimensional mistakes when adding/subtracting coordinates and elevations. While this may appear to be a reason to skip the initial review stage, I urge you not to do so because of the focus, as discussed earlier, this will bring to the piping effort. Instead of the V and M designations, leave blanks in the LDT until these lines are stressed. Be aware that creating stress isometrics for all lines will add hours to the piping design schedule, but may well reduce hours for the stress engineering effort.

Finally, it is a good idea for the stress engineers to have access to do their own model walkthroughs to aid them in solving stress problems. However, the job of the stress engineer is to explain an issue to the designer and provide rerouting suggestions, not to redesign the piping for the designer. The designer must work with the stress engineer to come up with an adequately flexible system while taking into consideration the other layout requirements, such as process, clearances, maintenance, and constructability.

3.6 MODEL REVIEWS

3D model reviews are the electronic equivalent of scale plastic model reviews that were very popular in the 1970s and 1980s. Both are a big improvement over the older method of reviewing piping arrangement drawings alone. It takes a lot of time and effort for those unfamiliar with a layout to build a 3D vision in their mind's eye solely from the drawings, and a lot of layout issues, particularly some of the detail surrounding maintenance and operability, e.g., valve handwheel elevations, would often make it all the way through to construction undetected. One of the first things the operations' personnel used to do after a turnover was to start compiling a wish list of retrofits and design changes.

Models greatly improve the reviewers' abilities to visualize the proposed layouts and lead to a better design and fewer surprises. But, there is a downside. Now everyone thinks that they are a piping designer, and if you are not careful the reviewers will go beyond the intent of the review and request changes based on personal preference. This is particularly true when the designer is not there to explain his/her decisions, and can lead to obvious frustration and unnecessary extra hours. You need ground rules and a strong facilitator to keep things on track in the model reviews:

- Always have an internal model review prior to a review with the client. You do not want to be debating the design among yourselves in front of the client.
- Know the parameters and level of design that you are going to discuss. What do you want to achieve in this meeting? For instance, in the initial stages the focus will be of a high level nature, on such things as construction execution, equipment spacing, and elevation clearances for egress/ingress and maintenance, building sizes, platform and ladder requirements, and future spacing requirements. Getting into discussions about such as a pressure gauge location in a 30% model review is premature and will bog down the proceedings.
- The project engineer should always be present. You will undoubtedly enter into discussions that will go beyond the project scope of work and outside of the client's own specifications. I have sat in on model reviews where the client's representative wanted platform access to all PSVs, something which was not in his/her own specifications, and staircases instead of ladders. Requests of this nature cannot be acted upon until it has been agreed that this is a scope change with the associated added costs.
- Keep personal preferences out of the discussions, or at least try to minimize them. If you gave two different designers the same area, each would come up with a different layout. As long as they both meet the requirements, one cannot be considered better than the other. You must adopt the adage "If it isn't broken, don't fix it."
- Do not revisit decisions already made unless new information requires that you do so. The spacing of a set of pumps that come in larger than expected needs to be revisited. The spacing of a set of pumps that come in smaller than expected does not.
- Identify who should be in the model reviews. For instance, if constructability and maintainability are to be discussed make sure that representatives of the construction management team and the client's maintenance group are invited.
- Prior to the client model review, verify that the models to be reviewed are converted to viewing format, that the files are deposited into the correct folders for retrieval and that the conference room computer set-up is in working order. There are very few things in life that are more embarrassing than not being able to access the models when the client is present and you have to call CAD support to correct avoidable issues before the model review meeting can begin.

Most engineering companies will have a model review procedure and a model review matrix that establishes the criteria for scheduled reviews at the 30%, 60%, and 90% stages of design (note that these are not percentages of project completion). These help to establish the priorities during design and bring focus to the goals of the reviews.

The periodic reviews ensure that the designs are progressing as planned and that the developments made up to that point become frozen. Because each area progresses according to a predetermined schedule of priority, each will reach these review stages at different times. For instance, pipe racks usually have a higher IFC priority than process areas, and therefore may be reaching a 60% review stage while a process area is just reaching a 30% review stage.

One of the accountabilities of the piping lead is to achieve the level of design detail stated in the matrix for each stage of model review, on schedule and within the budgeted hours.

3.6.1 Model review procedure

A common model review procedure includes the following:

A statement of the objectives:

- The objectives of the model review are to verify that the current stage of the design meets the minimum project requirements for operability, maintainability, constructability, and functionality, and that it reflects every disciplines' input to the design to date.

The responsibilities that lie with the primary organizers of the model reviews are as follows.

The project engineer:

- Decides the required attendees, and schedules and manages the formal model reviews.
- Ensures that the design progress meets the requirements for the review as defined in the model review matrix.
- Prepares and issues an agenda for the review.
- Coordinates the discussions and documents resolutions and action items.
- Ensures proper filing of all documentation.
- Distributes the model review comments to the attendees.

The piping lead:

- Coordinates with CAD support the assembly of the 3D models required for the review.
- Operates or designates a team member to operate the computer "walk through" during the review.

- Ensures that an interference check has been completed prior to the review.
- Ensure that a "snapshot in time" of the 3D model files used for the review is archived for future reference and record keeping after each review.
- Captures all comments/action items in the software package.
- Maintains a hard copy binder and logs and distributes the action items to the designers.

3.6.1.1 Instruction

- Formal reviews are to take place in three intervals during the development of the IFC 3D models, defined as 30%, 60%, and 90% model reviews. These model reviews are major checkpoints and milestones in the engineering design process. Deliverables required from each discipline to achieve each of these checkpoints are defined in the model review matrix. Typically a model review will not proceed until such time that all of the deliverables required for the specific review have been incorporated. When deliverables are missing for a particular review, the model review may only proceed provided that the associated risks and mitigations have been identified and approved by the project manager.

3.6.1.2 Review procedures

- Reviewing of the model is a joint responsibility of the piping lead, the designer/drafter, the project engineer, and other related disciplines.
- All comments shall be captured on model screenshots with an assigned action item number. See Fig. 3.19.
- All proposed changes to the design shall be categorized relative to cost and schedule impacts. This will set the priority for addressing the comments.
- The comments that are not the subject of a scope change shall be incorporated into the working model as a top priority.
- The comments that are the subject of a scope change shall be incorporated into the working model once the scope change has been approved.
- The action items shall be reviewed during the next internal review for completeness and during the next formal review with the client.
- Regular internal 3D model reviews, which may not be shown on the project schedule, should take place at time intervals as deemed necessary by the project engineer or piping lead, in conjunction with the other discipline leads. These reviews are considered as routine coordination and part of the design development process.

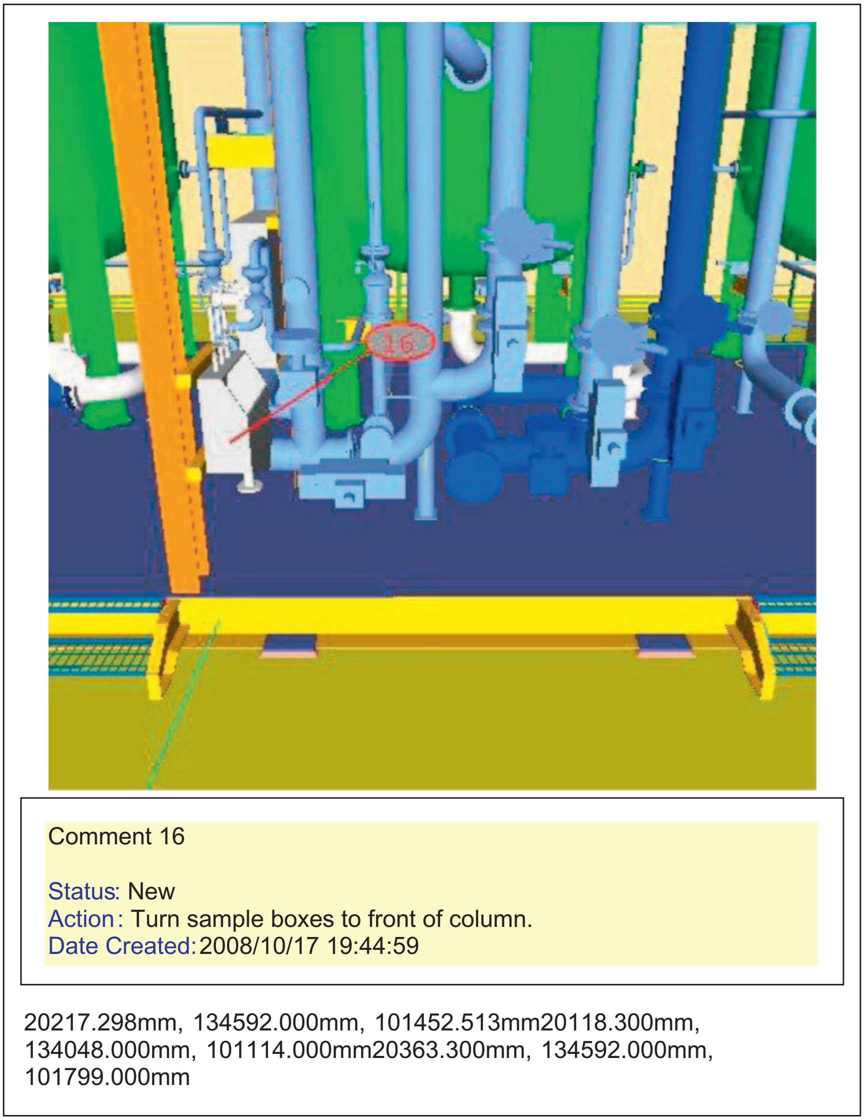

Figure 3.19 Model review comment.

3.6.2 Model review matrix

The model review matrix will outline the preparedness required by each discipline at each stage of review and the items to be reviewed at that stage. As this book is about piping design, we will limit the matrix to the piping aspects. Table 3.4 is an example of a model review matrix.

Table 3.4 Model review matrix

Required By Review Stage	30% Review	60% Review	90% Review
Process Design			
Process Studies	Complete	—	—
PFDs & Mass Balance	IFE	IFC	—
P&IDs	IFA	IFE	IFC
HAZOP	—	Complete	—
Line Sizing	Critical lines complete.	Complete	—
Line Designation Table	IFA	IFE	IFC
Piping Specifications	Approved	—	—
Vendor Info.			
Valves	Preliminary data for NPS 6 and above.	Approved data for NPS 4 and above.	Certified data for all NPS sizes.
Specialty Items	Preliminary data for NPS 6 and above.	Approved data for NPS 4 and above.	Certified data for all NPS sizes.
Equipment	Preliminary	Approved	Certified
Instruments	Preliminary	Approved	Certified
Piping Design			
Plot Plan	IFA	IFE	IFC
Piping Specifications	Calc wall complete.	—	—
Equipment Layout	Major equipment modeled to preliminary information.	Equipment locations finalized and modeled to approved information.	Equipment modeled to certified information.
Piping Stress Analysis	NPS 6 and above critical lines stressed. Other lines under review.	All NPS critical lines stressed. Other lines under review.	NPS 4 and above lines stressed. Other lines under review.

Table 3.4 Continued

Required By Review Stage	30% Review	60% Review	90% Review
Process Design (continued)			
Piping Design	NPS 6 and above lines are modeled and submitted to stress. (See Note 1.)	NPS 4 and above lines modeled and submitted to stress.	All NPS line sizes modeled and submitted to stress. Field welds and hydrotest vents and drains modeled.
Supports	All major temporary steel modeled.	All temporary steel modeled.	—
Tracing Manifolds/ Utility Stations/ Eye Wash/Safety Showers	Not Started.	Preliminary locations modeled.	Firm locations modeled.
Review Objectives			
	Escape routes, roads, paved areas and drainage.	30% model review comments.	60% model review comments.
	Maintainability, e.g., davits, monorails and cranage, access between equipment, width and height requirements under racks.	Maintainability. Pay particular attention to removal clearances, e.g., exchanger bundle removals, O/H cranes above split casings, etc.	—
	Operability, e.g., platform access.	Operability, e.g., valve heights, chain operators and rising stem requirements.	—
	Constructability, e.g., road access, crane reaches.	Constructability, e.g., field erected piping, module installation.	Field weld and hydrotest vent and drain locations.

Table 3.4 Continued

Required By Review Stage	30% Review	60% Review	90% Review
Process Design (continued)			
	Future piperack requirements, e.g., widths, number of levels.	—	—
	Main structures.	Minor structures.	Fireproofing of structures.
	Preliminary identification of platforms, ladders, walkways and staircases.	Platforms, ladders, walkways and staircases. Davits, monorails and cranage.	—
	Routing of NPS 6 and above critical lines.	Routing of all NPS critical lines and other lines as required.	Routing of all NPS line sizes as required.
	Pump piping.	Pump piping.	—
	Modularization vs. field erected piping.	Sample Points identified	Tracing Manifold locations.
	—	Utility Station locations.	—
	—	Eye Wash and Safety Shower locations.	—
	Inline instruments and piping configurations.	Inline instruments and piping configurations, and vessel mounted instruments (if available).	Minor instrument locations, e.g., PI and TI, and vessel mounted instruments.

Table 3.4 Continued

Ground Rules
1. The cut-off point of NPS 6 and above is a judgment call. Some areas, racks for instance, may require that NPS 2 and above be modeled at this stage. 2. All model review comments are to be addressed immediately following the model review. 3. No changes to approved or frozen items are allowed without Project Engineering approval. 4. The following guidelines have been established for initiating a change. Personal preference is not an acceptable reason: – Design does not meet the design criteria. – Design does not meet accepted design practice. – Design does not meet plant operating standards or client standards for operability, maintainability, fire protection, safe isolation of equipment, or safety requirements. – Design does not meet "What-if" review recommendations

3.7 CHECKING

Checking, without question, is one of the most important and necessary functions performed by the piping group. There was a time when the checker's job was to check absolutely everything that went into the drawings, down to the last nut and bolt, so to speak. Today, the process of checking piping arrangements and isometrics has changed, and many aspects of checking are dealt with throughout the life of the project. However, the checker is still the last chance to catch mistakes and omissions before the drawings are IFC.

The piping and equipment layouts are reviewed and approved by the client and all the disciplines during the model reviews. Therefore the piping arrangement and isometric checks are not intended to be a check of the overall layout or individual pipe routings, but rather a check to ensure that

- all items and process requirements shown on the P&IDs have been incorporated;
- the correct piping classes have been used;
- the correct standards have been referred to;
- the stress requirements have been incorporated.

Nonetheless, checkers must still use their experience and judgement and be on the lookout for poor piping design. For instance, model

reviewers may review the locations of PSVs, but fail to spot a pocket in the relief line. They may review a steam system, but not notice that drip pots and steam traps have not been provided at all low points. They may review exchanger layouts and bundle pulling requirements, and overlook the need for break out flanges.

It is not required to check the following:

- In theory the material descriptions, wall thicknesses (with the exception of calc. wall) and ratings of piping components in the Bills of Material (BOM) do not need to be checked as all of the components are selected from the piping classes which are prebuilt and checked at the beginning of the project. In practice I recommend that the checker initially checks everything until they have built up a comfort level and can have confidence that the piping class databases are consistently correct.
- Regardless of all choices within the piping classes, all out-of-spec components, specialty items, and the selected piping classes as per the P&IDs and LDTs must be checked.
- Checking is not required of either the overall or the fitting-to-fitting dimensions on the isometrics. The dimensions of the components are built to the ANSI standards, and provided that the key coordinates and elevations are correct in the model, the dimensions associated with the routing can also be taken as correct. For instance, let us assume that there is a line running from a vessel nozzle down to grade, through a control valve, back-up to a stringer elevation, then horizontally across the stringer, and dropping into a rack header. Once the coordinates and elevations of the vessel nozzle, the pipe rack steel and the header location have been verified in the model, the checker will only need to check the Bottom Of Pipe (BOP) of the horizontal run of the line, the face-to-face dimension and centerline elevation of the control valve, and the clearance for the removal of the actuator.
- Interferences do not need to be checked. Due to the ability to run clash check reports, it is unnecessary to check clearances. That is with one exception; interferences that can be caused by thermal growth have to be investigated.

In short, the items that need checking are those that are decided and input by the designers. All the decisions left to the designer must be checked. It is still a considerable list, as you will see.

The checkers will require access to the live 3D models and viewing software to actively work with the models to ID tags, line numbers,

dimensions, and elevations. Prior to and during the checking of equipment (vendor information) and piping (piping arrangements and isometrics) the following must be observed:

- Models are to be frozen. Designing is not allowed during the checking period.
- After checking, access will be allowed to the designer for backdrafting. Manual edits of the drawings must not be allowed. All changes are to be made in the models and the drawings regenerated for backchecking.
- Once the backchecking is complete, models must be frozen for IFC, and remain so until a revision is required.

The following sections detail the different checking procedures that are required:

3.7.1 Clash check reporting procedure

Under your instruction, the CAD support group will set up a project directory for the storing of clash reports. They will also help you establish the parameters of the clash reports. For instance, shoes resting on steel may be reported as clashes unless they are automatically removed. Shoes resting on steel can be filtered from the clash reports by setting the tolerances for reporting. Time will be saved by removing the many acceptable clashes from the reports automatically, because these will not have to be cleared individually.

The area leads, or a designated team member, will run periodic clash check reports for each design area during the designing phase, and a final report just before the checking starts. The designers are notified when this has been done. The clash check reports will be stored in the project directory and in a hard copy format for reference in a clash check reports binder(s) in the drafting area.

The six types of clash checks to be run are

- Piping to Piping (P to P)
- Piping to Equipment (P to E)
- Piping to Steel (P to S)
- Piping to Electrical (P to El.)
- Piping to Building (P to B)
- Equipment to Steel (E to S)

3.7.1.1 Actions

- The clash report will have the following information:
  - Clash report number

- Type of clash report (e.g., P to P)
- Models included in this clash report
- Name of the person who ran the clash report
- Date of this clash report
- Name of the person who addressed this clash report
- Date the clash report was addressed
- Screenshots of the clashes
- Comments

- The piping designers are to refer to the clash check reports to identify clashes. Clashes are to be resolved either by piping modifications or by negotiation with the structural or electrical designers who will initiate their own changes to resolve the clash.
- When the clashes are resolved the piping designer must run a new clash check report.

3.7.2 Equipment checking procedure

3.7.2.1 Purpose

- To ensure the dimensional accuracy and correct location of all vendor equipment built in the equipment models prior to piping arrangement and isometric production and checking.

3.7.2.2 Procedure

- Do not use the piping master vendor drawing from the piping files for checking. Obtain a checking copy of the latest vendor drawing from document control.
- This drawing should be preferably status "Certified" but not less than status "Approved."
- The vendor drawing and any comments should be the same as the piping master copy in the piping files, but check that there are no major unincorporated comments when compared to piping master copy. If major comments are still unresolved, do not continue the check. Inform the piping lead.
- Stamp the vendor drawing "Check Print" and date.
- Obtain the current equipment nozzle report. Stamp "Check Print" and date. Refer to Fig. 3.20.
- Obtain a screen print of the equipment dialogue box and stamp "Check Print." Refer to Fig. 3.21.
- ID the centerline coordinates, elevation and orientation from the equipment model and write them on the vendor check print.

Friday, July 10, 2009

Nozzle Schedule Report

Equipment Tag	Nozzle Tag	Description	Size	Rating	Projection (overall Length)	North	East	Elevation	Direction
V-1580A									
	V-1580A-N10A	NOZZLE 150LB RF	2	150LB	133 mm	131638 mm	14329 mm	104467 mm	W 30.00 N
	V-1580A-N1	NOZZLE 150LB RF	8	150LB	1300 mm	130800 mm	15780 mm	106783 mm	U
	V-1580A-N2	NOZZLE 150LB RF	8	150LB	914 mm	131562 mm	15780 mm	101521 mm	D
	V-1580A-N4	NOZZLE 150LB RF	3	150LB	1559 mm	131902 mm	14678 mm	104590 mm	N 45.00 W
	V-1580A-N5	NOZZLE 150LB RF	3	150LB	799 mm	130800 mm	15780 mm	101636 mm	D
	V-1580A-N6	NOZZLE 150LB RF	2	150LB	1300 mm	130800 mm	16136 mm	106783 mm	U
	V-1580A-N7	NOZZLE 150LB RF	8	150LB	202 mm	132545 mm	15780 mm	103400 mm	N
	V-1580A-N8A	NOZZLE 150LB RF	2	150LB	133 mm	130800 mm	14104 mm	102638 mm	W
	V-1580A-N8B	NOZZLE 150LB RF	2	150LB	133 mm	130800 mm	17456 mm	102638 mm	E
	V-1580A-N9	NOZZLE 150LB RF	3	150LB	133 mm	129615 mm	16965 mm	105026 mm	E 45.00 S
	V-1580A-N10B	NOZZLE 150LB RF	2	150LB	133 mm	131638 mm	14329 mm	102562 mm	W 30.00 N
	V-1580A-M1A	AXIAL ROOF MANWAY	24	150LB	1300 mm	130800 mm	15018 mm	106831 mm	U
	V-1580A-M1B	API STANDARD 650 RADIAL SHELL MANWAY	24	150LB	257 mm	129061 mm	15314 mm	103045 mm	S 15.00 W

Figure 3.20 Nozzle report.

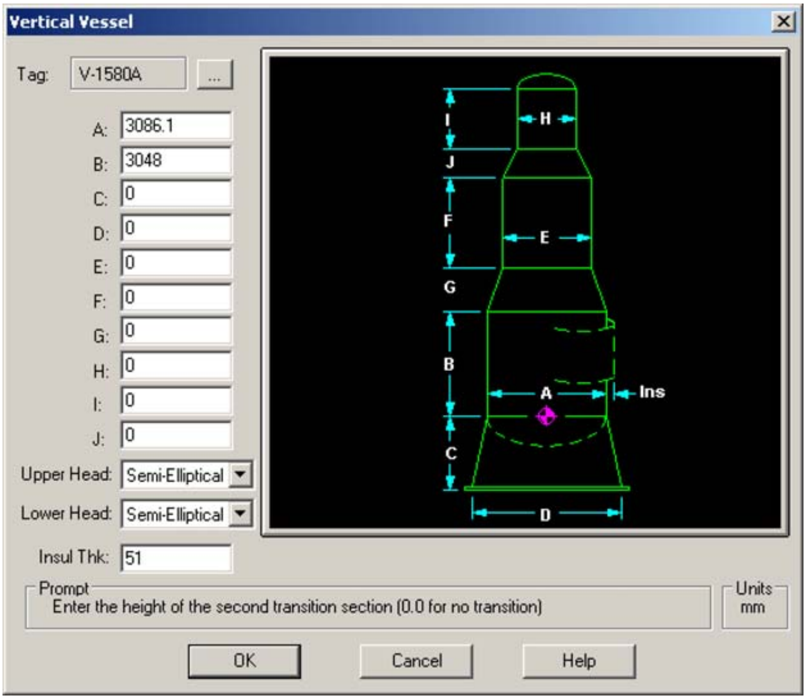

Figure 3.21 Equipment dialogue box.

- ID the underside elevation of base plates and the TOC or TOS of the foundation and write them on the vendor check print.
- Compare the coordinates and elevation with those noted on the master stick file equipment location plans.
- Yellow off the equipment location plan coordinates and elevation, or mark up the equipment location plan with any discrepancies after consultation with the piping lead.
- Check the nozzle report and the equipment dialogue box against the vendor drawing and yellow off all documents.
- Mark up any discrepancies on the nozzle report (at this stage it may be too late to revise the physical equipment) point out discrepancies to the piping lead who will request the changes to be made in the model if necessary.
- Check the dimensions on the vendor drawing against the equipment model carefully. The reference points used when building the equipment model may differ from the dimensions provided on the vendor drawing. For instance, horizontal drums are often built using seam-to-seam, whereas the vendor drawing may be dimensioned tangent-to-tangent.

- Gather together all checked documents and make up a file folder marked "Check Prints (Equipment No)." If there are no discrepancies in the checking package, place the folder in the piping equipment file behind the master copy of the vendor drawings. Do not file before pointing out any discrepancies to the piping lead.
- Discrepancies are resolved and required changes are made in the model by the designer. The designer provides the checker with a new equipment nozzle report and equipment dialogue box for backchecking.
- When checking is complete and changes, if required, have been made, the piping lead will instruct the CAD support to freeze the equipment model.

3.7.3 Piping arrangement and isometric checking

All 3D software has automatic piping arrangement and isometric generation functionality. While automation reduces the drafting and checking time over 2D CAD, these activities are not eliminated by automation. The automatic piping arrangement generation still requires that manual editing be done to the positioning of text and dimensions for good drafting presentation. Neither does automation change the fact that the design aspects in the model and the information on the drawings must be checked.

There was a time when piping arrangements were fully detailed, dimensioned, and sectioned, primarily for one simple reason; the person drawing the isometrics required fully detailed and dimensioned piping arrangements to work with. Due to the ability to automatically generate annotated and dimensioned isometrics from the model, fully detailed and dimensioned piping arrangements are now largely unnecessary. A secondary reason was for the benefit of the piping erectors. I say secondary because once you have isometrics to go by, the full dimensioning and sectioning on the piping arrangements takes on a lesser importance.

Piping arrangements are still an important reference document for construction, a document that shows the relationships between pipes, equipment, supports, and platforms, and in this context it is only necessary to provide sufficient information to the erectors. Now that 3D models are available for reference and isometrics are automatically generated, piping arrangements should be minimally detailed and dimensioned, and as far as possible, be limited to plans only. Partial sections and details

should only be required when a congested area or some vertical detail cannot be clarified in any other way.

The following is the information commonly contained within the plans:

- Plant North arrow.
- Key plan.
- General notes.
- Matchlines, coordinates, and continuation references.
- Area limits.
- Equipment tags.
- Equipment coordinates and elevations.
- Nozzle tags.
- Sliding and fixed saddles.
- Identify module tag numbers and limits.
- Datum point and plant coordinates located on the NW corner steel center-lines of the pipe rack or equipment modules.
- Shipping notes (pipe rack and equipment modules only).
- Pipe support and equipment supporting steel numbers and coordinates.
- Building tag numbers.
- Line numbers.
- Flow arrows.
- Reducer identification at equipment nozzles (inline identifications are not required).
- Miscellaneous line information, e.g., spec. breaks and tie-in numbers.
- Instrument tags.
- Location of shoes, anchors, guides, etc.
- BOP elevations.
- Centerline work point elevations and call-outs for trimmed shoes and shim heights on slopped lines.
- Miscellaneous information, e.g., cable trays and safety shower and eye wash tag numbers.
- Critical dimensions only. "Critical dimensions" are those that tie-down piping connections for the fabricators, the locations of which are essential in order to ensure match-up of a continuation, e.g., module to module or module to field erected. They are also dimensions from a reference point to vertical lines passing between upper and lower piping arrangements (these dimensions appear on the lower piping arrangement only), and reference dimensions required to assist the erectors, e.g., centerline of column to centerline of pipe.
- Tie-in numbers.

As much as is possible should be checked within the models themselves. Keeping in mind that the clash reports and equipment checks are done, the checker can focus primarily on checking that the piping in the models matches the latest P&IDs and LDTs and that the required information is included in the drawings. In other words, when the models are checked to ensure accuracy, the information that flows from them and appears on the drawings must be also accurate. The drawing checks are only required to ensure that the content on the drawings is complete.

It used to be a common practice to check the isometrics at a later date after the piping arrangements were completed and sufficient time had elapsed to draw these isometrics. As all information now comes from the model databases, this is no longer the case. The checking of the piping arrangements and the associated isometrics can be scheduled to happen separately or together. My preference is that the piping arrangements and isometrics be checked together. This way all information is before the checker at the same time. The downside to this is that the piping arrangements must be generated in order to do so. Another method is to check the isometrics first, make the changes to the models, and then generate the piping arrangements and check them during the backchecking of the isometrics. The upside to this is that the piping arrangements are not generated until after the models are corrected. The downside is that the checker does not have a complete package to work with until after the initial check. The choice is yours. You may want to try it both ways and see which approach works best for you.

3.7.4 Prerequisites and checking procedure

Before piping arrangement and isometric checking begins, the following documents should be complete. It is the responsibility of the checker to obtain and use the most current copy of the

- instrument list and data sheets;
- tie-in list (if applicable);
- specialty item list and data sheets;
- Piping Job Notes (PJN);
- piping classes;
- piping standards;
- IFC P&IDs;
- IFC LDT;

- 90% model review comments;
- final stress isometrics;
- spring support data sheets;
- structural steel drawings issued for checking;
- equipment check files;
- recent clash check report run and cleared.

Prior to commencement of checking, the piping arrangements and isometrics should be put on an IDR. Any comments arising from the IDR should be reviewed by the checker and incorporated into the piping arrangements and isometrics during the backdrafting.

3.7.4.1 Piping arrangement drawing content check list (must be established on the drawing)

- Plant North arrow (up or to the left) in top left-hand corner of drawing
- Key plan in top right-hand corner of the drawing
- Title block:
  - Drawing number
  - Drawing title
  - Project name and number
  - Revision number
  - Revision description and date
  - Drawing scale
  - Reference drawings
- Matchline coordinates and references to adjoining drawings
- Area limit coordinates
- Continuations to underground drawings
- Equipment tag numbers, coordinates, elevations, and nozzle tags (Note: These are already checked. Verify the information on the drawing)
- Flow arrows
- General notes
- Call-outs and notes for any temporary shipping supports or strapping, or for any part of a line that is shipped loose (pipe rack and equipment modules only)
- Critical dimensions
- Insulation breaks are 500 mm back from all termination points of butt welds to allow for later field welding (pipe rack and equipment modules only)
- Cloud "HOLDS" and create a holds list

3.7.4.2 Piping arrangement design content check list (checked in the model and verified on the drawing where applicable)

- Pipe and equipment support numbers, coordinates, and TOS elevations
- Modules are within the width, height, and length allowances for shipping requirements
- Line spacing. Check that line spacing also allows for expansion growth at changes of direction. Refer to Table 3.5
- Correct call-outs for shoes, anchors, guides, etc., per the stress isometrics
- BOP elevations
- Centerline work point elevations and trimmed shoe and shim heights for sloped lines
- Call-outs for reducers/swages at equipment nozzles: concentric, eccentric (FOB, FOT) with sizes
- Adequate space provision to swing spades and remove blinds
- Adequate space provision for valve rising stems
- Left- or right-hand instruments correctly orientated, e.g., ball pattern control valves
- Personnel protection insulation limits
- Drop zones
- ID the TOS to underside of shoe spring heights, or underside of steel to centerline of pipe of hanger rods and hanger springs
- Sliding/fixed saddle locations
- Vendor package tag numbers and limits
- Module tag numbers and limits
- Datum point and plant coordinates of pipe rack and equipment modules
- Building tag numbers
- Line numbers
- Spec. breaks
- Tie-in numbers
- Instrument tag numbers
- Cable trays shown
- Utility station tag numbers
- Safety shower and eye wash station tag numbers
- Sample cooler tag numbers

3.7.4.3 Isometric drawing content check list (must be established on the drawing)

- Plant North arrow up and to the left (preferred in industry) or up and to the right per company standard.

Table 3.5 Linear thermal expansion between 70°F/21°C and indicated temperature. (Inches per 100 feet or millimeters per 30.48 m)

Temp		Carbon Steel, Low Chrome (thru 3 Cr Mo)		5 Cr Mo thru 9 Cr Mo		Austenitic Stainless Steels	
°F	°C	inches	mm	inches	mm	inches	mm
–50	–46	–0.84	–21	–0.79	–20	–1.24	–32
–25	–32	–0.68	–17	–0.63	–16	–0.98	–25
0	–18	–0.49	–12	–0.46	–12	–0.72	–18
25	–4	–0.32	–8	–0.30	–8	–0.46	–12
50	10	–0.14	–4	–0.13	–3	–0.21	–5
70	21	0.00	0.00	0.00	0.00	0.00	0.00
100	38	0.23	6	0.22	6	0.34	9
125	52	0.42	11	0.40	10	0.62	16
150	66	0.61	15	0.58	15	0.90	23
175	80	0.80	20	0.76	19	1.18	30
200	93	0.99	25	0.94	24	1.46	37
225	107	1.21	31	1.13	29	1.75	44
250	121	1.40	36	1.33	34	2.03	52
275	135	1.61	41	1.52	39	2.32	59
300	149	1.82	46	1.71	43	2.61	66
325	163	2.04	52	1.90	48	2.90	74
350	177	2.26	57	2.10	53	3.20	81
375	191	2.48	63	2.30	58	3.50	89
400	204	2.70	69	2.50	64	3.80	97
425	219	2.93	74	2.72	69	4.10	104
450	232	3.16	80	2.93	74	4.41	112
475	246	3.39	86	3.14	80	4.71	120
500	260	3.62	92	3.35	85	5.01	127
525	274	3.86	98	3.58	91	5.31	135

Table 3.5 Continued

Temp		Carbon Steel, Low Chrome (thru 3 Cr Mo)		5 Cr Mo thru 9 Cr Mo		Austenitic Stainless Steels	
°F	°C	inches	mm	inches	mm	inches	mm
550	288	4.11	104	3.80	97	5.62	143
575	302	4.35	110	4.02	102	5.93	151
600	316	4.60	117	4.24	108	6.24	159
625	330	4.86	123	4.47	114	6.55	166
650	343	5.11	130	4.69	119	6.87	175

Identify the pipe material and the design temperature (use the higher number for in-between temperatures), then apply the following formula to calculate the expansion:

$$\frac{\text{length of pipe in feet}}{100} \times \text{exp. per 100 feet} = \text{exp. in inches}$$

or

$$\frac{\text{length of pipe in meters}}{100} \times \text{exp. per 30.48 meters} = \text{exp. in millimeters}$$

- Title block:
  - Drawing and sheet number
  - Project name and number
  - Revision number
  - Revision description and date
  - Line number
  - Area number
  - Model number reference
  - P&ID reference
  - NDE and PWHT requirements
  - Painting, insulation, and tracing requirements
  - Code, e.g., B31.3.
- Check the operating, design, and test conditions against the master stick file LDT. In theory, these will be correct because they are imported from the native spreadsheet, but do not assume this to be true. In reality the updating of the LDT native spreadsheet often trails behind the plotting of the isometrics for checking. (Note: When isometric production is out of sync with LDT updates, it is best to leave the conditions off of the isometrics and require that only the LDT be referred to as the governing document. This can be covered by a note on the isometrics and avoids manual edits and/or revising and re-issuing at a later date.)

- Isometric continuation references.
- Equipment tag numbers, coordinates, elevations, and nozzle tags (note: these are already checked. Verify the information on the drawing).
- Flow arrows.
- Isometrics without a piece of equipment in them, i.e., a nozzle, require a reference to a column centerline.
- Notes for base guides are correct, e.g., "ALLOW N-S or E-W MOVEMENT."
- Cloud "HOLDS" and create a holds list.

3.7.4.4 Isometric design content check list (checked in the model and verified on the drawing where applicable)

- Components in the BOM (note: do not check quantities).
- Correct piping class used.
- The correct calculated wall thickness is called out.
- Branch lines checked against the branch chart, and for vapor and liquid traps. It may seem unnecessary to check the branch fittings given that the choices available are predetermined and limited per the piping class database. However, I have seen reducers added to branch lines on P&ID's and designers who have followed this exactly, placing a straight tee and reducer when a reducing tee should have been used.
- Call-outs for shoes, anchors, guides, etc., are per the standards, and the locations and the piping configurations are per the latest stress isometrics.
- Pump suction piping checked for eccentric (FOT) reducers and 5–10 straight pipe diameters prior to the suction nozzle.
- Hydrostatic vents and drains have been provided at all high and low points, and are per standards and piping class, e.g., double block.
- Instrument connections are per standards and piping class, e.g., flanged thermowells versus threaded or socket welded.
- Piping configurations for inline instruments conform to the data sheets and standards, e.g., upstream and downstream requirements have been met.
- Orifice flanges are Class 300 minimum, and tap orientations are identified.
- Rotated valves' angles are possible, e.g., a valve with a flange pattern of eight bolts rotated to 45 degrees is possible. A valve with a flange pattern of 12 bolts rotated to 45 degrees is not.
- Check valves that are positioned in the direction of flow. Note that swing disk type check valves cannot be positioned in the vertical with the flow down.

- Out-of-spec items are identified (e.g., flanges at pumps).
- Spool sizes are within the shipping box size, Mark numbers are noted and field welds and field fit-up welds are logically located, e.g., field welds in the horizontal plane when possible, field fit-up welds between rotating equipment.
- Nonstandard bolt lengths on PSV inlets, wafer valves, and bleed rings.
- Shop material and field material split is correct in the BOM.
- Centerline elevations of control valve stations above grade and platforms are at the height required by the standards, i.e., adequate height to ensure drain valve clearance.
- Dimensional checking is to be limited to
  - face-to-face dimensions of inline instruments;
  - face-to-face dimensions of specialty items;
  - clearance is adequate for the removal of control valve operators;
  - clearance is adequate for the removal of equipment.
- Specialty items (SP) noted.
- Tie-in numbers noted.
- Platform, floor, and wall penetrations are shown.

A checking file is to be created. Initially this may be compiled by the designer and added to by the checker. This file must contain all of the drawings and information used or created for the check, and is to be stored for future record.

Backdrafting must be done in the models and the drawings regenerated. Never manually edit the automatically generated parts of any drawings using straight 2D CAD.

After the checks and backdrafting are completed the models are frozen, and prior to IFC a "Yellow Off" of the lines is conducted by the piping lead, or designate, on the master P&IDs. The piping arrangements and isometrics are followed and demarcations are noted to indicate the extent of the lines checked. This is one last quality check to ensure nothing slips through the cracks.

3.8 MANHOUR ESTIMATING AND MANPOWER PLANNING

Manhour estimating is the exercise of identifying the activities and estimating the number of hours that each activity will take, in order to arrive at the total number of hours required to complete the project. Manpower

planning is the identification of the required skill sets and assigning of the required number of personnel to these activities to support the schedule.

When it comes to the detailed estimate of the piping manhours and planning the piping manpower, it is the potential to overlook the detail that can cause your biggest headaches later on. You must consider all of the activities that you are responsible for and the skill sets you will require in order for your part of the project scope to be accomplished. Make yourself aware of the following before starting:

- Project scope definition: What are you designing and building? What activities are to be included? Read the Design Basis Memorandum (DBM) and the Project Execution Plan (PEP).
- Specifications and standards: Are you using existing company or client specifications and standards, or will you be developing them?
- Deliverables: What are your deliverables? For example, 3D models, piping arrangements, and isometrics?
- Fabrication and construction strategies: For instance, will this project entail modularization?
- Are you responsible for material control and/or stress analysis? It is not unusual for these activities to come under the management of the piping lead.

Prior to starting your manhour estimating and manpower planning, divide the plot plan as described below. It is very likely that your first cut at this will have to be refined as you work on your estimates because the construction execution plan, i.e., module versus nonmodule and construction sequencing, is firmed-up during the estimating process and the study phase of detailed design.

Dividing the plot plan will give you a feel for the complexity of the facility and will be particularly useful for the manpower planning. For smaller projects the first bullet below may be ignored and where I refer to "plant area" in the following bullets, read "plot plan."

For larger projects compile your estimates according to each plant area. The division of the plot plan is as follows:

- Divide the plot plan into the general geographical plant areas, e.g., tank farm area, hydro-treating area, and water treatment area.
- Divide each plant area into EWP boundaries according to field erected and module packages, and the construction schedule.
- Divide each EWP into model areas or designer areas. You will require a sufficient number of models in each EWP in order to assign the work to enough individual designers to meet the schedule. Flexibility

is the consideration; flexibility to parachute in another designer if needed, and flexibility to check and issue in stages.

- Divide each model area into piping arrangement drawings. Do not overlook that there may be multiple levels requiring separate plans for each.

For a more detailed explanation on plot plan division refer to Chapter Five, Detailed Design.

3.8.1 Manhour estimating

First of all, what is an estimate? It is your best educated guess. An educated guess being the best you believe you can do based on

- historical data gathered from similar projects;
- the level of detail/scope provided.

You should always approach your estimating from the point of view that everything will run smoothly. We both know that this will not be the case, however, do not pad your estimate with "what if" scenarios. Come up with a realistic number and leave it to the project management team to put in the contingencies.

Create a manhour estimate spreadsheet where you list each of the deliverables and the number of each deliverable, each of the activities and the hours associated with each activity, and the totals. This will be an accurate record of the basis for your estimate and what you agreed to. It will aid you greatly later when you have to submit estimates for trends and scope changes.

The below list of deliverables and activities for a 3D project is not a definitive list, and you may well identify items to be added, items that do not apply or items that you would combine into one for your own situation. My goal here is to point out that a good estimate requires thought and preparation so that you do not overlook anything.

- Number of P&IDs and the drafting hours required.
- Piping design hours.
- Number of piping arrangements and hours for generation.
- Number of isometrics and hours for generation.
- Number of heat tracing drawings and hours for the tracing design.
- Checking hours.
- Administration hours.
- CAD support hours.
- Material control hours.

- Stress analysis hours.
- Hours for the development of piping classes and piping standards.
- Hours for the inputting and checking of the piping classes and standards into the databases.
- Hours for as-built drafting and checking and project closeout.
- Supervision hours.
- On revamp projects: hours for gathering of existing information/ drawings, field trips for meetings, gathering of field information, and hanging of tie-in tags.

Search out historical data, as this will aid greatly to make your estimate as accurate as possible and to back-up your numbers.

Historical data compiled at the end of a project should contain the following:

- The type and size of the plant
- The design and drafting software used, i.e., 2D CAD and 3D CAD
- A list of the deliverables, i.e., piping arrangements and isometrics
- The manhours expended for each activity, e.g., design, checking, supervision, stress analysis, CAD support
- The manpower loading for the duration of the project, e.g., 40 designers for 2 years.

There are four basic methods used to estimate the piping design hours for a project. I recommend that you do at least two estimates for your project using two different methods for comparison.

Methods of estimating the piping design hours are

- Equipment count
- Nozzle count
- Line count
- Drawing count

The estimate for the piping design hours is used to estimate some of the other activities on a percentage basis, e.g., CAD support. Remaining activities are added as a function of time, e.g., supervision.

The following is an example of estimated hours. These figures come from numbers used for 3D grass root refineries and chemical plants. This is why historical data is so important, as different types of projects may or may not utilize similar numbers. These figures include design development time. For duplicated equipment or trains, estimate the piping design hours for the first at 100% and 50% for the subsequent duplicated equipment or trains. Estimates are made from the low number to the high number within a range, depending on the design complexity. For

instance, the design time allowed for a group of pumps or exchangers may be 150 hours and the design time allowed for a distillation column or reactor may be 400 hours.

Use one of the following four methods to estimate the piping design hours:

- Equipment counts obtained from the PFDs and P&IDs. Allow 150–400 hours per piece of equipment for piping design hours.
- Nozzle count obtained from the P&IDs. Allow 20 hours per nozzle for piping design hours. Include vents, drains, instrument connections, etc.
- Line count obtained from the P&IDs and the LDT. Allow 30 hours per line for piping design hours.
- Drawing count: allow 100–200 hours per piping arrangement for piping design hours.

Add the hours for the below activities to get the total estimated hours:

- P&IDs: allow 20 hours per drawing for drafting of new drawings and 5–10 hours for development of already created drawings.
- Piping arrangement generation: allow 5–8 hours per drawing for drawing generation.
- Isometric count: allow 2.5 isometrics per line and 2–3 hours per isometric for drawing generation.
- Tracing design and checking (hot oil, steam, or glycol): 10%–20% of the piping design hours.
- Checking: 20%–25% of the piping design hours.
- Administration, e.g., stress isometric coordination. This is a function of the project duration. Allow hours for the duration of the project, usually 40 hours per week per person.
- CAD support: 5%–10% of the total piping hours.
- Material take-off group: 8%–12% of the piping design hours.
- Stress analysis: 10%–15% of the piping design hours.
- Piping class and piping standard drawing development: 1%–3% of piping design hours dependent on whether you are accepting, modifying, or creating the client's piping classes and standard drawings.
- As-builts and project closeout: 1.5 hours per drawing.
- Supervision: overall piping lead and area leads are a function of the project duration. Allow hours for the duration of the project, usually 40 hours per week per person. Commonly there will be one lead per plant area, but you may have a small area that can be merged with a larger area, or a couple of smaller areas that can be managed under one lead to distribute the responsibilities evenly.

The hours above are based on 3D CAD; however, the differences of the overall piping hour's budget for a project using 3D CAD, 2D CAD or manual methods for design and drafting are not as appreciable as some people may believe. This is primarily due to the following reason:

- The time requirements for the planning and administration by the leads and the thought processes required of the designers and checkers that go into finished designs have not been reduced significantly. CAD software primarily reduces drafting time. The bulk of the hours, 75%–85% of the piping hours budget, has always been, and is still used in the supervision, administration, designing, and checking processes, and this does not change much regardless of the tool. Thinking and executing are still the largest parts of the piping effort.

  The savings in the number of hours for a 3D CAD project over a 2D or manual project are primarily the benefits and efficiencies that are realized by the downstream disciplines:
- The abilities to run reports for bid and purchasing purposes.
- The visualization that the models provide for design reviews internally and externally with the client.
- The visualization that the models provide for construction planning and execution.
- The improved attainable accuracy over manual and 2D leading to reduced field rework and lower Total Installed Cost (TIC).

The theoretical design, drafting, and checking hours saved from the piping budget on a 3D project are offset as the piping group now have added responsibilities and need added hours that were not previously required.

- The databases require maintenance, and the piping designers are responsible for doing their part.
- There will be downtime due to problems associated with the models.
- Junior designers do not get the level of training and mentoring prior to being involved in the layout of piping as was the case prior to 3D CAD, which can result in added hours for checking and rework. The training that is provided primarily focuses on the use of the software and not on piping layout and design.
- There is a whole new group of professionals required, the CAD support group, whose time must be paid for by the project, and who are often part of the piping budget. This is true of 2D also, but not to the same extent.

The bottom line is that while we have saved some piping hours in the areas of designing, drafting, and checking using CAD, in other ways we have only modified the methods and order of piping execution,

substituted one activity for another and added piping hours in areas of software complexity, database management, and CAD support requirements.

The next step in the estimating process, once you have submitted your hours to the project management, is the negotiation. They will have a number in mind factored from the capital cost of the project. If you are close to their number, your budget will most likely be accepted. However, if you are widely apart from their number you will be challenged and a negotiation will begin. When you are challenged, ask educated questions about the basis for the project management's numbers. Do the numbers they are using include all of the activities and/or deliverables that you have budgeted for? You will have to revisit your estimate and rework your numbers, but try not to be intimidated into an agreement that makes you uncomfortable. Be realistic. Your negotiation may be to strike certain activities/deliverables off of your list, or it may be to reduce your hours in an area where initially you may have been overly cautious. Eventually you will reach a number that suits you both.

Estimating is not an exact science and most likely you will get it wrong. Quite frankly it is an area that most leads struggle with. But the good news is that things often balance out; you will underestimate in one area and overestimate in another. Over a period of time as you gain experience you will also develop a gut feel and your ability to estimate will get better. Your best defense against overrunning your budget is to have the procedures in place to manage your work.

Once you have the budgeted hours established you have another task ahead, that of manpower planning to support the schedule.

3.8.2 Manpower planning

Again, manpower planning is not an exact science, but the taking of certain steps will help you bore down to a plan:

- Divide the plot plan
- Apportion the hours
- Load level
- Staff appropriately

3.8.2.1 Dividing up the plot plan

- Presumably, the plot plan has been divided into the general geographical plant areas, EWP boundaries, models, and piping arrangements.

3.8.2.2 Apportioning the hours

- If you have not already done so, you have to apportion the total budgeted manhours into each plant area. Break the hours of each plant area down further into each EWP. The manhours for each EWP are further divided into the model/design areas depending upon the complexity of the EWP. I personally use the piping arrangements as an indicator. Based on the number of piping arrangements in each EWP, I decide on the hours for each model/design area by giving a little and taking a little depending on the level of complexity.
- Create a manhour spreadsheet: on the left-hand side list the plant areas (rows), subdivided by EWP/model/design areas, and further by design and checking. Across the spreadsheet is the timeline divided by weeks (columns). See Fig. 3.22.
- By referring to your estimate and the schedule, divide the hours, usually 40 per week to give the number of weeks, and plug in the weekly hours for each model/design area. Remember that the issue dates will be the out-the-door dates and you will have to allow time for plotting and sign-off of the drawings. Working backward from the date that the checking must be completed will give you the start date that the designing must begin.

3.8.2.3 Load levelling

- Once your spreadsheet has been completed, it will become apparent that you have peaks and valleys in the workload. Even the peaks and valleys out by moving model/design areas forward or back by a week or two, e.g., the schedule requires 500 isometrics to be issued per week for a couple of weeks, followed by 100 isometrics per week for a couple of weeks. The logistical difficulties encountered in issuing 500 isometrics per week can be overcome by relaxing the schedule and spreading these out into the coming weeks. Refer to Fig. 3.23. You will have to go back to the project management team and renegotiate the schedule somewhat, but this is the time to do it. Later, when fabrication shop time has been booked, the pressure will be intense to stay on schedule. Not to mention that your abilities as a lead may be questioned if you start slipping from the schedule and have not been proactive in identifying and resolving problem areas.

MANPOWER REQUIREMENTS

PROJECT MANPOWER BY WEEK - STARTS ON MONDAY

2010

AREA	ACTIVITY	Name	Est. Hours	Est. M/W	04-Jan	11-Jan	18-Jan	25-Jan	01-Feb	08-Feb	15-Feb	22-Feb	01-Mar	08-Mar	15-Mar	22-Mar	29-Mar	05-Apr	12-Apr	19-Apr	26-Apr	03-May	10-May	17-May	24-May	31-May	07-Jun	14-Jun	21-Jun	28-Jun
ALL AREAS																														
	Piping Lead		1040		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
	CAD Support		960		16	16	24	24	40	40	48	48	48	48	48	48	48	48	48	48	48	48	48	48	32	32	24	24	8	8
	Material Control		480		8	8	12	12	20	20	24	24	24	24	24	24	24	24	24	24	24	24	24	24	16	16	12	12	4	4
	Stress Analysis		480		8	8	12	12	20	20	24	24	24	24	24	24	24	24	24	24	24	24	24	24	16	16	12	12	4	4
	Iso Coordination		640												40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Sub-Total All Areas Hours			**3600**		**72.0**	**72.0**	**88.0**	**88.0**	**120.0**	**120.0**	**136.0**	**136.0**	**136.0**	**136.0**	**176.0**	**176.0**	**176.0**	**176.0**	**176.0**	**176.0**	**176.0**	**176.0**	**176.0**	**176.0**	**144.0**	**144.0**	**128.0**	**128.0**	**96.0**	**96.0**
Total Area All Hours/Manweeks			**3600**	**90**	**1.8**	**1.8**	**2.2**	**2.2**	**3.0**	**3.0**	**3.4**	**3.4**	**3.4**	**3.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**3.6**	**3.6**	**3.2**	**3.2**	**2.4**	**2.4**
PLANT AREA 01																														
	Area Lead		1040		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Sub-Total Area 01 Lead Hours			**1040**		**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**
EWP Number 01-1 - Model 1	**Designing**	Designer 1	320		40	40	40	40	40	40	40	40																		
EWP Number 01-1 - Model 2	**Designing**	Designer 1	320										40	40	40	40	40	40	40	40										
EWP Number 01-2 - Model 1	**Designing**	Designer 2	320						40	40	40	40	40	40	40	40														
EWP Number 01-2 - Model 2	**Designing**	Designer 2	320														40	40	40	40	40	40	40	40						
Sub-Total Areas 01 Designing Hours			**1280**		**40.0**	**40.0**	**40.0**	**40.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**40.0**	**40.0**	**40.0**	**40.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
EWP Number 01-1 - Models 1 and 2	**Checking**	Checker 1	160																		40	40	40	40						
EWP Number 01-2 - Models 1 and 2	**Checking**	Checker 1	160																						40	40	40	40		
Sub-Total Area 01 Checking Hours			**320**		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**0.0**	**0.0**
Total Area 01 Hours/Manweeks			**2640**	**66**	**2.0**	**2.0**	**2.0**	**2.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**1.0**	**1.0**
PLANT AREA 02																														
	Area Lead		1040		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Sub-Total Area 02 Lead Hours			**1040**		**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**
EWP Number 02-1 - Model 1	**Designing**	Designer 3	320		40	40	40	40	40	40	40	40																		
EWP Number 02-1 - Model 2	**Designing**	Designer 3	320										40	40	40	40	40	40	40	40										
EWP Number 02-2 - Model 1	**Designing**	Designer 4	320						40	40	40	40	40	40	40	40														
EWP Number 02-2 - Model 2	**Designing**	Designer 4	320														40	40	40	40	40	40	40	40						
Sub-Total Areas 02 Designing Hours			**1280**		**40.0**	**40.0**	**40.0**	**40.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**40.0**	**40.0**	**40.0**	**40.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
EWP Number 02-1 - Models 1 and 2	**Checking**	Checker 2	160																		40	40	40	40						
EWP Number 02-2 - Models 1 and 2	**Checking**	Checker 2	160																						40	40	40	40		
Sub-Total Area 02 Checking Hours			**320**		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**0.0**	**0.0**
Total Area 02 Hours/Manweeks			**2640**	**66**	**2.0**	**2.0**	**2.0**	**2.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**1.0**	**1.0**
PLANT AREA 03																														
	Area Lead		1040		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Sub-Total Area 03 Lead Hours			**1040**		**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**
EWP Number 03-1 - Model 1	**Designing**	Designer 5	320				40	40	40	40	40	40	40	40																
EWP Number 03-1 - Model 2	**Designing**	Designer 5	320												40	40	40	40	40	40	40	40								
EWP Number 03-2 - Model 1	**Designing**	Designer 6	320								40	40	40	40	40	40	40	40												
EWP Number 03-2 - Model 2	**Designing**	Designer 6	320																40	40	40	40	40	40	40	40				
Sub-Total Area 03 Designing Hours			**1280**		**0.0**	**0.0**	**40.0**	**40.0**	**40.0**	**40.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**80.0**	**40.0**	**40.0**	**40.0**	**40.0**	**0.0**	**0.0**	**0.0**	**0.0**
EWP Number 03-1 - Models 1 and 2	**Checking**	Checker 3	160																				40	40	40	40				
EWP Number 03-2 - Models 1 and 2	**Checking**	Checker 3	160																								40	40	40	40
Sub-Total Area 03 Checking Hours			**320**		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**	**40.0**
Total Area 03 Hours/Manweeks			**2640**	**66**	**1.0**	**1.0**	**2.0**	**2.0**	**2.0**	**2.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**
Total All Hours/Manweeks			**11520**	**288**	04-Jan	11-Jan	18-Jan	25-Jan	01-Feb	08-Feb	15-Feb	22-Feb	01-Mar	08-Mar	15-Mar	22-Mar	29-Mar	05-Apr	12-Apr	19-Apr	26-Apr	03-May	10-May	17-May	24-May	31-May	07-Jun	14-Jun	21-Jun	28-Jun
		TOTAL DESIGNER HRS PER WEEK			**80.0**	**80.0**	**120.0**	**120.0**	**200.0**	**200.0**	**240.0**	**240.0**	**240.0**	**240.0**	**240.0**	**240.0**	**240.0**	**240.0**	**240.0**	**240.0**	**160.0**	**160.0**	**120.0**	**120.0**	**40.0**	**40.0**	**0.0**	**0.0**	**0.0**	**0.0**
		TOTAL CHECKER HRS PER WEEK			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**80.0**	**80.0**	**120.0**	**120.0**	**120.0**	**120.0**	**120.0**	**120.0**	**40.0**	**40.0**
		TOTAL MANHOURS PER WEEK			**272**	**272**	**328**	**328**	**440**	**440**	**496**	**496**	**496**	**496**	**536**	**536**	**536**	**536**	**536**	**536**	**536**	**536**	**536**	**536**	**424**	**424**	**368**	**368**	**256**	**256**
		TOTAL MANPOWER PER WEEK			**6.8**	**6.8**	**8.2**	**8.2**	**11.0**	**11.0**	**12.4**	**12.4**	**12.4**	**12.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**10.6**	**10.6**	**9.2**	**9.2**	**6.4**	**6.4**

Figure 3.22 Manhour spreadsheet example.

Figure 3.23 Manhour graph example.

3.8.2.4 Staffing

- Identify the area leads. Area leads will be from the ranks of the most senior designers, preferably those that have had previous lead experience.
- Now that the workload has been spread out over the duration of the project, you can clearly identify the number of designers and checkers you will need, and when you will need them. Preplan and assign all of the model/design areas to individual designers and checkers. If you know who the team members are, name the individuals and their assigned areas so that they know what they will be working on next.
- Take into account the level of experience you will need when assigning the work. For example, you cannot give a reactor area or distillation columns to a junior designer. More appropriately you would assign pipe racks or a storage tank to the more junior personnel.
- Make sure that the plant area leads have balanced teams in terms of senior, intermediate, and junior designers. A good ratio is that for every two seniors, there will be two intermediates and one junior.

3.8.3 Other considerations

- Do not staff up too soon. You have planned your manpower requirements to meet the schedule, but do not forget that this is contingent on receiving the information you need on time, i.e., P&IDs and preliminary vendor data. Until this becomes available, you will just be spinning your wheels and burning hours with little productivity. Start an action item list of the things that are holding you up.
- Trend all changes and rework, even though they may not be approved, and keep a record.
- Revisit and reforecast your plan a couple of times during the project.

Do not expect that your estimating and planning will go exactly as planned. They never will. They are tools intended to give you the heads-up when you are going off of the rails and give you time to react.

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CHAPTER FOUR

Deliverables

4.1 INTRODUCTION

In this chapter we will discuss each of the possible piping deliverables and the reasons why they are produced. When we talk of deliverables from the piping group, we are of course primarily referring to the piping drawings, but, given that deliverable is synonymous with scope, I also want you to consider the piping scope of work during this discussion.

Over the decades, industry has developed various deliverables to communicate specific aspects of the design to the other disciplines and to construction, and later to operations and maintenance. Each deliverable brings its own added value to the project by providing the needed details to construct that aspect of the scope. The deliverables cover all the information required to build the plant, from the larger overview down to the smallest components.

All of the possible deliverables are not required for every project; this is because all of the activities that they are designed to communicate are not within the project scope. Which deliverables are required should be a simple question of "Which of the list of possible deliverables do we need to communicate the scope of our design to construction?"

Unfortunately in the real world this is not usually the question. Often the best interests of the project as a whole are overlooked and the question asked is "How can we cut hours from the piping/engineering design budget?" An answer will emerge, most likely with poor reasoning and/or hastily reached decisions if you do not become involved to cut certain deliverables from the project scope without necessarily making adjustments to the scope of work itself.

On the surface a proposal to delete any deliverable, piping arrangements or isometrics, for instance, may appear to be a cost and schedule saving. However, the adoption of proposals such as these without

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weighing the consequences can be very damaging. The hours spent addressing queries and filling in the gaps that are created often exceed any hours saved by the omission. Therefore arbitrary decisions must not be allowed and the choice of deliverables must be intelligently decided after due consideration that recognizes the value of each. As the piping lead, and a subject matter expert, it behooves you to enter into the discussions to raise flags and to assist others to reach the right conclusions.

This chapter will not only describe the deliverables, but will also discuss their purpose and the implications of leaving any of them out (keep in mind that some deliverables, e.g., P&IDs, can never be left out due to being a regulatory requirement).

It is crucial for the project and the piping group in particular that you begin with a clear picture of your deliverables and scope. Do not expect that everyone is on the same page as you. You must verify your own thoughts with the project team. Many projects have been started before a consensus has been reached. This is bad because when your planning is based on assumptions that may prove later to be incorrect, the result may be the expenditure of unbudgeted hours to put right. Prior to starting your project you must engage all of the stakeholders and agree which deliverables are required and why. The major stakeholders are as follows:

- Project management, both engineering company and client
- Construction management
- Piping engineering
- Piping design

To start, let us consider three scenarios of decisions made about piping deliverables and scope, and discuss the implications.

I have witnessed small projects, such as a gas pipeline dehydration installation, where the equipment is primarily vendor supplied skidded units, and there is little, other than interconnecting piping, to be designed. The decision was made to provide a plot plan, the P&IDs and Line Designation Tables (LDTs) only, and run the piping in the field, the theory being that it is simple piping and the construction could get an earlier start by cutting the engineering scope. There are some projects that have been pulled off in this manner, but to deduce that it is simple piping not requiring piping arrangements and isometrics, and that time can be saved by omitting these, may not be true. It could in fact be

disastrous. When piping arrangements and isometrics are omitted as a deliverable the field personnel will have to design the routing of the piping. We have transferred design responsibility to the field, and in so doing added scope to the field effort. Before a decision is made to omit piping arrangements and isometrics consider the following:

- Is this the most efficient use of the field personnel's time? Do not forget that someone has to do the design, Material Take-Off (MTO), and material purchase before the pipe fitters and welders can get started.
- By saving on the office engineering hours, have we merely in fact increased the more costly field hours? That is, are we going to save money or will we just increase the total installed cost (TIC)? Most likely the construction schedule and costs will be increased. Time spent in the office is always a fraction of the time and cost that will be spent in the field.
- Are the skill sets available in the field to follow the P&IDs and run the piping? For example, will the field personnel recognize "no pockets" requirements?
- How are the engineering aspects to be addressed? And, what will be the permanent stamped record? For example, stress analysis.
- The decision may entail that a full-time field engineer be assigned to oversee the installation and testing.
- Most importantly, how do we ensure that the installation will be safe? Engineering companies make their money by selling engineering capabilities. Construction companies make their money by selling erection capabilities. It is not that the two do not overlap or understand each other, but it is that the agendas are different.

The theoretical and the practical worlds invariably depart also when the field starts to run into problems and require support from the engineering staff. This interrupts the other projects that the engineering staff has moved on to and leads to unbudgeted hours being expended.

In this scenario, I believe it is best to have the engineers and designers do what they do best and have the field construction team do what they do best. It is not efficient to mix the two. Instead, I would campaign for full engineering in the office and the omission of the piping arrangements and construction isometrics in favor of full system isometrics (on D size or A1 size sheets) as the deliverable, and allowing the construction team to decide on the best fabrication and erection strategy.

This second scenario is not so much one of omission of deliverables, as it is one of deletion of scope from the piping group by the engineering company's project team. In the above example I mentioned vendor supplied skidded units. These are commonly almost off-the-shelf items such as inline heaters and compressor packages that the manufacturers do on a daily basis. No one would suggest that the engineering company could or should compete and design these skidded units and the associated piping themselves. However, there are misconceptions on modularized projects that these skid manufacturers and/or module fabricators are also best suited to design one-off equipment modules, and that engineering hours and schedule (a spreading around or division of labor approach to the work) can be saved by placing the design in their hands. The issue for you as the piping lead in this scenario is that if you do not recognize and discuss the downside of this thinking, all of the design hours may well be taken out of your budget for that scope. At the least you will still need hours above the normal vendor squad checking hours in order to interface your designs with the manufacturer's designs and to resolve issues that will arise due to the following reasons:

- A skidded unit, if not already predesigned, is at least available as a preliminary layout at an early enough stage for the engineering company's designer to position it into the overall design to accommodate all around access. A one-off equipment module however is not a predesigned off-the-shelf unit, and when the scope of a module design is removed from the surrounding plant design, effectively there are two designers working in the same area at the same time. When two designers are designing around each other there will be communication and efficiency issues to be overcome, especially when they are isolated from each other. A designer who is laying out a module with no knowledge of the surrounding area will likely block access and clearance.
- The engineering company has no control over the level of experience of the manufacturer's designers. A designer who primarily lays out skids, or primarily draws spool details for a living, may lack the experience to design more complex plant piping, and the fact that they are working in isolation from the engineering team means that communication is primarily through the vendor's drawing submissions and model reviews. When the engineering company's designers see the manufacturer's designs they will undoubtedly want to change them. Their mark-ups will not only take time, but will often become a

threat of schedule delay on the part of the manufacturer. The connecting piping, having been designed to the mark-ups the vendor was expected to comply with, may eventually have to be redesigned to accommodate the vendor's original submissions in the interest of not delaying the module delivery.

- There will likely be retrofits required in the field to rectify access and clearance issues.
- You may have stress interface issues. Skid manufacturers and module fabricators do not usually have their own stress analysis capability and the engineering company may even have to provide the stress analysis. (A consideration when your project chooses the path of this scenario is to have anchors placed at the module edge.)
- You may have heat tracing design issues. Even when the tracing design is left within the scope of one company the coordination required will be very challenging. Should it be divided between companies, the coordination required can be considerable. (Another consideration is to have the manufacturer include supply and return heat tracing manifolds on each module so that the tracing is self-contained. You will need to run supply and return lines to each module, but you can avoid the difficulty of interfacing circuit designs.)
- There may be CAD coordination issues. The vendor's CAD software may not be compatible with the software you are using, leading to import and interface difficulties.

Just to clarify, there are companies that provide full engineering and module fabrication capabilities. My reference is not to these companies; however, any division of the plant layout and design effort to a third party will invariably require a great deal of time for the interactions.

Ultimately it is your choice whether or not to challenge decisions such as this, but I believe it is preferable to not relinquish the design of an equipment module to a skid or module manufacturer.

My third scenario is quite a simple one. Many people believe that spooling fabricators create isometrics, so why spend the time and money in the engineering office to create something that the spooling fabricator will do anyway? There is a big difference between a spool drawing or cut sheet and a construction isometric. The only similarity is that spool drawings are often also drawn in an isometric format. This will be discussed further in this chapter and in Chapter Six, Shop Fabrication.

In the above scenarios I have made some observations and drawn conclusions. It is not my intent that you accept these scenarios for your own

experience. My point is that the piping deliverables are not just drawings. They are inextricably linked to, and a part of, the overall project execution strategy. Taking any of them out of the equation may not save the intended design and engineering hours, and can even have an adverse effect on the project outcome. You must understand your deliverables and scope and provide input into what they will be.

Having addressed some of the possible pit-falls of leaving out a deliverable and scope, we will now move on to the deliverables themselves.

4.2 DELIVERABLES

Piping deliverables can include all of the following:

- Cover sheets and drawing indexes
- Plot plan
- Key plans:
  - Piping arrangement key plan
  - Model key plan
  - Module key plan
  - Engineering Work Package (EWP) key plan
- Location plans:
  - Equipment location plans
  - Tie-in location plan
  - Utility station location plan
  - Safety shower and eye wash location plan
  - Heat tracing manifold location plan
- Piping arrangements
- Isometrics
- Isometric logs
- Tie-in isometrics
- Tie-in list
- Demolition drawings
- Heat tracing circuit layouts
- Heat tracing logs
- 3D models
- Model indexes
- EWP Drawing Packages and Scopes of Work (SOW)

Other deliverables worked on in many companies by the piping group are the following:

- Process Flow Diagrams (PFD)
- Piping and Instrumentation Diagrams (P&IDs)
- LDTs

While these are not strictly a piping deliverable, so much as they are a process group deliverable, the pipers have a large role to play in the drafting and management of these documents, and in particular the P&IDs.

4.2.1 Cover sheets and drawing indexes

4.2.1.1 A cover sheet identifies

- The project
- The area of work
- The EWP number
- A description of the package
- The reason for issuing, e.g., Issue For Bid, Issue For Construction

4.2.1.2 Drawing indexes list

- The EWP number
- The types of drawing, e.g., piping arrangements and isometrics
- The drawing numbers
- The drawing titles
- The revision numbers

Each EWP drawing package will require a drawing index of the above format. There should also be a "REMARKS" column. This is used to note certain drawing anomalies, e.g., "DRAWING ON HOLD," "DRAWING REVISED," "DRAWING ADDED," and "FOR INFORMATION ONLY." The index itself should have a revision number that is incremented each time a revision to the package is issued. The drawings are to be assembled in the same order as they are listed.

Cover sheets and drawing indexes are required to help maintain the integrity of a EWP drawing package. Constructors need a list to check against in order to verify that they have all the drawings required for their scope. The identification of a package and the drawings contained within also helps tremendously when drawings are revised and re-issued. They help identify to whom these revised drawings are to be

Figure 4.1 Drawing index.

COMPANY LOGO

EWP NUMBER: X
PROJECT NUMBER: X
ISSUE DATE YYYY/MM/DD
DRAWING INDEX REV. X

FACILITY, PAD or PIPELINE DESCRIPTION - PROJECT DESCRIPTION
PLANT AREA DESCRIPTION
PACKAGE DESCRIPTION
DISCIPLINE - DRAWING DESCRIPTION (E.g. PIPING - PIPING ARRANGEMENTS, ISOMETRICS)

NO.	DRAWING NO.	TITLE	REVISION	REMARKS
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
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31				

sent and which package they belong in. The individual EWP drawing package indexes are also used to create a master drawing list at close-out.

It must be noted that a drawing package is a dynamic (ever changing) collection of drawings, i.e., new revisions are inevitable. The drawing index is a very important document that captures these changes for the end user.

There may be more than one drawing type within a drawing package, i.e., piping packages will have piping arrangements and isometrics. In these cases list the groups of drawings separately with a heading for each in the drawing index in the same order as they are arranged within the package, i.e., "PIPING ARRANGEMENTS" and "ISOMETRICS." Fig. 4.1 is an example of a Drawing Index.

4.2.2 Plot plan

A plot plan shows an overall view of the plant and the area of real estate the facility is to be built on. It identifies plant north, true north, and prevailing wind direction and includes a plant grid coordinate system for the location of all of the buildings, equipment, pipe racks, and roads, and may also include an equipment list. This drawing is to scale, e.g., 1:1000. Civil and electrical will overlay their work on the plot plan to produce the foundation location plans and area classifications. Certain information is mandatory for the development of the plot plan:

- P&IDs
- Preliminary equipment sizes
- The plot limits
- The lay of the land
- Road and power access
- Prevailing wind direction

The development of the plot plan is based on the following:

- Spacing guidelines
- Construction execution
- Maintenance ingress and egress
- Product shipping, e.g., rail, road, and pipeline
- Process requirements

Plot plans are fine-tuned during the piping study stage. Fig. 4.2 is an example of a plot plan.

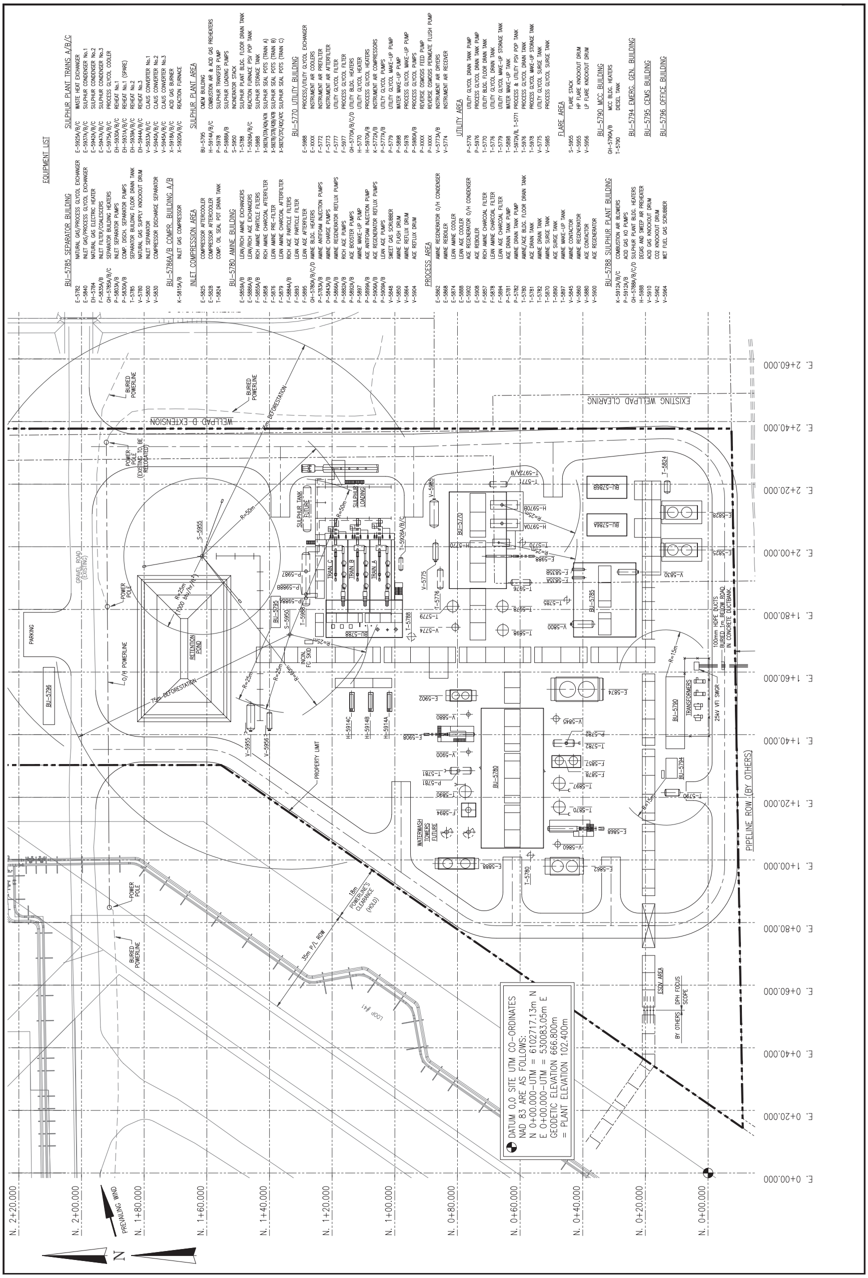


Figure 4.2 Plot plan.

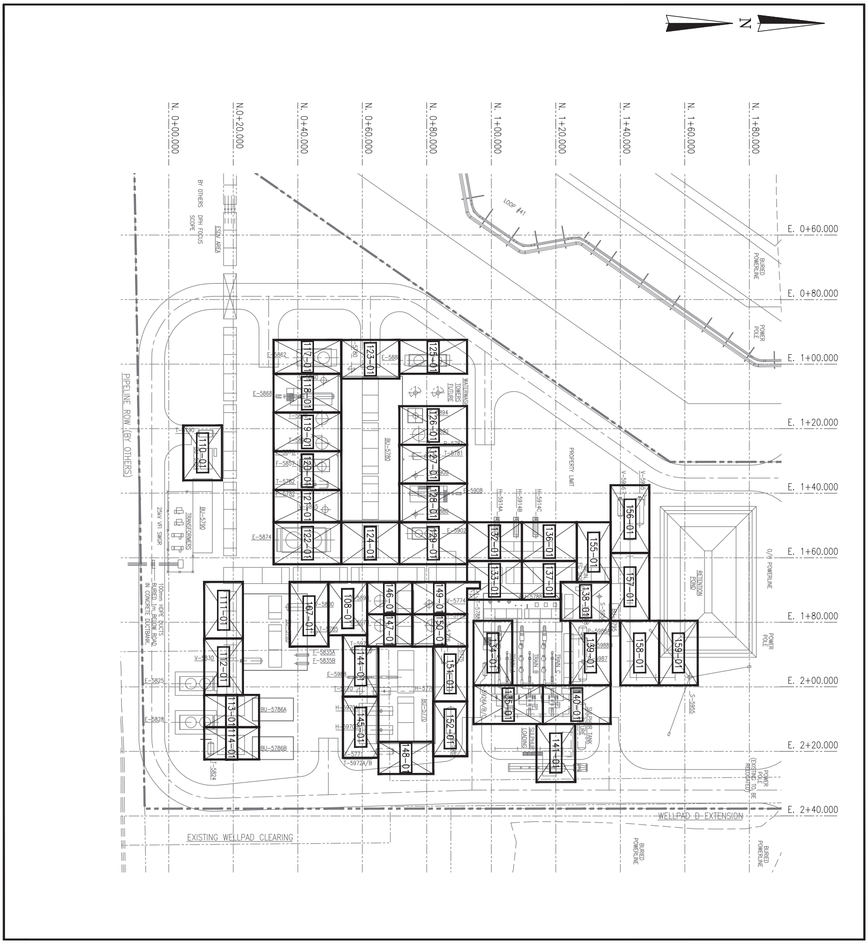


Figure 4.3 Piping arrangement key plan.

4.2.3 Key plans

All key plans have several things in common:

- They are an overlay to the plot plan.
- They are important reference documents for relating the subject matter boundaries.

Fig. 4.3 is an example of a key plan, specifically a piping arrangement key plan.

4.2.3.1 Piping arrangement key plan

The piping arrangement key plan shows the matchline limits and the drawing numbers of each of the piping plans that will be drawn at a 1:30 scale on an ANSI D or an ISO A1 size sheet of paper.

4.2.3.2 Model key plan

A piping model key plan shows the limits of each of the models and the model numbers. All disciplines will create their own model key plan, and the primary use during detailed design is as a reference for the designers to know which models they are required to externally reference into their own models. Later they become an important document during construction for locating the models of a given area.

4.2.3.3 Module key plan

It is important to have a module key plan. A module key plan not only references the limits of the modules and the module numbers, it is also used for construction planning, such as the movement and laydown of modules and critical lifts.

4.2.3.4 Engineering Work Package key plan

The EWP key plan shows the limits of the EWPs and the EWP numbers. As with the module key plan, it is an important document for construction planning.

4.2.4 Location plans

All location plans are created for quick reference as to the location of the subject matter, and, with the exception of the equipment location plans, they are an overlay to the plot plan.

4.2.4.1 Equipment location plans

Plot plans of larger facilities are often at too small a scale for all of the smaller pieces of equipment to be located by coordinates and equipment tag numbers due to the physical constraints of placing the text on the drawing. Therefore equipment location plans are created at a larger scale, e.g., 1:400. Several equipment location plans are required to cover the same area as the plot plan, each with a list of the equipment located within the drawing. The list includes the following:

- Equipment tag number
- Equipment description
- Coordinates
- Elevation

Equipment location plans simplify the location of the individual pieces of equipment. On larger projects where the plot plan is too small a scale, these are the drawings that will be used by the civil group for foundation location plan development.

4.2.4.2 Tie-in location plan

As a companion to the tie-in list, the tie-in location plan will show the tie-in numbers. Commonly the tie-in numbers are noted within a hexagon and a leader line from the hexagon points to the approximate plant location. Because a typical project with tie-ins may have dozens of tie-ins, this is a handy reference for location identification and planning purposes.

4.2.4.3 Utility station location plan

A utility station location plan indicates the utility stations by tag number at the approximate plant locations. Often a symbol for the type of utility station and a legend are employed within the drawing, along with a list by tag number to identify each of the utility stations:

- Type, i.e., the combination of utilities servicing the station: air, nitrogen, steam, and water
- Coordinates and elevation

4.2.4.4 Safety shower and eye wash location plan

A safety shower and eye wash location plan indicate the safety shower and eye wash stations by tag number at the approximate plant locations. Similar to the utility station location plan, a symbol for the type of safety shower/eye wash and a legend are often employed within the drawing along with a list by tag number to identify each of the safety shower and eye wash stations:

- Type, i.e., safety shower, eye wash, or both
- Coordinates and elevation

This is a document related to safety, and you will often see them pinned to the walls in the operations room and around the plant.

4.2.4.5 Heat tracing manifold location plan

A heat tracing manifold location plan indicates the manifolds by tag number at the approximate plant locations. Also, similar to the utility station location, and eye wash and safety shower location plans, a symbol for the type of manifold and a legend are employed within the drawing along with a list by tag number to identify each of the manifold stations:

- Type, i.e., horizontal or vertical, number of connections, supply or return
- Coordinates and elevation

4.2.5 Piping arrangements

Piping arrangements are also known as piping layouts. They are commonly drawn at a 1:30, 1:40, or 1:50 scale depending on an industry standard, and show all equipment, pipe routings, valves, instruments, shoes, anchors, guides and attached supports, and supporting steel locations. Dimensions, elevations, and coordinates are also included. Other information also shown on these drawings are the instrumentation and the platforms and ladders. The purpose of the piping arrangements is that they enable the user to visualize the overall relationship of all the piping systems, steel, and equipment. The lack of piping arrangement drawings will force construction personnel to create their own layout sketches by reference to multiple isometrics. While screenshots of the 3D models will help, it can be a time consuming exercise to recreate the same information in another format and errors may be made when doing so.

There are two types of piping arrangements:

- Area piping arrangements (above ground and underground)
- Module piping arrangements

Figs. 4.4 and 4.5 are examples of piping arrangements.

4.2.6 Isometrics

Isometrics are referred to as isos for short. These drawings are produced so that the piping can be broken down into manageable line segments. They are also produced to show the trim (trim isometrics) of the materials required on equipment, such as for vents, drains, and level instruments. They are not drawn to scale, but will be of reasonable proportion. Because an isometric shows the routing of one line only, in a 3D format, they are easy to read. They are also smaller drawings (ANSI B or ISO A3) making them easy to handle. A "Bill of Material" (BOM) is included on each isometric for the fabrication and erection of the line. The BOM identifies whether delivery of material is to be directed to the shop or to the field. They may also include design, operating and test conditions, and insulation and tracing requirements taken from the LDT. The inclusion of this last part though can be problematic in the 3D world. The functionality of automatically populating the isometric titleblock with this information is intended to save time. It is however only of value provided that the database is current. Often though, updating the LDT information lags behind isometric production, which leads to extra checking time, manual editing, and erroneous data slipping through. As a result, a

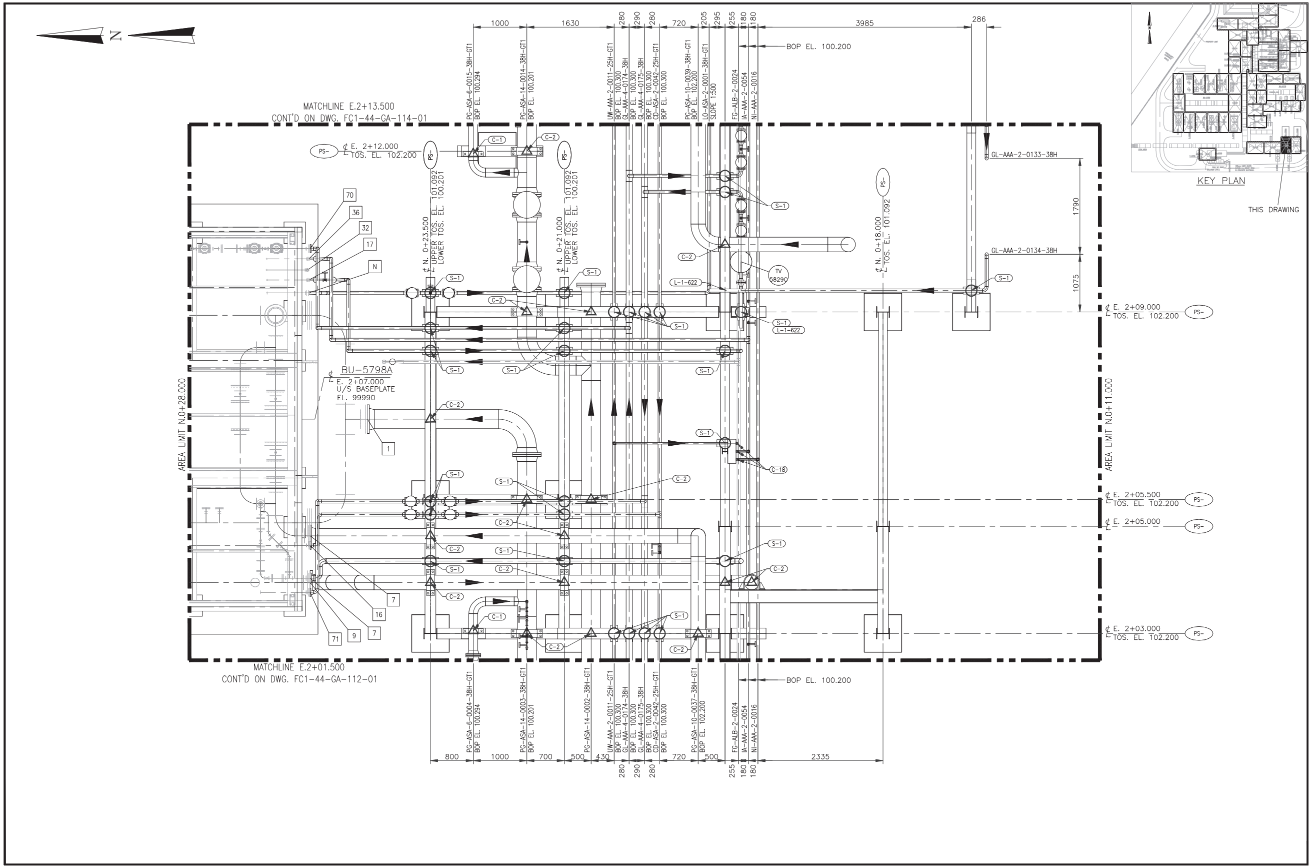


Figure 4.4 Area piping arrangement.

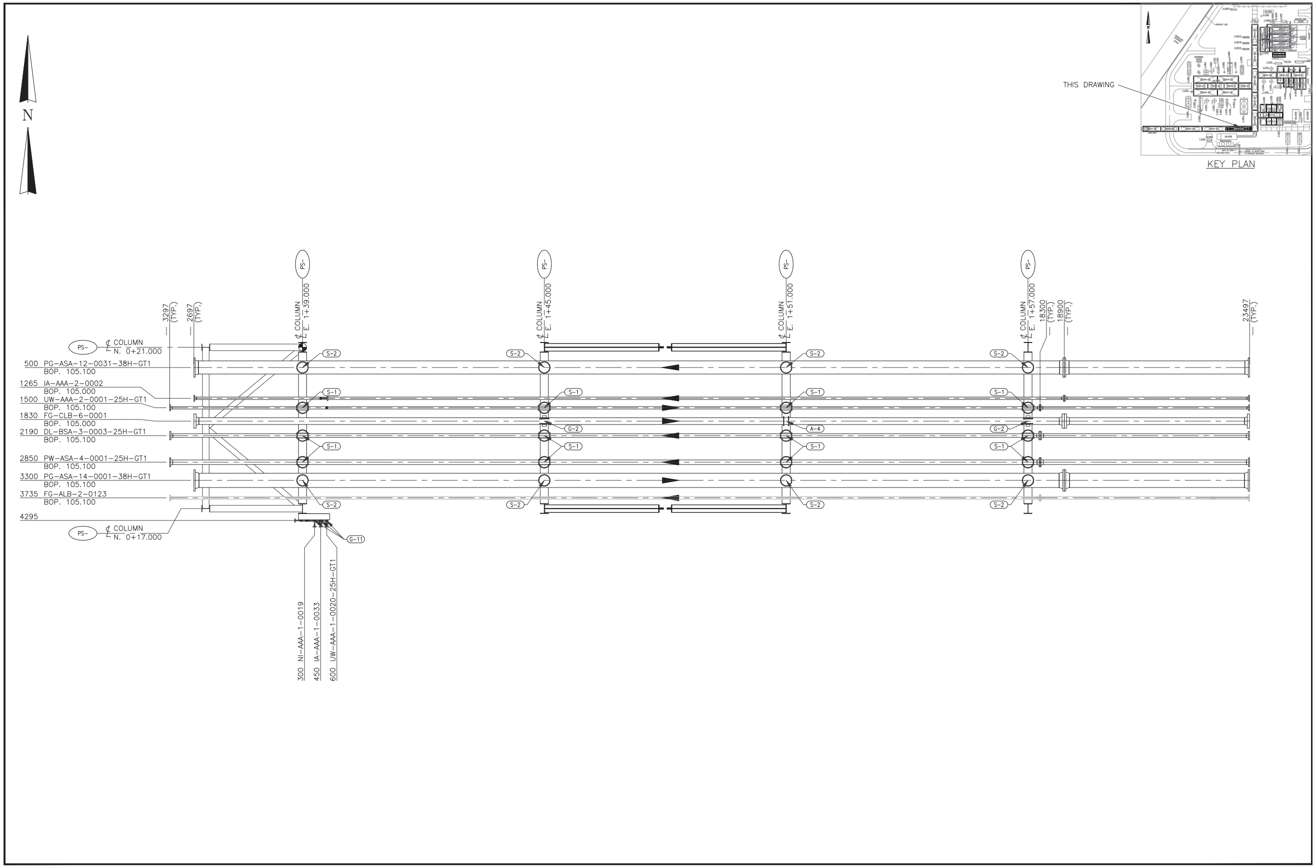


Figure 4.5 Module piping arrangement.

practice adopted by many companies is to not include this information and to place a reliance only on the checked LDT.

The spooling fabricators use isometrics for estimating and planning the work and to follow for the production of their own spool sheets. On this note, isometrics should also contain spool mark numbering. You should also be aware that fabricators will charge less to produce spool sheets when isos are provided than they will charge when they have to work from piping arrangements only.

The electrical group use isos as background for electrical heat tracing drawings. The field construction use isos for

- identifying and assembling the spool pieces;
- progress monitoring;
- weld mapping;
- setting up hydrotest packages;
- walk down of the lines and identification of deficiencies (punch lists);
- testing and commissioning.

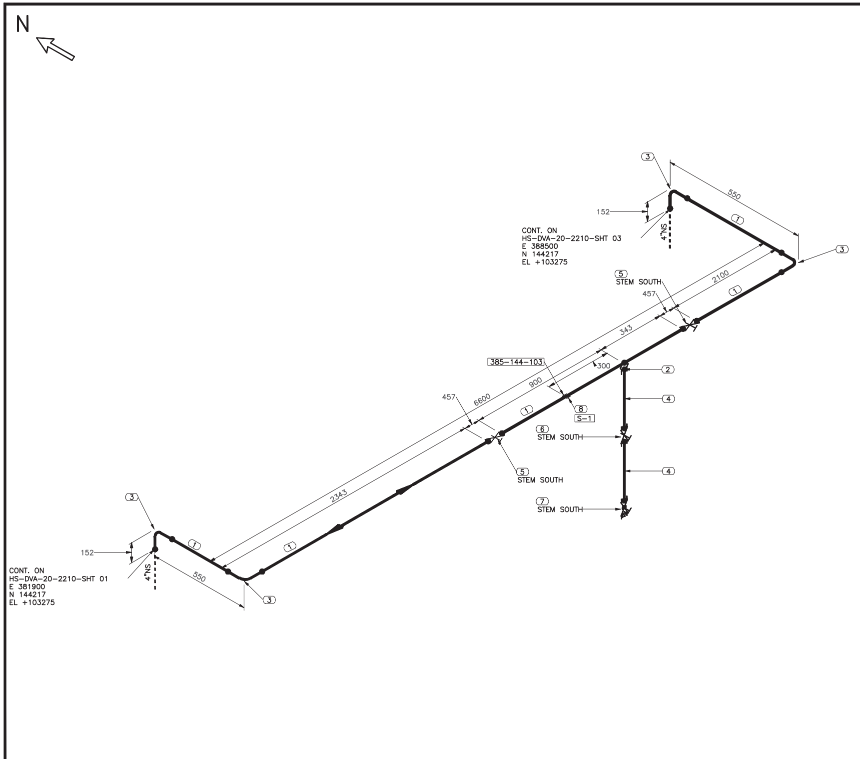
The isometrics are another important tool to be provided for fabrication and construction from the engineering company. Without isometrics, fabrication and construction will be obliged to create their own sketches to divide the work down into the components of single lines for BOM take-off, work allocation, and work execution. Fig. 4.6 is an example of an Isometric.

It is worthy of note that on 3D CAD projects engineers often stamp the isometrics. This is because the automatic isometrics are generated directly from the 3D model databases created by the designers. This is in contrast to 2D CAD projects where commonly it is the piping arrangements that are stamped and the isometrics (drafted by following the information found in the piping arrangements) are reviewed for compliance to the piping arrangements, but not necessarily stamped by an engineer.

4.2.7 Isometric logs

Isometric logs are used to list and track all of the isometrics. The two logs you require cross reference each other and are

- one that lists all of the isometrics in numerical order and the line numbers that are included within each isometric;
- one that lists all of the line numbers and the isometric that the line may be found on.



BILL OF MATERIALS				
PART	QTY	SIZE	ITEM CODE	DESCRIPTION
				SHOP
1	5874 MM	4	P000H0PCAB	PIPE SCH 120 A106–B
2	1	4X3/4	Q2S02LFCAA	SOCKOLET A105N 6000LB
3	4	4	E1ALH0FCCA	ELBOW 90 LR BW SCH 120 A234–WPB
4	2	3/4	N101K4PCAB	NIPPLE PBE 4" LG SCH 160 A106–B
5	2	4	GB–09V00	VALVE GATE BW SCH 120 CS 900LB
6	1	3/4	GS–15V00	VALVE GATE SW CS 1500LB
7	1	3/4	TS–15V00	VALVE GLOBE SW CS 1500LB
8	1	4	S–1	PIPE SHOE, S–1

NOTE:
1– ALL ELEVATIONS ARE CL ELEVATION UNLESS OTHERWISE NOTED.

REFERENCE GA				OPERATING PRESSURE	9900 kPag	XRAY	100% BW
LINE SPEC	DVA	DESIGN CODE	B31.3	OPERATING TEMPERATURE	311 °C	OTHER NDT	III
REFERENCE MODEL				DESIGN PRESSURE	11032 kPag	PWHT	YES
REFERENCE P&ID				DESIGN TEMPERATURE	319 °C	INSULATION	H 76
DATE	2008.04.03			TEST PRESSURE	WATER 19168 kPag	HEAT TRACE	ET3

REV	DATE	DESCRIPTION	PREP	CHK	APP	ENG
0		ISSUED FOR CONSTRUCTION	PJL			

PROJECT NO.: PKG TYPE:
AREA: 00 UNIT:
LINE: HS–DVA–20–2210
DRAWING: HS–DVA–20–2210–SHT 02
REV 0

Figure 4.6 Isometric.

The manual methods of creation and management of isometric logs are giving way to reports that can be generated by software. Regardless of how they are generated, they are a needed document.

4.2.8 Tie-in isometrics

Prior to your regular construction isometrics being issued, it will be required to issue the tie-in isometrics. There are no real differences between a tie-in isometric and any other isometrics. The exception is that they detail only the tie-in and temporary material requirements that will be removed once the continuation piping is connected. For example, a blind flange and a bleed connection are often added to the isolation valve for testing the soundness of the valve prior to the continuation being connected.

4.2.9 Tie-in list

Tie-in lists identify the tie-in numbers assigned to the locations where a new piping system is to be joined to an existing piping system. The tie-in numbers are shown on the P&IDs, the piping arrangements, and the isometrics. The tie-in list includes the following:

- The tie-in number
- The reference drawings, i.e., P&ID, piping arrangement, isometric
- The type of tie-in, e.g., hot tap
- Any special engineering instructions to the field

The piping group will assign the tie-in numbers and fill-in the reference columns. The piping engineer will populate the engineering data. Projects with tie-ins require a field trip to establish the type of tie-in with operations, tag the tie-in locations, and route the continuation piping from them through the existing area. Fig. 4.7 is an example of a tie-in list.

4.2.10 Demolition drawings

Demolition drawings are required as an aid to construction for revamp projects in an existing facility where existing piping is to be removed. They are copied/created from the existing P&IDs and piping arrangements prior to any revisions being done for the new piping that will be installed. They are an aid to construction and are created in order to show the existing piping that must be removed. The piping to be removed is clouded and cross-hatched, and includes the tie-in numbers where new piping will be

TIE-IN NUMBER	LINE, EQUIPMENT, INSTR. EXISTING	LINE, EQUIPMENT, INSTR. NEW	P & ID DRAWING NUMBER	PIPING ARRANGEMENT DRAWING NUMBER	ISOMETRIC DRAWING NUMBER	SUPPLEMENTAL ENGINEERING INSTRUCTION

Figure 4.7 Tie-in list.

tied in. The tie-in numbers shown correspond with those found on the P&IDs, tie-in list, piping arrangements, and isometrics.

While they are a deliverable for the project, they are not usually a deliverable at close-out. At close-out the client is only interested in receiving the revised as-built drawings. Fig. 4.8 is an example of a demolition drawing.

4.2.11 Heat tracing circuit layouts

The heat tracing, be it by medium of hot oil, steam, or glycol, is there to provide heat for freeze protection or process requirements. Electrical tracing may also be used, but it will not be a part of this discussion of piping deliverables.

For the heat tracing circuit layouts, the piping arrangements and isometrics are used as a background and the circuits are drawn using the heat trace specifications and standards. The circuits are drafted using polylines, originating from the supply manifold, along the traced line, and terminating at the return manifold. Tag numbers and flow arrows are used to identify the circuits. The manifold numbers are also indicated on the heat trace drawings.

It has been my experience that this is a task for which adequate hours are often not provided. It has also been my experience that this is a prime example where the transference of a task to the field to save engineering hours results in increased overall project hours.

Additionally, the decision to make heat tracing design part of the field construction process often leads to designing on the fly that can result in poor circuit design: tracer lengths that are exceeded, wrong number or size of tracers, dead legs, and insufficient record keeping. Once a line has been insulated it is difficult or impossible to determine the tracing that lies underneath. Design in the office will save time in the field and will result in a superior product and a permanent record for the client.

4.2.12 Heat tracing logs

Heat trace logs are the companion to the heat trace drawings and describe the individual tracer number, the originating and terminating manifolds, the piping line number that is traced, and the tracer length and size.

You will require three heat trace logs:

- One for each supply manifold, which lists the number of tracers originating from that manifold, the tap number that each individual tracer

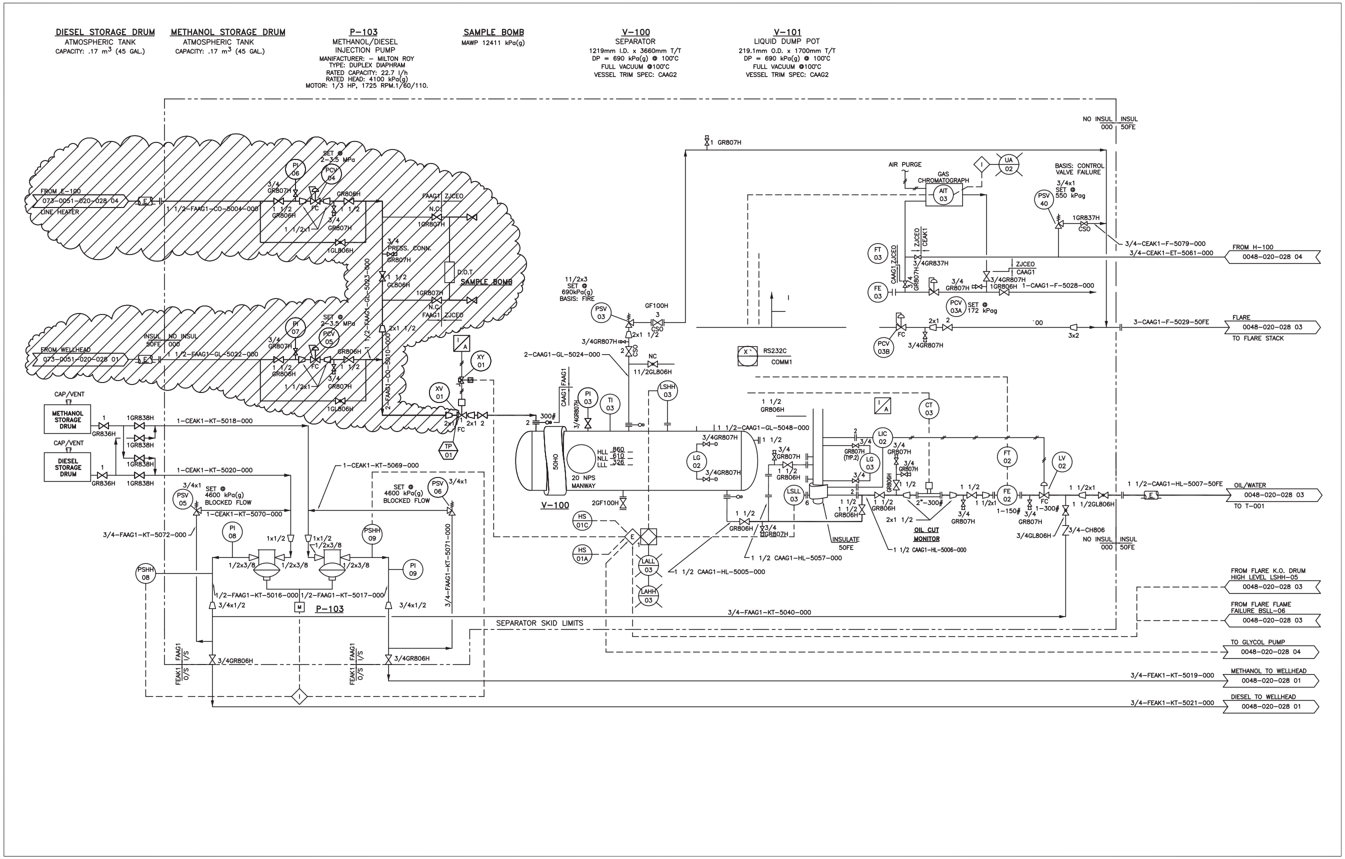


Figure 4.8 Demolition drawing.

originates from, the lines traced by each tracer, and the return manifold of each tracer.

- A companion log of each return manifold that lists the number of tracers, the tap number that each individual tracer returns to, the lines traced by each tracer, and the supply manifold of each tracer.
- A cross reference log by line number that lists all of the tracers associated with that line.

Fig. 4.9 is an example of a heat trace log.

4.2.13 3D models

Of all the deliverables that can be provided, the 3D models are often initially the least understood, the least discussed, and later become the most controversial. Too often clients assume that they have paid for the models, but if they are not in the contracts as a deliverable the engineering company may not be willing to hand them over. Even when they are listed in the contracts or the engineering company is willing to hand them over regardless, they may still be unwilling to hand over the customizations and the configurations that they have made to the software. In effect this can render the models almost unusable for future expansion work by another engineering company.

Assuming the client wants the models, which is the first thing to determine, I can only offer the following advice:

For those on the engineering company side of the fence:

Clearly define the software you will be using, the version of that software, and what will not be included in the turnover but can be available at an additional prescribed cost. You do not want to lose the possibility of future work due to a disagreement with your client that can be anticipated and avoided ahead of time by discussion and written documentation.

For those on the client side of the fence:

- Understand that the models and databases are many faceted beasts. Merely stating that you want the models turned over at the end of the project will not be sufficient.
- Document the software, version of software, your turnover requirements, and your expectations in terms of usability after turnover.
- If you lack the in-house expertise, engage an outside independent consultant to help you define the parameters of the turnover.

Tracer Number				LINES/EQUIPMENT/ INSTRUMENT TRACED (INSERT ADDITIONAL ROWS IF MULTIPLE LINES ARE TRACED BY A SINGLE TRACER)	Return Connection Number				REMARKS
AREA	SM - SUPPLY MANIFOLD	SUPPLY MANIFOLD SEQUENTIAL NUMBER	VALVE CONNECTION NUMBER		AREA	RM - RETURN MANIFOLD	RETURN MANIFOLD SEQUENTIAL NUMBER	VALVE CONNECTION NUMBER	
0X-	SM-	XX-	01		0X-	RM-	XX-		
0X-	SM-	XX-	02		0X-	RM-	XX-		
0X-	SM-	XX-	03		0X-	RM-	XX-		
0X-	SM-	XX-	04		0X-	RM-	XX-		
0X-	SM-	XX-	05		0X-	RM-	XX-		
0X-	SM-	XX-	06		0X-	RM-	XX-		
0X-	SM-	XX-	07		0X-	RM-	XX-		
0X-	SM-	XX-	08		0X-	RM-	XX-		
0X-	SM-	XX-	09		0X-	RM-	XX-		
0X-	SM-	XX-	10		0X-	RM-	XX-		
0X-	SM-	XX-	11		0X-	RM-	XX-		
0X-	SM-	XX-	12		0X-	RM-	XX-		
0X-	SM-	XX-	13		0X-	RM-	XX-		
0X-	SM-	XX-	14		0X-	RM-	XX-		
0X-	SM-	XX-	15		0X-	RM-	XX-		
0X-	SM-	XX-	16	SPARE	0X-	RM-	XX-	SPARE	
0X-	SM-	XX-	17	SPARE	0X-	RM-	XX-	SPARE	
0X-	SM-	XX-	18	SPARE	0X-	RM-	XX-	SPARE	
0X-	SM-	XX-	19	SPARE	0X-	RM-	XX-	SPARE	
0X-	SM-	XX-	20	SPARE	0X-	RM-	XX-	SPARE	

REV NO.	DATE	DESCRIPTION	BY	CHKD	APPD

PROJECT	SUPPLY MANIFOLD TRACING SCHEDULE		
PROJECT NO.	DOCUMENT NUMBER	SHEET	REV

Figure 4.9 Heat trace log.

4.2.14 Model indexes

As per the drawing indexes, you must create model indexes that list all of the models generated for the project and they must concur with the model key plan. This is an invaluable document at the time of close-out for the project and is often a requirement from the client. Ensure that you have a list that is current at all times.

4.2.15 EWP drawing packages and Scopes of Work (SOW)

An EWP is a well-defined scope of construction work that produces a specific deliverable. The deliverable is defined in enough detail that the end result is clear, as are the budget and schedule associated with the work. As a result, a properly prepared and executed Engineering Work Package, or EWP, is very manageable.

The EWP may be used as the basis for a contract between the owner and the construction contractor because of its high degree of definition and manageability. The scope of work in an EWP should not overlap that of another work package.

Common EWPs include the following:

- A description of the scope of the work to be performed, accurately defining the limits. Each EWP may require several SOWs for the completion of the package.
- The work that is not included. A description of any associated work which is not included in the contractor's scope for the EWP, i.e., activities that are required to complete the EWP that will be conducted by others.
- A list of the materials and services that will be supplied. The list will identify all materials and services that will be supplied, including when, to where, how, and in what quantities.
- A statement to the effect that the contractor is responsible for all other materials and services required to complete the work.
- A schedule for the work that identifies the expected start and completion dates, together with any intermediate milestones that must be achieved.
- Quality Assurance (QA) and Quality Control (QC) requirements.
- The EWP drawing package—Issued For Construction.
- Reference drawings stamped "FOR INFORMATION ONLY."
- A list of the company standards and specifications to be used during construction.
- A list of the vendor drawings (if required) and other attachments.

4.2.15.1 EWP drawing packages

It is very important that consideration be given to the EWP boundaries and drawing packages that are to be included in each of the EWPs in order to provide clarity and avoid confusion for the fabricators and erectors.

For this you must plan ahead from the very moment you are dividing up the plot plan. I have two simple rules that I follow:

- Only include the construction drawings in the EWP drawing package. Do not include the project drawings. Project drawings are drawings that do not have a EWP boundary and cover all plant areas, such as P&IDs and plot plans. These are to be issued separately.
- A drawing must never be included in more than one EWP drawing package. This requires a split between module and field erected piping drawings. For instance, do not create a piping drawing that includes both a pipe rack module and the field continuations. Create two drawings: one with the pipe rack piping detailed and the field continuations grayed out for reference, and a second for the field continuations with the module piping grayed out for reference.

The following is a description of the way I have packages assembled. As is the thread throughout the book, you may well choose a different approach, but, be sure you give due consideration to this beforehand.

There are three basic piping construction drawing package arrangements:

- Module piping
- Field erected piping
- Heat tracing

There are four basic categories of drawings:

- Project drawings that cover all areas
- Construction drawings
- Standard drawings
- Vendor drawings

The management of each is covered in the following paragraphs.

4.2.15.1.1 Project drawings

Project drawings are drawings that cover all areas. These are to be assembled into separate packages with a cover sheet and drawing index. The following list covers the types of drawings that fall into this category:

- PFDs
- P&IDs
- LDTs
- Plot plans
- Key plans
- Location plans

PFDs are to be assembled into one package with a cover sheet and drawing index.

P&IDs are to be assembled into packages by process area, one package for each with a cover sheet and drawing index.

LDTs are to be assembled into packages by process area, one package for each with a cover sheet.

Plot plans, key plans, and location plans are to be assembled into one package with a cover sheet and drawing index.

Project drawings are not included in the EWP drawing packages because they cross EWP boundaries. Were they to be included, the same drawings would have to be a part of multiple EWPs, and apart from the extra paper and handling involved, the real risk exists that it is impossible to keep track of all of the packages these drawings are included in, and revisions would never be issued for all of them. It is simpler and safer to have them in a separate package.

4.2.15.1.2 Construction drawings

Construction drawings are the engineering company's stamped (IFC) drawings used for fabrication and erection. These drawings are assembled into the individual EWP drawing packages. Each EWP package of drawings is to be a stand-alone set with a cover sheet and drawing index.

- Piping arrangements
- Isometrics
- Heat tracing circuitry

4.2.15.1.3 Standard drawings

Standard drawings are the typical fabrication and/or installation details of common items. Standards come from two sources: the client and the engineering company. All standards are to be found in the project set of standard drawings. Commonly, standard drawings are not to be included in the EWP packages as contractors will receive a project control copy set as part of their award documentation.

4.2.15.1.4 Vendor drawings

Vendor drawings are the detail drawings provided to the engineering company for approval by an external supplier of purchased equipment. They are used by the external supplier for the fabrication of this equipment. These take the form of such items as pumps, vessels, tanks, exchangers, specialty items, and instruments. They can also be complete skidded units such as compressors. Generally speaking, the external supplier will ship these items to the field or to a module fabrication shop to be

installed by others. The installer requires copies of the vendor drawings in order to cost and plan the execution of the installation.

Vendor drawings are issued as a listed attachment to the EWP. A cover sheet and a drawing index are not required.

4.2.15.2 Scopes of Work (SOW)

A part of the EWP is the SOW. The SOWs are the instruction to the spooling fabricators, module assemblers, and field piping and equipment erectors as to the scope that has been contracted to them, and as such must be very explicit in their description.

Depending on the construction and contract award strategies, the same EWP may have several different SOWs. These different scopes are for the different activities required for the completion of the EWP and are identified by the Work Breakdown Structure (WBS). For instance, there may be several SOWs associated with a field erected piping EWP:

- Fabrication and supply of the piping spools
- Field erection of the spools and other nonwelded components, e.g., flanged valves
- Field repair of painted pipe
- Field heat tracing
- Field insulating of the piping

It is quite possible that as the piping lead you will be required to have input into, if not to write entirely, the piping SOWs and assemble the EWP drawing packages. As it is most likely that someone else will assemble the packages on your instruction, you should review the packages before issuing. At the same time you should review that the general layout and the content of the drawings are clear and concise in their instruction, i.e., ask yourself, "Would I be able to build from these drawings?"

(See Chapter Six: Shop Fabrication and Chapter Seven: Field Construction for sample SOWs.)

4.2.16 Process Flow Diagrams (PFDs)

Process Flow Diagrams (PFDs) are schematic diagrams that identify the major process streams (lines), equipment, and controls. A companion chart, often included within the PFD, is the mass flow balance. PFDs are a flow diagram, without a scale and are of value to the piping group in that they provide an overall view of the process and are the basis for the P&IDs. Fig. 4.10 is an example of a PFD.

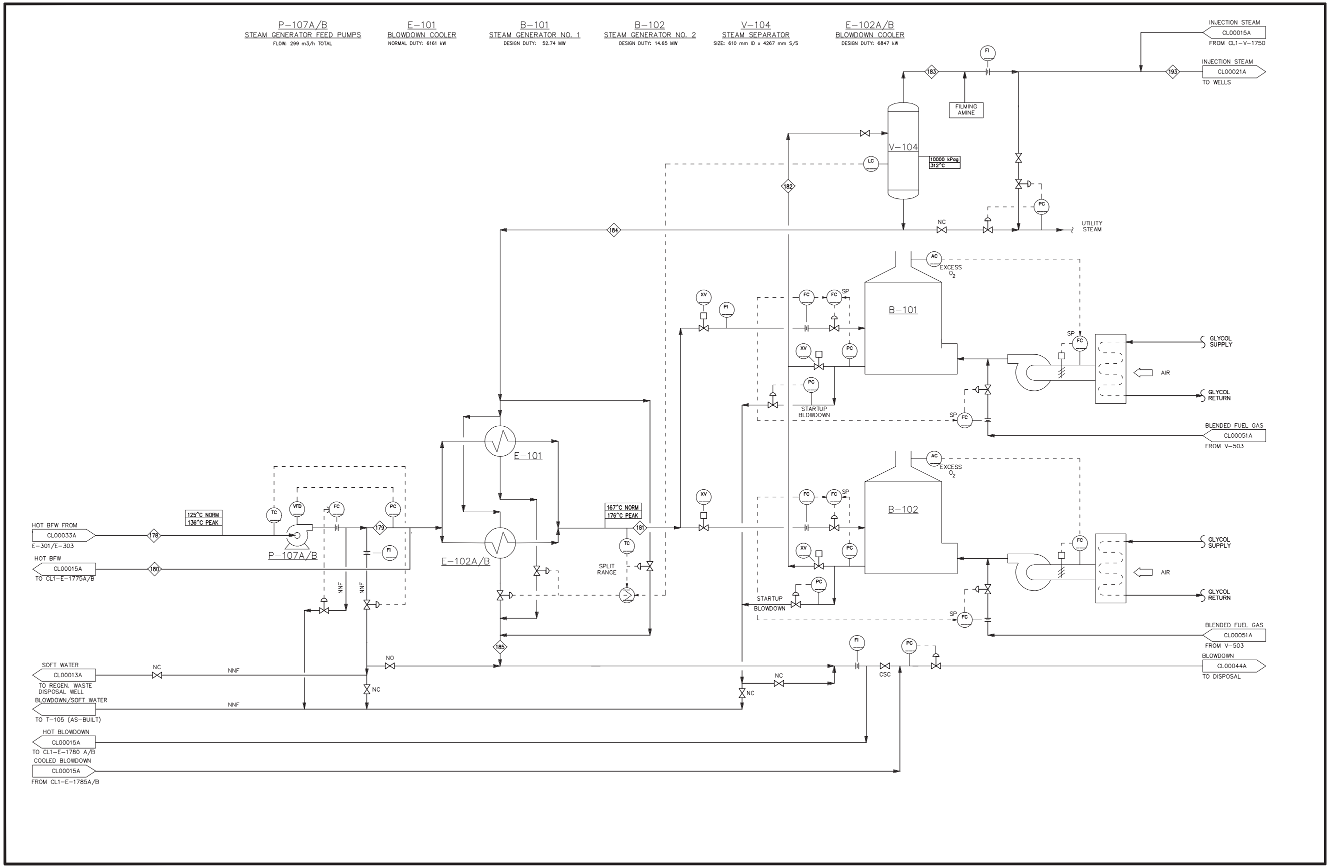


Figure 4.10 PFD.

4.2.17 Piping and Instrumentation Diagrams (P&IDs)

Piping and Instrumentation Diagrams (P&ID) are "the road map" as far as the piping group is concerned. They are the drawings that allow the piping design to move forward. Consequently, they can also be the bane of every piping designer if they are changing throughout the project. Changes that will appear to be small to the process group can be significant to the piping group.

As per the PFDs, P&IDs are also schematic diagrams that do not have a scale. They include information of great importance to the piping designers. They show all equipment, valves, instrumentation and controls logic, specialty items, line and equipment isolation requirements such as double block and bleed, spectacle blinds and car seals, and note all process requirements, e.g., piping that must not be pocketed, and process vents and drains. They also identify each line by a line number which identifies the line size, piping class, commodity, and insulation and heat tracing requirements. Other needed information, such as vessel liquid levels, vessel tangent elevations, PSV requirements, and instrument types and sizes, are also included.

In every project there will come a time, usually at the IFE or first IFC issue stage, when the P&IDs will come under the auspices of the piping group. This is because the initial process layout will not reflect the developing piping layout of headers, subheaders, and branches. It is required that the piping group mark up the actual sequence of the take-off of branches from the headers, and identify the need for subheaders when two or more separate lines of the same commodity branch into the same area according to the P&ID. Obviously, the piping group will not change the process, as this is clearly not their expertise, but they do need to bring the realities of the piping configurations to these drawings.

An aspect of P&ID drafting to be investigated is the practice of "black boxing." Black boxing refers to showing the limits of a vendor skid package as a box on the engineering company's P&ID with a reference to the vendor's P&ID. The primary consideration is one of saving drafting time, however extra time is required of the end users due to the inherited need to cross reference between P&IDs. Consequently, many clients do not allow this and require that the information within a vendor's P&ID must be replicated on the engineering company's P&ID.

Fig. 4.11 is an example of a P&ID.

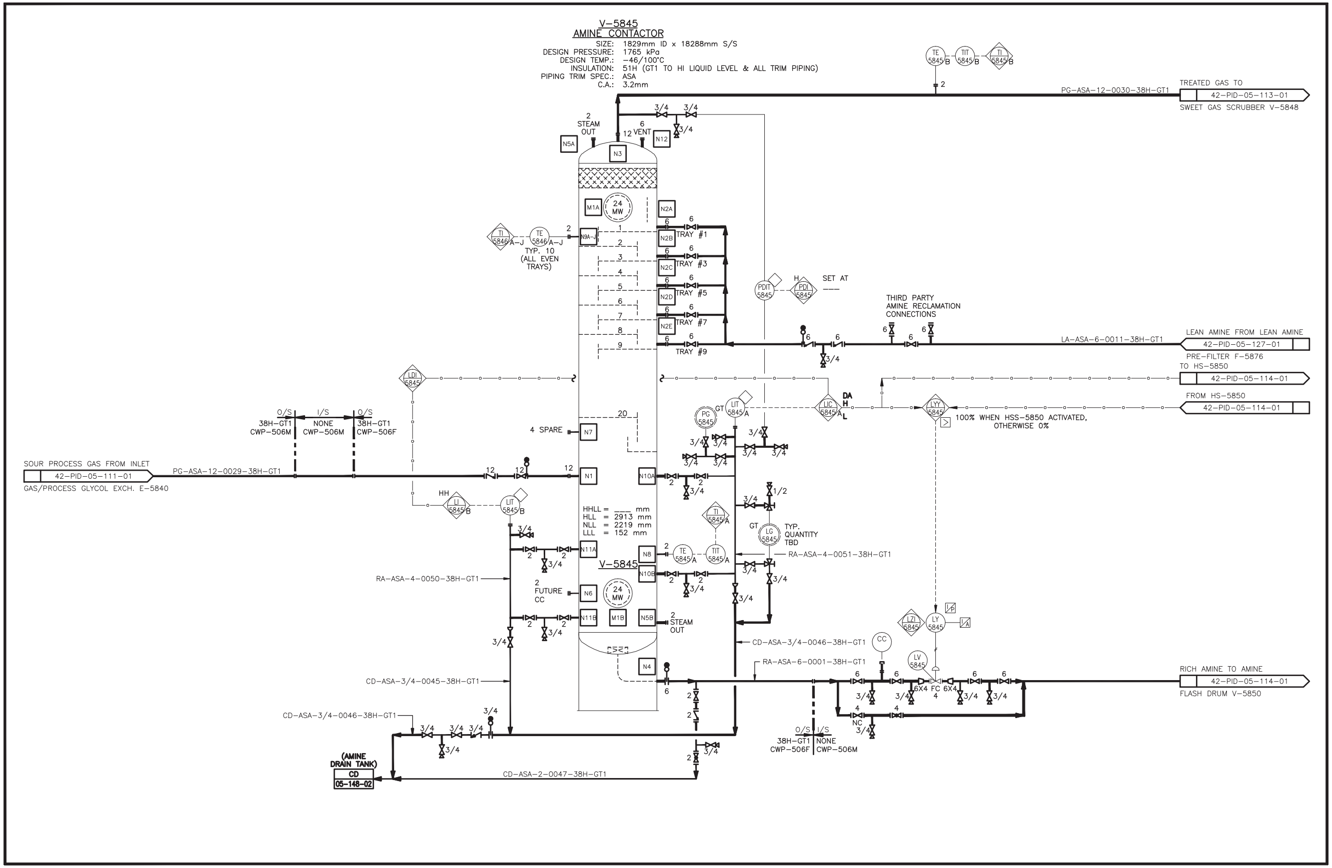


Figure 4.11 P&ID.

LINE DESIGNATION TABLE
REV. XX

LINE DESCRIPTION					INSULATION		TRACING DESIGN			LINE ROUTING		ORIGINATING P&ID NO.	SCH OR WALL THK	FLUID PHASE	OPERATING		DESIGN		TEST		EXP TEMP	UPSET P&T FOR STRESS CALCS		MDMT TEMP	CORR ALLOW	X-RAY	NDE CAT	STRESS REL.	PAINT'G SYSTEM	INTERNAL COATING, LINER	CODE	NOTES
AREA ID	COMM CODE	CLASS SERVICE MATERIA	SIZE NPS	LINE NO.	THK (mm)	TYPE	TYPE	HOLD TEMP °C	NUMBER TRACERS	FROM	TO		mm	V/L/M	PRESS kPag	TEMP °C	PRESS kPag	TEMP °C	PRESS kPag	MEDIUM	°C	PRESS kPag	TEMP °C	°C	mm	°C							

Figure 4.12 LDT.

4.2.18 Line Designation Tables (LDTs)

The LDTs are created by the process and mechanical engineering groups and are later maintained by the piping group at the same time as the P&IDs are turned over. The two documents go hand-in-glove and the marking up of the P&IDs will often require the marking-up of the LDT.

LDTs list the following:

- Process commodity
- Piping specification
- Line number
- Line size
- Insulation requirements
- Heat tracing requirements
- Pipe wall schedule
- Origin and termination of the line
- P&ID reference (originating P&ID only)
- Operating conditions
- Design conditions
- Stress analysis requirements, if different from design conditions, e.g., steam out
- Testing requirements, e.g., hydrotest and X-ray
- Code

Fig. 4.12 is an example of an LDT.

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CHAPTER FIVE

Detailed Design

5.1 INTRODUCTION

As the piping lead you will have many issues to deal with throughout the detailed design stage of your project. This is the most intense phase of your project, where the bulk of your manhours will be expended.

So far we have discussed all of the preplanning required for you to set yourself up for success. All of your preparation and planning will now pay off as the interruptions that would otherwise have taken you away from the piping execution will be minimal. Having already addressed the aforementioned preparations will enable you to be more focused on the detailed design.

Recapping the previous chapters, the following have been established:

- Standards to be used
- Specifications to be used
- Procedures to be used
- Software to be used
- Manhour estimates and manpower planning
- The deliverables

But, there is still a lot to do in the way of planning and maintenance. The detailed design involves putting into play all of the decisions made and following through with other decisions. In this chapter, and the following two chapters, we will discuss the execution of the detailed design and highlight other activities and decisions that you will be required to make or have input into.

Because they are so important to the success of the project, and because not everything will have been firmed up entirely during the planning and estimating stage, we will begin by recapping in more detail some of the previously discussed topics that may have to be finalized during the study phase of detailed design.

The Planning Guide to Piping Design.
DOI: http://dx.doi.org/10.1016/B978-0-12-812661-5.00005-2

5.2 CONTRACTING AND PROCUREMENT PLAN AND CONSTRUCTION EXECUTION PLAN

As has been previously discussed in Chapter One, Before You Begin, the Contracting and Procurement Plan and the Construction Execution Plan contain the procurement and construction philosophies and are the basis from which other decisions and planning by you, the piping lead, will stem. These are as follows:

- Modularized and Field-erected piping splits
- Engineering Work Package (EWP) boundaries
- Model boundaries
- Shop and Field material splits
- Procurement splits
- EWP drawing packages
- Scopes of Work (SOW)

It is unlikely that the contracting, procurement, and construction plans will list all the details. For instance, it may be stated in the Contracting and Procurement Plan that the engineering company will purchase all NPS 2 and above pipe, fittings, and valves. It may be stated in the construction execution plan that modularization will be utilized on the project. But you will have to help to decide the details of the procurement split and what can be modularized.

5.3 MODULARIZED AND FIELD-ERECTED PIPING SPLITS AND EWP BOUNDARIES

The plot plan is divided into the general process areas and each process area is broken into EWP boundaries. Equipment that falls within a general process area boundary that is tagged according to a different process will be a part of the general process area that it is located in. That is, do not create a separate EWP for a piece of equipment just because of its process designation. Commonly, a piece of equipment tagged for a different process than the area it sits in will be erected at the same time as all the other piping and equipment in that area.

The identification of the EWP boundaries should be done with the view in mind of providing clearly defined SOWs for fabrication and erection, and also for flexibility in the awarding and management of the contracts.

- An obvious boundary is the boundary between modularized and field-erected piping due to different construction philosophies. Once you have decided on these splits you can then decide on further divisions.
- Dividing a large area into several EWPs instead of having one large EWP will allow greater flexibility in the awarding and managing of contracts. With smaller packages it is possible to issue on an ongoing basis or issue to more than one fabricator.
- For instance, it may be desirable to break a long run of pipe rack modules into two EWPs rather than one EWP. You can choose to issue the two EWPs to one fabricator at intervals or to two different fabricators at the same time. If you have issued both of the EWPs to one fabricator who is not performing, it is an easier matter to pull one EWP back and re-issue it to another fabricator than it would be to start dividing the work of one larger EWP.
- It is easier to monitor the progress and manage the schedules and materials of smaller work packages than larger work packages.

The above is best illustrated by an example. Refer to Fig. 5.1. This example uses modularized pipe racks, an equipment module, and a field-erected piping area.

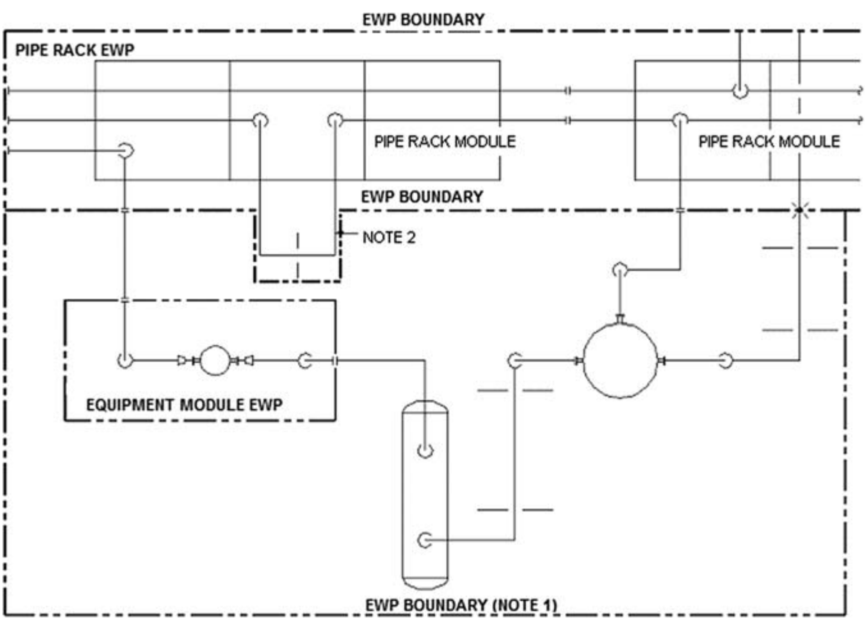

Figure 5.1 EWP boundaries.

5.3.1 Figure 5.1 notes

1. EWP boundaries are established according to fabrication and erection methodology and the construction schedule. For instance, pipe rack and equipment modules are assembled as complete units in a shop with pipe rack modules being the first to be required at site; field-erected piping involves spooling in a shop and later field erection.
2. EWP boundaries are not always "straight lines" that cannot be transgressed. In this example, the expansion loop is included in the pipe rack module EWP because it is needed in the field during the erection of the pipe racks.

5.4 MODEL BOUNDARIES

The establishing of the EWP boundaries precedes the establishing of the 3D model boundaries. This is followed by the establishing of the piping arrangements and isometric boundaries. The model and drawing boundaries will therefore align with the EWP boundaries.

A simple rule to follow when deciding on model boundaries is to break models along the same lines as the components will be built. In other words, model it as you will build it. A prime example of this is separate models for separate modules. You must discuss this with your counterpart in the structural group as they must follow the same model boundaries as yourself.

Clearly defined boundaries equate to clearly defined information flow and good communication. The downstream team members are less likely to make misinterpretations. For instance, the Material Take-Off (MTO) reports will accurately reflect the EWP, which in turn vastly increases the chances that the material quantities are accurately purchased and shipped to the correct locations. Blurred boundaries inevitably lead to confusion and added costs.

The breaking down of a EWP into several models also allows segregation of work between designers. Designers can be assigned to each model area and the designing may be executed simultaneously, with the work having been divided sufficiently to meet the required issued for construction (IFC) dates in the timeframe allotted.

General Instruction:

- The boundary of a piping model will be determined by
  - One EWP boundary. Smaller EWPs will not be combined to form one larger model;
  - Module boundary. Each module must be in a separate model;
  - The schedule and manpower plan. Separate models are required for areas that will be issued in stages, and for EWP areas where the schedule dictates that two or more designers must be working simultaneously;
  - Size of the model. Models that are too large may have a tendency to crash.
- Each piping model will require an equipment model separate from the piping model. Vendor supplied piping on skids must be modeled in the equipment model so that this piping does not show up in the MTO report.

I strongly believe in a hierarchy of design development. Designing must be done in stages that build upon each other:

- P&ID transpositions
- Piping layout studies
- Detailed piping design

This is in keeping with the manual drafting days when it was common practice to start designing by the creation of a transposition on a print of the plot plan. Nowadays this can be accomplished in CAD.

The transposition is the routing of the critical lines from point to point on the plot plan (or equipment location plans when the plot plan is too small a scale), done in single line format without scale and without detail. The line numbers are indicated, and control valves and flow instruments are identified by an instrument bubble. The purpose of this is to

- establish the basic piping arrangement, i.e., the piping within the racks, subracks, and directly between equipment;
- establish a preliminary pipe rack line sequence, rack spacing, and number of levels;
- firm up the equipment locations on the plot plan; long runs of the expensive piping, i.e., high temperature, high pressure, and alloys may be shortened by moving equipment.

I witnessed a 3D project where a transposition was not conducted. At a congested interface section of the main rack between two subracks, the number of lines started to crowd out of the main rack onto outriggers. Eventually it was realized that the outriggers were not going to work and

a new section of rack was added beside the main pipe rack, and the whole section had to be re-designed. This was not good midway through the project, especially when this could have been identified as a problematic area at a much earlier stage.

The transposition is followed by the piping layout studies. The purpose of the studies is to establish

- preliminary pipe routings
- elevations: equipment, piping, overhead clearances
- major support and column locations
- platforms, ladders, and ingress and egress requirements
- building sizes
- nozzle orientations
- equipment spacing between pumps, exchangers, vessels, etc.
- control valve locations and meter run requirements
- bulk MTO
- the start of preliminary stress analysis, particularly in the racks to identify nested loops
- module limits

In this context, studies have a limited purpose. Because they have a limited purpose, the level of detail can be less than will be required for the final detailed designs. The following are guidelines for studying in models:

- Model the NPS 4 and above piping only.
- Do not model pressure connections, temperature connections, or vents and drains.
- Do not model field welds.
- Specialty items, instruments, and vendor supplied packages that you have little information for can be modeled as simple blocks to identify the space requirement.
- Use a color code to clearly identify preliminary vendor information.

Referring to the manual drafting days again, the designers would begin their layouts on vellum paper, and it would take several attempts to produce a preliminary layout that he/she would be happy with after which the manual drafters started over with a clean sheet of Mylar for the finished drawings. The modern day equivalent is the study model followed by the detailed design model. While not necessarily the populist view, I favor this to working in one model throughout study and into design.

At the study stage all P&IDs, vendor equipment, and instrumentation are preliminary, and a considerable amount of manipulation of the model will be required if you maintain that the same models will be worked in continually from study through detailed design. Experience has shown

that this can cause database corruption and rework, and will take longer than starting fresh with a new model. Therefore new modeling should begin once the purposes of the study have been completed, and firmer P&IDs and vendor data are available. The study models may be referenced into the detailed design models as a guide for detailed design.

A variation to the study model is the utilization of automatic pipe routing software such as ASD Pipe Router.

Whether you choose to have separate study models followed by detailed design models or not, this study stage is required to take the layouts to the next level of design.

In my experience, the piping designers begin their studies by manually sketching out their thoughts for the piping routings/configurations. Following this, he/she will then start building the piping in the 3D model and will also place temporary steel, often referred to by its color, e.g., "white steel" or "pink steel" depending on the company standard. This temporary steel is a piping designer's first pass at where main piping and equipment supporting beams, columns, and platforms are required, and are built for visual representation only, formed using three dimension boxes of guesstimated width and depth steel sizes for the structural designer to follow. The piping designer will also begin submitting preliminary stress isometrics generated from the 3D model to the stress group, which are imported into the stress analysis software by the stress engineer.

The structural designers reference these piping studies into their blank model spaces and start building the structural models with accurate steel as directed by the structural engineers who are designing the structures; the types and sizes of beams, columns, bracing requirements, etc. The structural engineers do not usually have access to the 3D CAD software itself, and will review the structural designs in 3D viewing software, such as Navisworks. Pipe racks may be handled a little differently in that they are usually located at the plot plan stage with standard 6 m support spacing. Once the piping group has determined the TOS elevations and widths, the structural engineers will often size steel according to a full rack loading of a selected water filled pipe size. For instance NPS 10 or NPS 12 pipes. The stress group send stress loading reports with x, y, z coordinates to the structural group. At the same time anchor and guide locations and any additional piping support requirements are communicated back to the piping designer. If required, the piping designers revise the temporary steel layouts to be followed by their structural design colleagues.

For a while as the piping designs are progressing, the piping designer will reference in the structural designs and compare these to their

temporary steel. At some point, as the structures are sufficiently progressed and firmed up, the piping designers will remove the temporary steel from their models and work to the structural references only. And so it goes until the designs are complete, with peripheral exercises, such as model reviews and clash detection, being a part of the design process.

Contrary to the sometimes popular belief though, everything cannot be done in the models alone, and, starting with the hand sketches, further hand sketches and white board discussions also form part of the ongoing communication between the two groups.

While there are many 3D CAD software packages available, the process of initial piping layout and communication with structural remains essentially the same regardless of which one you are using.

The following two examples apply to the creation of study and detailed models on a project. These examples are per the EWP example and use modularized pipe racks, an equipment module, and a field-erected piping area.

5.4.1 Study model boundaries

Refer to Fig. 5.2.

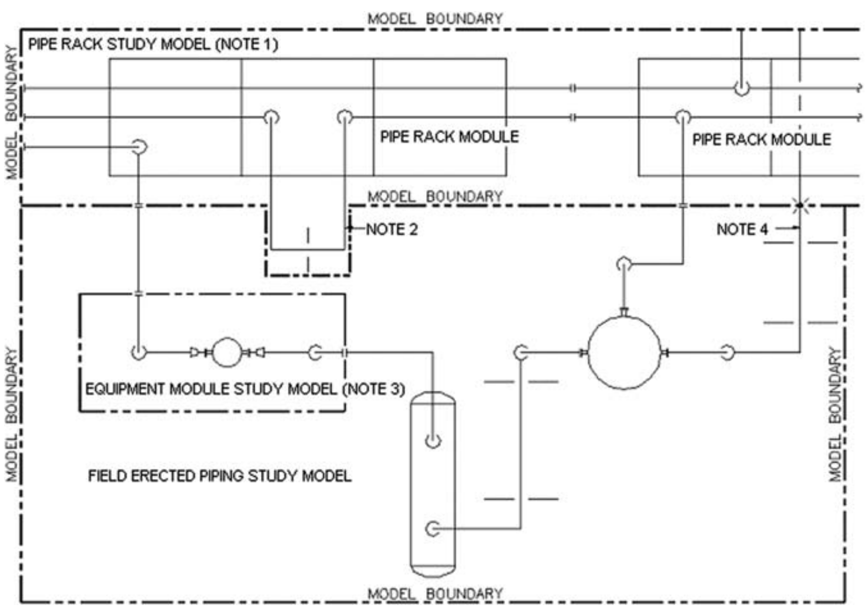

Figure 5.2 Study model boundaries.

5.4.1.1 *Figure 5.2 notes*

1. During the study stage all piping may be placed within one pipe rack model. During the study stage pipe rack module boundaries are established. Pipe rack modules will be remodeled as individual models during the detailed design stage.
2. Model boundaries are not always "straight lines" that cannot be transgressed. Logically, in this example, the expansion loop is in the pipe rack model.
3. During the study stage all piping may be placed within the field-erected piping model. During the study stage, equipment module boundaries are established. Equipment modules will be remodeled as individual models during the detailed design stage.
4. For study purposes, piping leaving an area may be stopped at the model boundary. Note that this may not be the case for detailed design models.

5.4.2 Detailed model boundaries

Refer to Fig. 5.3 and Fig. 5.4.

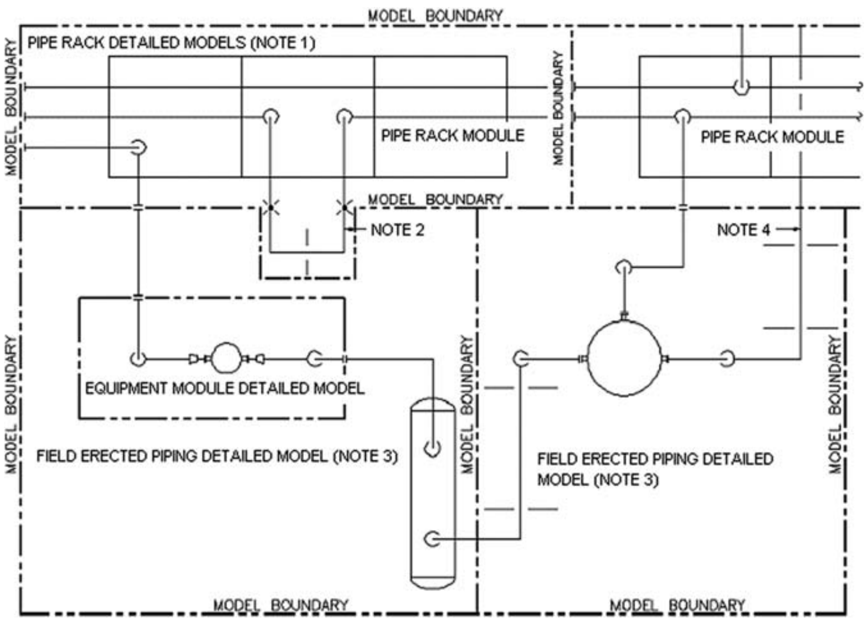

Figure 5.3 Detailed model boundaries.

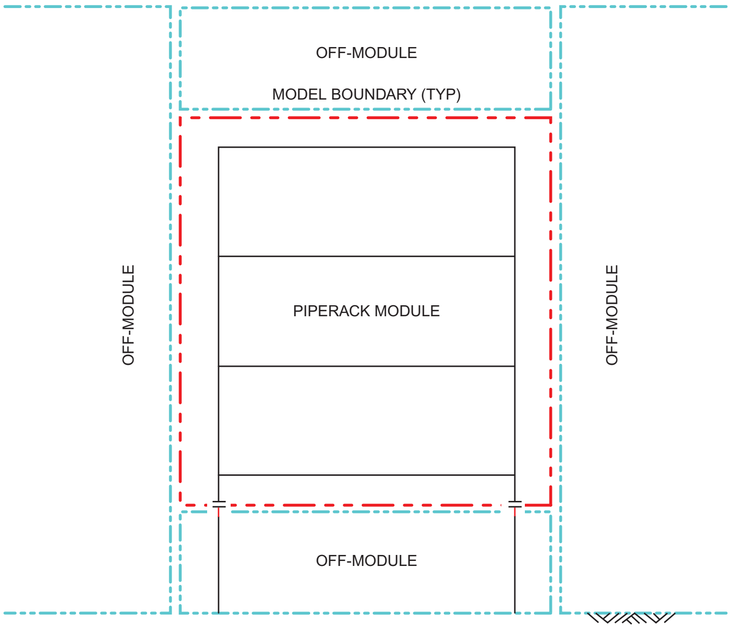

Figure 5.4 Model boundary section.

5.4.2.1 Figure 5.3 notes

1. Separate models are required for each pipe rack module and the field piping below the modules.
2. Consider construction when dealing with piping and associated supporting. In this case, construction would require the loop spool in order to complete the pipe racks, and therefore it is to be included in the pipe rack module model, not in the field-erected piping model.
3. In this example the field-erected piping EWP has been divided into two detailed design models.
4. Consider construction when dealing with piping that crosses the model and piping arrangement boundary. In this case, consider

continuing the piping to a natural break such as a valve or the limit of the spool shipping box size. Breaking the pipe each time a model boundary is crossed introduces unnecessary field welding and added field costs. These small piping continuations are to be part of the model they originate in and included in the EWP.

5.5 SHOP AND FIELD MATERIAL SPLITS

The 3D software will have settings for the "shop" and "field" material splits (also known as "fabrication" and "erection"). Shop material is the material required by the spooling and module fabricators, and field material is the material required in the field for the erection and completion of the piping systems. You will have to inform your team of these material splits so that the designers make the correct selection when modeling.

These shop and field material splits will vary by industry, construction methodology, and the piping classes used. For example, in the oil industry piping classes often specify NPS 1½ and below piping as socket welded or threaded and NPS 2 and above piping as butt weld and flanged. The NPS 1½ and below piping is designated as field material because these are field run lines, while the NPS 2 and above piping is designated as a mix of shop and field. The butt-welded fittings, weld neck flanges, and welded attachments are designated shop materials and the nonwelded components, such as gaskets and bolts, are designated field materials required for the field erection.

The below example of shop and field material splits is based on oil projects that I have worked on. You will need to determine the material splits for the type of projects you are involved in.

- NPS 11/2 AND BELOW PIPING MATERIALS—FIELD-RUN, FIELD-ERECTED:
  - All materials, including pipe supports, are to be designated "*field*," with the exception of TOL and SOL branches on NPS 2 and above piping which are to be designed "*shop*."
- NPS 2 AND ABOVE PIPING MATERIALS—SHOP SPOOLED, FIELD-ERECTED:
  - Bolts and Gaskets, Flanged Valves, Blind Flanges, Spectacle Blinds and Spades, Flanged Instruments, and Nonbutt Welded Specialty Items are to be designated "*field*."

Table 5.1 Pipe support shop/field designation chart

Support Type	Shop	Field
Anchors (shipped loose, field installed)	X	—
Shoes (Welded shoes installed in shop. Clamp-on shoes shipped loose, field installed)	X	—
Base Supports, Dummy Legs, Trunnions	X	—
U Bolts	—	X
Guides (shipped loose, field installed)	X	—
Hangers & Springs	—	X
Repads	X	—
Field Supports	—	X

  - Fittings, Welded Flanges, Butt-Welded End Valves, Butt-Welded End Specialty Items, and Butt-Welded End Instruments are to be designated "*shop*."
  - Pipe supports are to be designated per Table 5.1.
- EQUIPMENT AND PIPE RACK MODULE PIPING MATERIALS—SHOP FABRICATED AND FIELD-ERECTED:
  - All materials, including pipe supports, are to be designated "*shop*," with the exception of nuts, bolts, and gaskets at module connections which are to be designated "*field*."

Correct designations are extremely important. Without accurate listings the MTO reports and the isometric BOMs will not have the correct information and purchasers will direct the materials to the wrong locations.

5.6 PROCUREMENT SPLITS

Establishing the above "shop" and "field" material splits will inform those dealing with the contracts and procurements as to where the piping materials must be directed; however, this does not clarify who is purchasing which of the materials. As a minimum, the engineering company will purchase all long delivery items such as high pressure and alloy pipe, fittings and valves, specialty items, and instruments, while the fabricators

and erectors will purchase everything else, but because there are many components in a piping system, statements, such as this still do not give sufficient direction. To ensure that everyone has a clear understanding of the materials required and who is responsible for purchasing them, a summary document is required.

Given that there are many ways for the material purchasing to be split and that this may change from project to project, in order to avoid any confusion it is very important that this summary document list all of the possible piping components and who is purchasing which components. Needless to say, confusion over the purchasing of materials, overlooking the purchasing of materials, and misdirected materials all add up to schedule delays and added costs.

A good summary document is a piping material purchase matrix. By far, the best person to list the piping components and create this matrix will be you, the piping lead. You need to follow the contracting and procurement plans and ask questions in order to compile the piping material purchase matrix, however, it is time well spent. This is a much needed document that will consolidate the information in one place and help to avoid potential material issues.

Refer to Table 5.2. This particular matrix is based on the engineering company purchasing all NPS 2 and above pipe, fittings, flanges, valves, and all specialty items and instruments, and the fabricators and erectors purchasing all NPS 1½ and below pipe, fittings, flanges, valves, and all pipe support materials.

In the sections that follow, topics that have not been mentioned or discussed at any length to this point are covered. They are in no particular order of importance, but are topics that a piping lead must address early on and throughout the detail design phase duration of the project.

5.7 ISSUED FOR BID AND BID EVALUATIONS

During the course of detailed design you will be involved, at least to some extent, in issuing information for bid and the bid evaluations.

5.7.1 Issued for bid

Issuing documents for bid will take the form of reports and drawings. It is not always required to provide drawings, for instance, bids for bulk

Table 5.2 Piping material purchasing matrix

	Field Erected Piping				Modules			
	SHOP SPOOLING FABRICATION (NPS 2 and above spooling and pre-fab of some field materials)		FIELD ERECTION (NPS 2 and above spools, NPS 11/2 and below and other field materials)		PIPING FABRICATION AND MODULE ASSEMBLY (NPS all sizes)		FIELD ERECTION (NPS all sizes field material to connect module to module and module to off module)	
	Engineering Company Supply to Fabricator	Fabricator Supply	Engineering Company Supply to Field Erector	Field Erector Supply	Engineering Company Supply to Fabricator	Module Shop Supply	Engineering Company Supply to Field Erector	Field Erector Supply
PIPE MATERIALS, NPS 2 and above								
Pipe	X				X			
BW Fittings (tees, elbows, caps)	X				X			
WOL's	X				X			
Flanges (WN, SO, RJ, LJ)	X				X			
Orifice Flanges	X				X			
Blind Flanges			X		X			
Studs, Nuts, and Gaskets			X		X		X	
BW Valves	X				X			
Flanged Valves			X		X			
BW Specialty Items	X				X			
Flanged Specialty Items			X		X			
BW Instruments	X				X			
Flanged Instruments			X		X			
Lined Pipe and Fittings			X		X			
PIPE MATERIALS, NPS 11/2 and below								
Pipe				X		X		
Nipples				X		X		

SW/Thr'd Fittings (tees, elbows, unions, couplings, caps, plugs)				X		X		
SOL's/TOL's		X				X		
Flanges (SW/Thr'd/Blind)				X		X		
Studs, Nuts, and Gaskets				X		X		X
SW/Thr'd Valves				X		X		
SW Specialty Items			X		X			
Flanged/Thr'd Specialty Items			X		X			
SW Instruments			X		X			
Thr'd Instruments			X		X			
Lined Pipe and Fittings			X		X			
Supports								
Welded Shoes		X				X		
Clamp-on Shoes		X				X		
Dummy Legs		X				X		
Trunnions		X				X		
Base Ell Supports		X				X		
Directional and Fixed Anchors		X				X		
Guides		X				X		
Hangers			X		X			
Spring Supports			X		X			
Field Supports (misc. structural, 'U' bolts, etc.)				X		X		
Miscellaneous Pipe Materials								
Re-pads		X				X		
Insulation				X		X		
Heat Tracing Manifolds		X				X		
Heat Tracing				X		X		

material purchases will be done using a bulk MTO report or a bulk valve report, or contractors may base their bid on the reports of MTO, weld count, diameter inches of welding, and weights of materials. These reports are commonly compiled and generated by your material control and CAD support groups.

Should it be required to generate drawings to accompany a bid package then you must stamp them "FOR BID PURPOSES ONLY. NOT TO BE USED FOR CONSTRUCTION." You may be surprised at how often a contractor will use the bid drawings after the contract is awarded to start the purchasing of materials and fabrication, rather than wait for the up-to-date EWP in an attempt to get a head start on the work. While you cannot necessarily stop this practice, at the least no one could accuse you of being complicit in the event of the contractor ordering wrong materials and/or having to scrap work that was started too soon.

Contracting strategies vary, but as an example, a spooling fabricator may receive a bid package for a EWP that includes

- isometrics
- MTO report
- weld count report, e.g., 50 times NPS 12 welds
- unfactored diameter inches of welding report, e.g., an NPS 12 butt weld is 12 diameter inches of welding
- weights of materials

With this information, plus other documentation such as specifications and standards, the spooling fabricator may price the job as follows:

- Unit prices for factored diameter inch welds. This price includes labor (cutting, beveling, and welding) and handling charges (moving spools around, unloading materials, and loading spools). Factored inches are based on standard wall thickness, e.g., an NPS 12 standard wall thickness is 0.375″ therefore an NPS 12 standard wall butt weld has a factor of 1 times the unit price (0.375/0.375) whereas an NPS 12 extra strong butt weld has a factor of 1.33 times the unit price (0.500/0.375).
- Unit prices for items such as shoes, dummy legs, and base supports.
- The costs of the materials that are not supplied.
- Hydro testing as an extra cost.
- X-ray and other NDE as an extra cost.
- Stress Relieving as an extra cost.

The above is only a broad overview and other factors may affect the bid price such as exotic alloys and spools that have two or more planes

requiring extra set-up and handling time. Also, unfactored diameter inches of welding reports and applying unit factors based on wall thickness are only one method of pricing. Fabricators may use a price guide that lists the cost of welding standard wall carbon steel (CS) by the NPS size with different factoring for heavier walls and other materials.

It is necessary that you understand the contracting and procurement strategies for your project in order to have input into the report generation set-up with your CAD support group and to inform your designers of the requirements to be followed by them.

5.7.2 Clarifications from bidders and bid evaluations

You may be required to assist in the bid process by answering clarifications from the bidders and participating in bid evaluations from the point of view that everything has been covered. It is neither in the interest of the project nor the client to accept the lowest bidder, particularly when the bid is substantially lower than the others. This may be an indication that the contractor has overlooked a major aspect of the work. It is not good to have to deal with a contractor who is losing money, or worse, on the brink of bankruptcy, in the middle of a project. High bids should also be looked at to understand if the bidder included work that the others did not. This could be a misunderstanding of the scope, but there is also a possibility that this bidder took into account scope missed by everyone else.

5.8 EQUIPMENT COORDINATES AND ELEVATIONS

The 3D modeling software will be set up with reference points for equipment center lines and elevations, but in order for everyone to have a complete understanding of these, written documentation is required. The equipment center lines to be used for coordinates, and the reference points to be used for elevations, are required to ensure that everyone who is reading and marking up the equipment location plans has a clear understanding of the meaning of these coordinates and elevations, and that communication between the piping team and the other disciplines is clear. You should create a matrix for the types of equipment that will be encountered on your project similar to Table 5.3.

Table 5.3 Equipment coordinates and elevations matrix

Equipment Type	Northing & Easting	Elevation
Vertical Vessel or Drum	Centre Lines	Bottom Tangent Line
Horizontal Vessel or Drum	Horizontal Centre Line and Centre Line of Fixed End Saddle	Horizontal Centre Line
Vertical Tank	Centre Lines	U/S of Base Plate
Horizontal Centrifugal Pumps	Horizontal Centre Line of Motor Shaft and Centre Line of Discharge Nozzle	Centre Line of Suction Nozzle or Motor Shaft
Inline & Vertical Pumps	Centre Lines of Motor	Centre line of Suction Nozzle
Shell and Tube Exchangers	Horizontal Centre Line and Centre Line of Fixed End Saddle	Horizontal Centre Line
Aerial Coolers	Horizontal Centre Line and Centre Line of Inlet Nozzles	F.O.F. of Inlet Nozzle
Misc. Horizontal Equipment (Steam Generators, Air Make-Up Units)	Horizontal Centre Line and Centre Line of Major Feature (e.g. Stack)	U/S of Base Plate
Buildings	Centre Lines of Building Column at North West Corner	H.P. of Finished Floor
Modules	Centre Line of Steel at North West Corner	T.O.S.

You should also agree the plant elevations to be used with your counterparts in the civil/structural group. This establishes further criteria that everyone will follow and eliminates a lot of discussion and coordination. The following are suggested based on a plant finished grade elevation of EL. 100.000:

- Equipment modules inside a building will be at TOS EL. AS SPECIFIED BY THE STRUCTURAL GROUP.
- Equipment modules outside of a building will be set at TOS EL. 100.600.

- Vertical vessels will be set at U/S B.P. EL. 100.300.
- Pumps will be set at U/S B.P. EL. 100.450.
- Other equipment will be set at U/S EL. AS SPECIFIED BY THE PROCESS/PIPING GROUP.

5.9 MODULE DESIGN

Modularized design is the prefabricated assembly of structural steel skids and the associated piping, instrumentation, insulation, tracing and equipment at a fabrication shop for transportation to the field. As is the case with prefabricated pipe spools, there are many advantages to modularized design:

- Reduced field personnel and associated mobilization and camp costs.
- Shop labor costs are cheaper than field labor costs.
- The site work can proceed concurrently with the piping design.
- Large projects can use multiple fabrication shops.
- A shortened construction schedule.
- Better quality control due to a controlled environment and contented workers who live at home.
- More ground level access that reduces the need for scaffolding.

The disadvantages are as follows:

- Modules are limited in size by the transportation route: road access and weight limitations, telephone and power line clearance, tunnels and bridges.
- Extra structural steel required for rigging and bracing.
- Greater requirement for logistical planning and scheduling.

5.9.1 Design considerations

You may have to make decisions on what will be modularized. Modularization lends itself well to equipment of a size that can fit on the modules within the shipping size, such as pumps and exchangers. Modularization also lends itself well to pipe racks. The concept is to maximize shop installation of traditionally field-installed piping and peripherals, such as insulation and heat tracing, heat trace manifolds, sample coolers, and utility stations.

General design considerations for modules are as follows:

- Transportation planning must happen early in the design stage since weight and size restrictions will determine the module parameters.

Module sizes will vary according to transportation corridors and local and federal laws, but as an example may be in the range of 7.5 m wide × 4.5 m high × 30 m long.

- Involve construction and operating personnel early in the planning and design stages.
- You may have to consider using a 1:40 scale if you are drawing the modules on ISO A1 or ANSI D size paper in order to show the complete module on one sheet.

Design considerations for equipment modules are as follows:

- Revise existing layout and clearance specifications for lower space usage.
- Equipment and large valves subject to removal should be along the outer sides of the module for unobstructed access.
- Provide an interior access aisle 1 m wide and 2.2 m high.
- Valves and instruments should be accessible from the interior aisle or from the outside of the module, but should not project into either.
- Reserve space above the interior aisle for cable trays.
- Provide maintenance access around the module.
- Provide supply and return heat trace manifolds on the module in order that the tracing circuitry may be self-contained, completed, and tested in the shop.
- Commonly, connections to the field-erected piping are flanged, but may be butt welded.

Design considerations for pipe rack modules are as follows:

- Flanged or butt-welded connections may be used. When flanged connections are used it will be required to stagger the flanges at the module ends. For instance, assuming 6 m bays, the centerline of support to FOF dimension for the pipe overhang will be alternately 2.7 and 3.3 m.
- A horizontal dimension from centerline of support steel to the FOF or butt weld must be determined for the piping that leaves from the side of the module. A dimension of 500 mm generally provides adequate clearance for bolt-ups or welding, and for installation of shoes.
- Expansion loops that extend beyond the module shipping width must be shipped loose and field installed.
- Lines exiting below the lowest piping level may have to be field installed if they drop below the bottom of the steel of the lowest module beam. The lowest module beam may be designed to accept the entire module load and to rest on the truck bed. Check with the

structural engineer and the person arranging the shipping. It is possible to raise a module up on the truck bed by the use of shipping beams under the column base plates; however this may also reduce the allowable height of the module.

- Consider vents when determining the overall module height.
- A rule when deciding the elevation difference between pipe rack levels is three times the largest Nominal Pipe Size (NPS) of pipe that runs in the rack. Stringer levels, the steel beams between columns that support the pipes leaving the pipe rack, are set mid-way between the main beam levels or 1½ times the largest NPS pipe. This allows that the largest pipe can be rolled out of the rack with a fitting-to-fitting LR 90 degree elbow and a 45 degree elbow and that a pipe size of half the largest NPS pipe can use two fitting-to-fitting LR 90 degree elbows to leave the rack.
- For example, let us assume that the largest pipe size is NPS 24. An NPS 24 pipe is 610 mm in diameter. Multiplying 610 mm times 3 equals 1830 mm between main beam levels and 1 ½ times 610 mm equals 915 mm to the stringers above and below the main beam levels. 915 mm is also the center to center distance between two NPS 12 LR 90 degree elbows and one rolled NPS 24 LR 90 degree elbow close-coupled to a NPS 24 45 degree elbow. Therefore all lines NPS 12 and below use two LR 90 degree elbows for elevation change to leave the pipe rack, and all lines NPS 14 up to NPS 24 will use one rolled LR 90 degree elbow and a 45 degree elbow.
- If the largest pipe size is NPS 20 then the elevation difference between main beam levels will be 1520 and 760 mm between stringers and levels. The elevation change of 760 mm will be by two LR 90 degree elbows for NPS 10 and below, and by a rolled LR 90 and 45 degree elbows for NPS 12 up to NPS 20. For NPS 16 the numbers become 1220 mm, 610 mm, NPS 8 and below and NPS 10 up to NPS 16, respectively. Given that there has to be space to work within the pipe racks, 1220 mm between levels is probably the minimum you would want to use.
- When laying out the piping for the larger NPS lines, make the 45 degree change in line with the pipe run whenever possible. There are two reasons for this: rolling the 45 degree change in the direction of the stringer may require a larger line space to the adjacent line, and can also result in having to push these larger lines further in toward the middle of the

rack. Rolling toward the stringer may also create interference with the stringer before your elevation change can be accomplished.

- Decide the distance between bents. A common distance for supporting is 6 m.
- Once you have established the elevation change between levels, stick with it throughout the plant. Running pipes from racks to subracks is made a lot easier when the stringer levels of the main pipe racks match the levels of the subracks. Also, when you change direction, change the steel elevations by the same main beam to stringer dimension, do not turn flat.
- Legs will be required to elevate the pipe rack modules. The plant elevations of the pipe racks are established by knowing the lowest allowed elevation above the roads and maintenance access requirements below the racks.

Much of the information above pertains to pipe rack layout in general whether they are modularized or stick-built pipe racks.

5.10 MODULE NUMBERING

It is a requirement that all modules have a unique number for tracking the designing, fabrication, transportation, and installation. You will need to establish the numbering system to be used for your modules. For this, look to your EWP numbering system. Use the unique EWP sequential number (usually a three or four-digit number). This number will require an abbreviated prefix to identify the module as an equipment module or a pipe rack module, such as EQM and PRM.

Transportation restrictions will put maximum limits on the width, height, and weight of modules for shipping. These restrictions mandate that breaks be incorporated into the designs. Therefore it is common to have more than one module in a EWP. Modules that do not require vertical breaks, i.e., modules that have not been split into two or more stacked modules, can be identified by a numeric identifying suffix of 01, 02, etc., e.g., EQM-XXXX-01, EQM-XXXX-02, and PRM-XXXX-01, PRM-XXXX-02. Refer to Fig. 5.5A.

Module designs that have a vertical split to accommodate the height restrictions of transportation require an additional identifier for the different levels. Two or more stacked modules can be identified by the addition of an alpha character to the suffix. The first alpha "A" identifies the

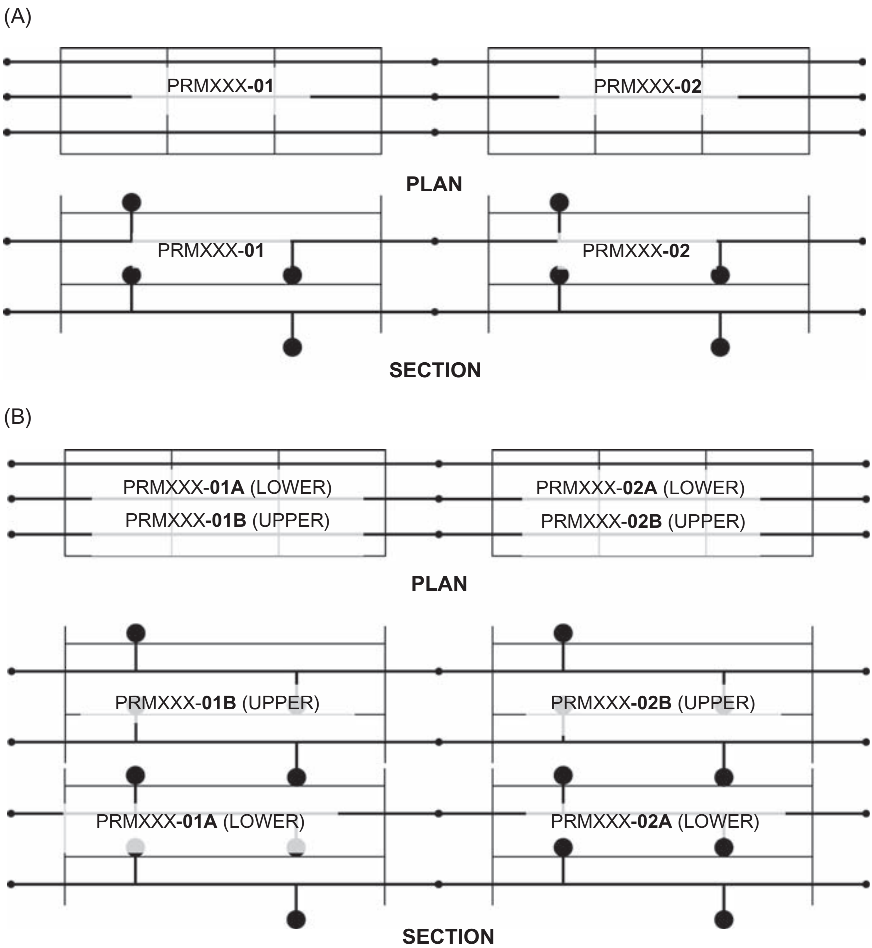

Figure 5.5 (A) Single level module numbering. (B) Multiple level module numbering.

module as being at the lowest level. Upper modules are sequentially B, C, etc., e.g., EQM-XXXX-01A, EQM-XXXX-01B, EQM-XXXX-02A, EQM-XXXX-02B and PRM-XXXX-01A, PRM-XXXX-01B, PRM-XXXX-02A, PRM-XXXX-02B. Refer to Fig. 5.5B.

You will need a set of rules for your area leads to follow when assigning the module sequential numbering. I have used the following guidelines on projects because it is a logical, easily remembered approach.

- Modules are numbered from west to east or from south to north with the exception that subrack modules that branch from a main pipe rack are numbered from the main pipe rack outward.

- For subracks that are in a different EWP to the main pipe rack, start with PRM-XXXX-01 for the first module (the one attached to main pipe rack) and number outward.
- For subracks that are in the same EWP to the main pipe rack, start with the next sequential number for the first module attached to the main pipe rack, after numbering the main pipe rack modules. When several subracks are involved, start with the most westerly or southerly subrack modules.

  This last rule is best explained with an example. Let us say that there is a main pipe rack running west to east comprising of ten modules with two branching subracks comprising of three modules each.

  The main pipe rack is numbered PRM-XXXX-01 to PRM-XXXX-10 from west to east. The most westerly subrack modules are numbered PRM-XXXX-11, 12, and 13. The next subrack modules are numbered PRM-XXXX-14, 15, and 16.

It is important to have a set of rules in order to be consistent and avoid confusion. The above works well because everyone generally expects that numbering will go from west to east and south to north per the coordinate system. However, when dealing with subracks the expectation is that the numbering will go from the main pipe rack out as per the sequence that pipe racks are erected—the main pipe racks first, followed by the subracks working outward from the main pipe rack.

5.11 DRAFTING PRACTICE

You have a responsibility as the piping lead to ensure the quality of the deliverables that your group produces. One of your primary deliverables is the drawings, the quality of which are a product of the drafting practice. Drafting practice refers to the presentation and content of the drawings, and part of the lead's job is to ensure that the designers have adequate training and a vision of the finished product.

Regardless of the tools being used, what has not changed over the years is the requirement to portray the information in a clear and concise manner—the need to consider the layout, set-up, and content of the drawings so that the designs are accurately and succinctly communicated. These are still human choices. The choices are just as important today as they were a hundred years ago for the end users and the drawings are still a testament to the professionalism of the designer and the company as a

whole. Drawings that are congested and poorly dimensioned are difficult to read and vastly diminished in their usefulness. Poor drawings can cause confusion leading to an increased number of Requests For Information (RFIs), mistakes, lost productivity, and added schedule and costs.

5.11.1 A brief history

In the days of manual drafting, which was common into the early 1990s, drafting practice or drawing presentation was one's calling card. Drafting practice referred to a nice hand lettering style, an understanding of and ability to draw differing line weights consistently, and an ability to understand and accurately portray the information in a clear and concise manner. The manual drawing was not just pleasing to the eye, it was a clearly thought out document that was a tribute to the technical and drafting expertise of the designer. Tremendous pride of ownership was taken in the presentation of the work.

With the advent of 2D CAD the need to have a steady hand for line work and ability to hand letter became unnecessary as much of the presentation was dealt with by predetermined line weights, text styles, and symbols. The ability to move things around also allowed that some of the previously required advanced planning could be decided or adjusted later, something not possible for the manual drafter. The designer was now utilizing a new tool, the 2D CAD software, but very little else changed in the approach to drawing creation and the knowledge required of the draftsman. Manual drafting and 2D CAD drafting both require that the drawings are being created as the design progresses. The drafting of the plans and sections, details, dimensioning, and notes are an ongoing function of the design, decided by the designer during the project.

Many projects now utilize 3D CAD software and, as with 2D CAD, the line weights, text styles, and symbols are predetermined. However, the drawings are now automatically or almost automatically (selection of cutting planes and clean-up are required) generated from the databases after the designs, in particular after the 3D modeling, has been finished. It is this automatic drawing generation as opposed to an ongoing drawing development that differentiates 3D CAD drawings from the manual and 2D CAD drawings.

An often seen result has been a loss of emphasis, accountabilities, and ownership where drawings are concerned with a corresponding diminishment of the quality. The standard of care and general drafting know-how

expected of the designer has been replaced by CAD set-ups and database management. While the move to more automated drafting methods is understandable and not without reason, poor quality is unnecessary and can be avoided with forethought.

5.11.2 3D CAD drafting practice

Drafting practice utilizing 3D CAD is now more about the management of the 3D models and the databases than it is about the format of the finished drawings. This is not so much a criticism as it is rather a statement about how drafting has changed.

To ensure the integrity of the information that later appears on the drawings and the reports that so many downstream people will later rely on, the designer utilizing 3D CAD has to manage a series of tasks never imagined by the manual drafters or even the 2D CAD drafters. As the piping lead, you will require the full support of your CAD support group and CAD Job Notes (CJNs) to provide training in order to ensure that these activities are carried out correctly. Many of these tasks must be carried out daily:

- Connectivity checking. The intelligent components can lose their connectivity to adjacent components in the model due to moving and copying. Models must have 100% connectivity to ensure trouble-free generation of isometrics and electronic files that are to be imported into the stress analysis software.
- Database cleaning. When components are deleted from the model their associated data may be left in the database. It is also possible that items displayed in the model may no longer have associated data in the database. Therefore it is required that the designers clean the databases of their piping models.
- Updating the components from the specification. The descriptive data in the model database files are generated as the model piping components are being created from the piping class material library. During the course of a project, the description within a piping class may change. For instance, a wall thickness. New components added to the model after this change will come with the new descriptor, but already modeled components will have to be updated for the new description to change accordingly in the isometric BOMs and material reports.

  Note that these updates will only apply to the descriptions. Changes that affect the dimensions, such as a change of flange rating

or a change of line size, will require that the previous components be deleted and that the designer remodel them.

- Running daily isometrics. To ensure that all models are functioning properly, designers should run an isometric of all added or modified lines toward the end of each day and correct any problems.
- Corrupted or disconnected databases. Occasionally, the problems will be beyond the knowledge of the designer to understand and correct. When this happens, the designer must stop all modeling and contact the CAD Support Group immediately. Continued modeling can cause permanent problems that can only be corrected by modeling everything over again.

In addition to the above daily tasks that must be carried out by the designers, the designers must also fix the issues that CAD support will bring forth in other reports. The CAD support group is not assigned to your project to respond only when there are problems. As is the case with any professionals that are expert in their field, the CAD support group will anticipate problems before they arise and will offer preventative maintenance throughout the project. Your CAD support will run a number of reports comparing models, databases, and line designation tables to monitor the continued integrity of all aspects of the models. Discuss the frequency of these reports and how they will be addressed with the CAD support lead and your area leads. You may also have suggestions for reporting of your own that the CAD support will be able to implement.

The following are reports that you can expect from the CAD support group to be passed through you and your leads for investigation and action by the designers:

- Discrepancies between the designation of the components and the model number. The components must be designated according to the number of the model they reside in. A discrepancy indicates that the components are either incorrectly designated or that they are in the wrong model.
- The line numbers in the models match with the P&IDs and LDT. Throughout the project lines may be deleted or added, or line origins and terminations may change.
- The associated information for the line numbers in the models are consistent with the P&IDs and LDT:
  - The piping classes.
  - The NPS.

  - The process commodity abbreviation. Many companies have a designator for the process in their line numbering.
  - The insulation requirements.
  - The tracing requirements.
- Instrument Tags. A report can identify if instrument tags have the correct number of digits and prefixes, or that there are instruments without a tag associated with them.

Clearly, the designer of today utilizing 3D CAD has a large responsibility and significant tasks to ensure trouble-free drawing generation. But in many ways, the designers of today share the same challenges as their predecessors. Attention to detail and the task of producing a deliverable that is accurate and has clarity have been requirements for the vocation of piping designer throughout the years. The difference is that yesterday's designers were writing the information on their drawings, not building the information into a database.

5.11.3 Ownership and training

Successful model and database management alone will not guarantee successful deliverables. Poor CAD set-up of the drawing templates and drafting practice may present a problem to the portrayal of information unless the lead is aware and takes the necessary steps to avoid this. Ownership of the models and drawings and training in drawing content are two important precautionary aspects to consider. What used to be a natural progression and consequence of a younger junior designer moving through the ranks to that of a senior designer now has to be taught in a much shorter timeframe due to the following reasons:

- In the manual drafting days the leads and even the chief draftsman would walk around and observe the designs in progress. They received instant feedback by looking at the drawings on the drafting boards, and gave instant feedback on aspects of design and drafting to the designers. This form of mentoring was lost in the 2D CAD world as it is not possible for senior personnel to easily follow the design on the designer's computer screen. He/she has to make a conscious effort to review the designs either on their own monitor or by making prints of the drawings.
- There is a lack of opportunity. Junior designers used to have the opportunity to hone their drafting and design skills by drafting P&IDs and standard drawings. They also learned from the more experienced

designers by drawing isometrics from the finished piping arrangements, and assisting the senior designers in the drawing of sections and details. Once a junior had developed good drafting skills, they may have been trusted to backdraft the checked drawings for the senior designer. In short, they had many years of design and drafting involvement before ever reaching the goal of doing their own layout work. This opportunity has largely been lost in the 3D world. Companies have little choice but to allow the junior designers to start designing in 3D after a year or two of drafting P&IDs and standards and generating drawings, partly because there are no intermediate steps that can be taken and partly to keep them interested.

- An emphasis has developed on the pursuit of knowledge in the operation of 3D CAD software for designing, and a de-emphasis has developed on the attainment of drafting skills for drawing presentation. As an automatically or almost automatically generated product, it is often perceived that drawing creation no longer requires a drafting ability. This in turn has led to a heavier reliance on the abilities of the people providing the CAD set-up, rather than that of a trained draftsman.
- It is a widely accepted belief that the designer must work within the constraints of the software and that he/she is not responsible for the end result, whereas in truth, the input of an individual with sound drafting knowledge is both possible and beneficial.
- The activity of drawing creation has been separated from the activity of designing and the designers no longer claim ownership of the finished drawings. Drafting for the more senior designers means selecting the cutting plains in the models. Drafting for the more junior designers means bringing the work of someone else into a titleblock and dressing up the drawing content (text and dimensions).

  This lack of ownership may be compounded by coupling the assigning of the task of annotating the piping arrangements and generating the construction isometrics to the more junior personnel without adequate drafting knowledge and input from the designer. Unlike the juniors of the past who had the privilege of working alongside the seniors, the juniors of today are often assigned the task of drawing generation without knowledge of, or participation in, the design development. A disconnect often exists between the senior, the junior, and the end product.

- The drawings are no longer being worked on as the design evolves. They are generated toward the end of the design stage. At this point there is pressure to get the design finished and the drawings issued, which commonly translates into less time being spent on drawing consideration by the designers and the acceptance of some shortcomings in the finished product by the checkers.

You may think from the preceding that I lament the passing of the manual drafting era, and there is some truth to this. Clearly I have strong views on drafting and I miss the opportunity to admire the work of art of a skilled manual draftsman; it is a skill that I believe gave inspiration to the following younger generation of designers. I also believe that it is regrettable that the system of training and mentoring that prepared the junior piping designer to take on more responsibility as they progressed in their career has been lost.

However, I also believe in the efficiencies and benefits of CAD, 3D CAD in particular, and I cannot imagine going back to the manual ways. It is a matter of recognizing how the design and drafting world has changed and adjusting accordingly. There are a few things you can do as the lead:

- Speak with the fabrication and erection contractors and find out what problems they may be encountering with the drawings. Listen to their advice on how things may be improved.
- Provide additional training and instruction by way of classroom and written Piping Job Notes (PJNs) and CJNs.
- Always have the designers generate their own piping arrangements and isometrics and do their own backdrafting to maintain ownership. Backdrafting in the 3D world means making the changes in the models and regenerating the drawings.
- Never allow manually backdrafted edits to the drawings by anyone for any reason. The area designer must make all changes in their models, and the drawings are to be regenerated. This is not just a drawing ownership issue; it is also a model integrity issue.
- Create examples of the piping drawings as you wish to see them for your team. This will help to ensure a consistent product.

I have another reason as the lead for wanting the designers to generate and backdraft their own drawings. It is one of accountability and responsibility. I do not think it fair that someone else has to clean up the problems caused by poor attention to detail or the lack of understanding of another individual. Specifically, I am referring to poor modeling practices that can cause issues in reporting and drawing generation from the

databases. By having each designer complete their area in its entirety I have the opportunity to gauge their capabilities and performance, and they have the opportunity to learn from their mistakes.

I realize that it is tempting and even unavoidable at times when an area is in a crunch to spread the work around, but do not do it as a general rule. Consider this during your manpower planning and scheduling.

In short, take charge and be involved in the CAD set-up, promote a culture of ownership, and provide drafting guidance both in training and examples, and you will attain a level of drawing superiority that even an old time manual draftsman would be pleased with.

The following sections discuss some areas of training and set-ups that I recommend.

5.11.4 Intelligent P&IDs

The following are considerations concerning the use of intelligent P&IDs that you may need to address. Intelligent P&IDs can provide great benefit for the creation of equipment lists, instrument lists, specialty item lists, line designation tables, valve lists, etc., in that the databases created during P&ID development can be used to automatically generate these lists. A proviso however is that in order to get maximum benefit, the software requires a proficient user. Given that commonly the P&ID drafting personnel are the most junior of the team and often come from the rank and file of fresh technical school graduates, you will have to carefully select those who will work with the software and provide adequate training.

You must also be aware of the connection between intelligent P&IDs and the 3D models. Data populated during P&ID development is used to build the 3D models (line size, specification, etc.). When a designer starts to build a line, the software validates that the designer's input is to these same parameters and may interfere with 3D modeling when the two do not match. For instance, a line on a P&ID is NPS 4, but the designer knows that it has been changed to NPS 6 and wants to build it as such. Conflict resolution of this nature can take time and may be best addressed by severing the connection. The workflow when connections such as this are employed must be carefully analyzed before being implemented.

5.11.5 LDT extraction

Likewise to the P&IDs to the 3D models connection, so must the workflow of a connection between the LDTs and isometrics for the extraction

of design, operating and test data be thoroughly analyzed. There is only efficiency to this when the LDT data is kept current. When the LDT is not current, as is frequently the case for an ongoing project, this feature can cause more work than it will save. Alternatively, a solution I have seen implemented is a modified isometric titleblock that does not include the design, operating and test data. Users of the isometrics are directed to the LDT for this information by way of a note on the drawing. This approach save on piping checking time and places an onus back where it belongs on the process group to issue an up-to-date LDT.

5.11.6 Piping arrangements

The two mistakes I see most often on piping arrangements are congestion and poor dimensioning. Piping arrangements require planning in order to avoid piping in the foreground that would block the detail of the piping in the background. Separating a plan into upper and lower elevations may be required to obtain the needed clarity. Careful attention must be paid to dimensioning. Over-dimensioning, double-dimensioning, dimensioning from matchlines, and dimensioning between pipes that are at different elevations are not useful practices. Dimensioning in particular is an area that I believe is requiring of attention.

5.11.7 Isometrics

The out-of-the-box product for automatic isometric generation requires set-up in order to achieve the desired line weights and format. The automatically generated isometrics will never look like their manually drawn counterparts, but they can be very functional. With a little effort and time spent with your CAD support group, a company configuration can be developed that will be very much to the satisfaction of yourself and the construction personnel.

Left to its own devices, automatic isometric generation will break unpredictably and may have far too much information to be easily readable. Many lines may be crossing and smaller items, such as vents, often lack clarity because they appear too small on the drawing. Therefore you need to have a few rules for your designers to follow:

- Identify the spools and spool breaks in the model. Natural breaks occur at flanges whereas field weld locations must be selected.
- For shop fabricated piping, field weld locations are decided by considering the shipping box dimension limitation and handling constraints

such as floor, wall, and platform penetrations. An additional limitation for spools that require postweld heat treatment (PWHT) may be the oven size. (Note: it is generally unnecessary for the designers to identify field welds for piping erected on a module due to the spooling and erection being under the full control of the module fabricator.)

- For clarity, allow a maximum of 3 or 4 spools per isometric for field-erected piping or the equivalent for module piping. Assign the isometric sheets and breaks in the model.
- Force the breaks between isometric sheets to be at a logical point, i.e., a flange or a field weld location.
- The automatically generated isometrics want to break at line number changes. Include short branch connections as part of the main line isometric. The introduction of another isometric beginning with a short stub may be construed as a field weld location by the fabricators. For instance, imagine a header with a branch consisting of a WOL, pup piece, flange, valve, flange and branch line continuation. Should the branch line isometric begin right at the WOL, there is a good chance that the fabricator will assume a field weld location, whereas the WOL to pup piece can be a shop weld with the isometric break at the flange.

Consideration must also be given to the drawing numbering of the isometrics. It is very common practice to use the line number and sheet numbers for the isometrics of a given line. The problem is that it is impossible to schedule the generation of isometrics such that the sheets are numbered consecutively, starting with Sheet 1, from the beginning to end of the line in the direction of flow.

I suggest that you use a prefix to the isometric drawing number with such as the EWP sequential number/model number. By doing so, the isometrics for all lines within the EWP/model can begin with Sheet 1, and it is clear to everyone that the isometrics belong to that EWP. This can be a real advantage when there are thousands of isometrics to deal with.

For example, let us assume a EWP sequential number of 123, and two models numbered 123-01 and 123-02. Clearly, there will be other identifiers within the EWP and model numbers, the discipline being one of them for instance, but the EWP and model sequential numbers are the ones to focus on. Let us also assume a line number of HS-DVA-20-2210. The isometrics for this line in model 123-01 would be numbered 123-01-HS-DVA-20-2210 SHT 01, 02, etc., and the isometrics for this line in model 123-02 would be numbered 123-02-HS-DVA-20-2210 SHT 01, 02, etc.

5.12 HOLDS

It is not appropriate to hold back a EWP for issuing due to an inability to verify 100% of the information. It is better to release a package that is 95% complete for fabrication than to release nothing due to 5% of unknowns.

During the checking stage there may still be some items for which the approved data are not yet available. An example can be a control valve face-to-face dimension. For these situations it is required that the checker creates a Holds List and clouds the area of concern on the drawings with a "HOLD" cloud (the holds should also be listed on the drawing). This is a flag to the engineering and design teams that there is an unresolved issue still to be addressed, and it will notify the fabricator not to build this portion of the piping system until otherwise informed. The holds list should be compared against your needs list and the project action item list. Hold items that are not already identified should be added. In this way these holds will not fall through the cracks and be forgotten. Ideally you will be able to remove these and re-issue the drawings before the fabricator gets to them and is required to send an RFI. An RFI should prompt that the issue becomes a high priority. If it cannot be resolved, then a decision may be needed to proceed with the fabrication, possibly with field fit allowance added. This is a calculated decision that may later result in a further RFI during construction and an as-built to correct.

5.13 PROJECT DOCUMENTS AND LISTS

There are a number of project documents and lists that you must ensure are available to the designers throughout the project, commonly in dedicated locations on your network. For the most part they will be managed by your document control group, but in some cases (e.g., Action Items List and Needs List) may have to be managed by you. You will need to inform each of the designers of the whereabouts of these. As the project proceeds, you will need to alert your designers when revised or new documents have been added:

- Master project documentation
- Equipment list and vendor drawings

- Instrument list and instrument data sheets
- Other lists and data sheets
- Specification waivers and deviations
- Action item list
- Needs list

5.13.1 Master project documents

Master project documents of the following must be available to your designers:

- The Design Basis Memorandum (DBM)
- The Project Execution Plan (PEP) (specifically the contracting, procurement and construction)
- Piping specifications
- Piping standards

5.13.2 Equipment list and vendor drawings

The equipment list is the responsibility of the process/mechanical engineering groups. The document control group will keep a master expediting status report and copies of the vendor information. You should keep your own up-to-date copy of the equipment list and receive the status reports for your records. Try to keep one step ahead and compare these with your schedule to determine if the vendor information is going to be available when your team will need it.

5.13.3 Instrument list and instrument data sheets

It goes without saying that the instrument list and data sheets will come from your instrument group. If one does not exist, you should request that a column be added to the instrument list for the identification of left and right hand mounts. Ball pattern control valves in particular, and other types of instruments, come in either a left- or a right-hand mount configuration, and as the designers are laying out an area they should fill this in to inform the instrument group of the correct orientation to be purchased.

5.13.4 Other lists and data sheets

There are two other types of lists and data sheet to be managed throughout the project for your team. These are the following:

- Spring supports list and data sheets. These will come to you from the stress group after the stress analysis for a given line has been completed.
- Specialty items list and data sheets. These will come to you from the mechanical/piping engineering group.

5.13.5 Specification waivers and deviations

Client specifications may be waived or deviated from during the project. Your designers must be aware of all of these for incorporation into their designs (note: regulatory and code requirements cannot be waivered or deviated from):

- A waiver is an agreement to not follow a certain requirement. An example of a waiver is a relaxation of the spacing guidelines between pieces of equipment.
- A deviation is an agreement to change a certain requirement. An example of a deviation is the use of a thinner wall pipe or a different material than that specified in a piping class.

5.13.6 Action item list and needs list

You will need to create an action item list spreadsheet and a needs list spreadsheet. The action item list is a list of items and tasks within your control that require resolution, such as a CAD software issue.

The needs list is a list of all the issues that are holding up the progress, such as missing vendor data. These are tasks that will require the assistance of another group to resolve, sometimes with the influence of your project management team.

These lists should have several columns of information:

- An item number, 1, 2, 3, etc., will suffice.
- A brief description.
- The date of entry.
- The name of the person/group responsible for resolution.
- The date that the resolution/completion is required by.
- The date it was resolved.
- The priority, high, medium, and low.
- The status, i.e., open or closed.
- A remarks or comments column.

You will find that items for the action item list will end up on the needs list and vice versa. This is not very important. What is important is that they get listed and resolved in a timely fashion.

Take these lists with you to your project meetings and discuss the items with the project team.

5.14 MANAGING STANDARD DRAWINGS

The standard drawings that are to be used on the project will be issued and frozen for the project at the beginning of the job. These standards may be from the client or your company, but because standards are ever evolving there will likely be revisions that will come your way. This is because the custodians of the standards are outside of the framework of the project. They will be listening to feedback from your project and other projects and revising and re-issuing accordingly. There are two reasons for issuing:

- A new standard has been created
- An existing standard has been revised

It is important that you have control of the acceptance of revisions to the standards and the issuing of new standards during the project. There are three reasons why a standard may be revised or a new standard created:

- Costs and/or efficiency savings by changing the existing design
- The existing design has to be changed due to a safety issue
- A new standard is required to fill a gap

These are all good reasons for issuing standards, but new and revised standards that do not emanate for known and approved project reasons should not be allowed on the project without the approval of the project manager. It is not likely that a safety issue would be turned down, but timing is important and other reasons for issuing may not warrant the repercussions they can have on cost and schedule. Do not forget that the project manager holds the purse strings to the project and must be made aware of changes to the standards.

Inform your team that if an unapproved standard comes their way they must bring it to your attention. Unapproved standards have been known to show up on a project and have led to the retrofitting of the already completed work. Should a new or revised standard be approved, be clear in your instruction of the usage, i.e., that it is only to be used as

the project moves forward, not on already designed work, unless of course that is what you want.

5.15 PROJECT MEETINGS

Like it or not you will have to attend project meetings with the project team and the other discipline leads, and have meetings with your own team.

The subject of the project team meetings will primarily be schedule. Are you on schedule, and if not, why not? This is where your action item list and needs list will be very relative. Get your concerns and issues out into the open and onto the project action item list. What you can do, and must do, is go into the project meetings prepared and armed with the information on what exactly is preventing you from meeting the schedule. What you cannot do is arrive uninformed and therefore vulnerable and unable to defend your position. The message you deliver may not be well received, but it will be respected if it is factual and accurate. If you come in with vague statements it will appear that you are not organized enough to get the job done, and others will doubt your abilities. Your project management team will usually be very good at their jobs, but they are not mind readers, and you have to be able to present your situation in a clear and decisive manner.

During the meeting do not make any commitments that you are unsure of. It is far better to walk away with the promise to investigate and report back than to commit in the moment under pressure and not to be able to deliver in the long run.

Your own team meetings will also be centered on the schedule. Listen, offer solutions, and document the issues. Here are a few guidelines for running your meetings:

- Have regularly scheduled meetings. Decide on the attendees and send out a recurring meeting notice. Primarily, the attendees will be your leads and the CAD manager, but also consider inviting the other discipline leads and your department manager as optional attendees. When staffing needs are going to be a topic, you should give your department manager the heads up and request that he/she be there. This is the primary person that will help you fill your staffing requirements.

I find that one meeting every 2 weeks is sufficient. Weekly meetings come around too soon, although in the early stages when things may be progressing quite rapidly, you may want to start with weekly meetings and then switch to bi-weekly.

- Keep the meeting focused. People will often drift into tangents on topics that are best taken outside of the regular meeting. They will also start their own mini meetings while you are talking. Politely remind them that you are all there to discuss things as a group.
- Keep the meeting as short as possible. You can cover a lot in one to one and a half hours. Beyond this, people will start to become restless.
- Use the time to make announcements and share any news.
- Keep minutes. Distribute these and the updated action item and needs lists as soon as possible.
- Do not be late for your own meeting. If it is necessary to cancel a meeting be sure to send out a cancelation notice.
- I do not voice any rules for cell phones. No doubt we have all experienced cell phones ringing during a meeting, but I find that most people will turn them off immediately or excuse themselves and take the conversation outside of the room. Personally, I turn my cell phone off when I go into a meeting. The momentary disruptions that others' cell phones may cause have never warranted comment.

5.16 PROGRESS MONITORING

Larger engineering companies will have software to track the progress of the piping design effort. The leads and designers must enter predetermined data into the required fields for progress monitoring. At smaller companies you will have to establish a tracking system. Discuss this with your project management team and your area leads to establish the parameters to be monitored. A simple spreadsheet divided by area and activity will suffice as your "tracker," such as the examples Fig. 5.6A, B.

It does not have to be anything fancy, in fact, you do not want to make it an arduous exercise, but it must have a breakdown that can reasonably be expected to be tracked, and to give a fair estimate of where you are in the progress. Referring to Fig. 5.6A you will notice that the fifth column lists "Lines > or = to 4″ modeled (15% of total effort.)." As long as you have the total line count of NPS 4 and above lines in Area 1,

Construction Area	EWP/Model Area Number	Models included in Model Area	Equipment modelled to vendor data (0% to 3% of total effort.)	Lines > or = to 4" modelled (15% of total effort.)	Lines < or = to 3" modelled (10% of total effort.)	Lines > or = to 4" with stress comments incorporated (10% to 13% of total effort.)	Lines < or = to 3" with stress comments incorporated (7% of total effort.)	Valves modelled to vendor data (3% of total effort.)	Instruments modelled to vendor data (3% of total effort.)	Tempory Structural Steel modelled (7% of total effort.)	Clash Checking (final steel req'd) and Personal Isos run (7% of total effort.)	% Complete (ready for checking @ 60% to 65% complete)	Comments
Area 1	0001	5001		15%	8%	13%	7%	3%	3%	7%	7%	63%	1/ Miscellaneous piping to be completed.
	0002	5002		15%	8%	13%	7%	3%	3%	7%	7%	63%	1/ Miscellaneous piping to be completed.
	0006	1006		0%	0%	0%	0%	0%	0%	0%	0%	0%	1/ Not started. Require air make-up units
		8006	0%										
	0007	1007		15%	10%	9%	6%	3%	3%	7%	5%	58%	1/ Require info on OTSG to complete stress. 2/ Miscellaneous piping to be completed.
		8007A	2%										
		8007B	2%										
	0010	1010		15%	10%	9%	6%	3%	3%	7%	5%	58%	1/ Require info on OTSG to complete stress. 2/ Miscellaneous piping to be completed.
		8010A	2%										
		8010B	2%										
	0011	1011		15%	8%	10%	5%	3%	3%	7%	5%	56%	1/ Missing final vendor data. 2/ Miscellaneous piping to be completed.
		8011	3%										
	0013	1013		15%	10%	9%	6%	3%	3%	7%	5%	58%	1/ Require pre-heaters. 2/ Require info on OTSG to complete stress. 3/ Miscellaneous piping to be completed.
		8013A	2%										
		8013B	2%										
	0014	1014		15%	8%	10%	6%	3%	3%	7%	6%	58%	1/ Miscellaneous piping to be completed.
		8014	3%										
	0015	1015		0%	0%	0%	0%	0%	0%	0%	0%	0%	1/ Not started. Require air make-up units
		8015	0%										
	0016	1016		13%	8%	8%	5%	3%	3%	6%	4%	50%	1/ Require air make-up units 2/ Require pre-heaters. 3/ Require info on OTSG to complete stress. 4/ Miscellaneous piping to be completed.
		8016A	2%										
		8016B	2%										
	0017	1017		8%	5%	5%	3%	2%	2%	4%	6%	60%	1/ Catalog info only on glycol circulation pump. 2/ Utility piping to be completed.
		6017		8%	5%	5%	3%	2%	2%	4%			
		8017	3%										
	0018	1018		15%	10%	10%	6%	3%	3%	7%	6%	60%	
		8018	3%										

Figure 5.6 (A) Piping design progress spreadsheet. (B) Piping checking progress spreadsheet.

Construction Area	EWP/Model Area Number	Models included in Model Area	Ready for checking (60% to 65% of total effort.)	Equipment checked in model (0% to 2% of total effort.)	Piping Arrangements generated (5% to 10% of total effort.)	Isometrics generated (5% of total effort.)	Piping Arrangements checked (15% to 20% of total effort.)	Isometrics checked (0% to 3% of total effort.)	Piping Arrangements backdrafted (3% to 5% of total effort.)	Isometrics backdrafted (0% to 2% of total effort.)	Package IFC	Comments
Area 1	0001	5001	63%		10%		20%		5%		98%	Issued with some "HOLDS".
	0002	5002	63%		10%		20%		5%		98%	Issued with some "HOLDS".
	0006	1006	0%		0%	0%	0%	0%	0%	0%	0%	
		8006		0%								
	0007	1007	58%		0%	0%	0%	0%	0%	0%	58%	
		8007A		0%								
		8007B		0%								
	0010	1010	58%		0%	0%	0%	0%	0%	0%	58%	
		8010A		0%								
		8010B		0%								
	0011	1011	56%		0%	0%	0%	0%	0%	0%	56%	
		8011		0%								
	0013	1013	58%		0%	0%	0%	0%	0%	0%	58%	
		8013A		0%								
		8013B		0%								
	0014	1014	58%		0%	0%	0%	0%	0%	0%	58%	
		8014		0%								
	0015	1015	0%		0%	0%	0%	0%	0%	0%	0%	
		8015		0%								
	0016	1016	50%		0%	0%	0%	0%	0%	0%	50%	
		8016A										
		8016B		0%								
	0017	1017	60%		2%	2%	0%	0%	0%	0%	68%	
		6017			3%	3%	0%	0%	0%	0%		
		8017		0%								
	0018	1018	60%		0%	0%	0%	0%	0%	0%	60%	
		8018		0%								

Figure 5.6 (Continued)

it is a fairly straightforward task to estimate the progress. Your designers should be "yellowing-off" their set of P&ID's and can tell you how many lines they have modeled. You may also be able to obtain reports through your CAD support group from the model database. If a third of the lines are modeled, 5% would be entered.

It is a thankless task that few people want to do, but a very necessary one. I suggest that you have each area lead update the tracker for their area. Your project team will want this done on a regular basis, at least once a month.

From this, the earned value will be calculated which is a measure of how much real progress (i.e., value) has been achieved to date, and is the indication of how well you are doing.

Let us assume that a particular area has a total hour allotment of 5000 hours and the estimate is that you are 50% complete. You have earned 2500 hours. If you have actually used 2000 hours to this point (hours being used are referred to as the burn rate) then your productivity is the earned hours divided by the actual hours, which is 2500/2000 or 1.25. Another way of saying this is that for every hour expended, 1 hour and 15 minutes (60×0.25) of productivity was gained. This would be amazing and likely an indication that the progress is being overestimated, that the budgeted hours are overestimated, or that your designers are charging some of this work to another code.

On the other hand, if you used 3000 hours then your productivity is 2500/3000 or 0.83 (for every hour expended, 50 minutes (60×0.83) of productivity were gained), which is an indication that you are in danger of going over the budgeted hours and schedule. One month of low productivity may raise some eyebrows and questions, but would not be of great concern in the big picture. Continued low productivity will prompt investigation to determine what is happening. Possibly the budgeted hours are underestimated, possibly some trending has been overlooked, or it may be that your designers are charging other work to the code for this work.

For that matter, continued high productivity will be investigated to determine the truth of the reporting. Is there overestimating of the productivity happening or were the hours originally overestimated? A productivity of 1 is, of course, right on target.

These reports will be used to forecast the burn rate, the completion dates against the original target dates, and will help determine where some overtime may be required or resources may be re-allocated to bring things back on track.

They will also be used to forecast the final costs, i.e., if you are going to go over budget. Clients may also only be willing to pay based on the earned hours and not on the actual hours used.

Progress monitoring is useful in estimating how the project is likely to finish in terms of budget and schedule, and serves the very important purpose of identifying when you are running into trouble. It also helps to identify the requirement for a mid-course adjustment before you are so far into trouble that you can never recover.

5.17 CHANGE NOTICES AND REQUESTS

During the course of a project, particularly after drawings and other documents start to be IFC, a means of internal and external communications between teams for changes and requests is needed. These changes and requests and any follow-up responses must be maintained for project record, therefore formalized templated documents and tracking procedures are used. This formal documentation takes the form of

- Design Change Notice (DCN)
- Field Change Notice (FCN)
- Request For Information (RFI)
- Request For Change (RFC)

5.17.1 Design Change Notice (DCN)

A DCN is a document distributed from the project team to the affected disciplines to give notification of an approved design change. These take the form of such as changes to the designs, changes to the scope and/or budget, and deviations and waivers. This document includes the following:

- The details of the change, with a sketch if needed
- The reason for the change
- The impact on the schedule

You must distribute these to your leads as soon as you receive them. A DCN often follows an approved scope change request, but can also be used to document design changes that are not scope changes but are changes in budget. For instance, a deviation from the material specified in a piping class to a substitute material is not a scope change, but can affect cost. Also be aware that a DCN may trigger a trend.

5.17.2 Field Change Notice (FCN)

A FCN is a document distributed from the project team to the fabricators, construction, and affected disciplines after the drawings are issued IFC. This can be for changes in scope, changes in design, and the adding or removing of holds. Its purpose is to give advanced warning and instruction, during the time it takes to revise and re-issue the drawings, so that any affected work may be acted on without delay. This may be to enact an immediate change to an IFC design or to place a hold for the time being in order to avoid possible rework. As with the DCN, this document similarly includes details of the change, the reason for the change, and the impact on the schedule.

For any changes to IFC piping work that you become aware of, you have to mark up the affected drawing(s) as soon as possible, then pass this on to the project engineer to notify everyone involved that a change is coming.

5.17.3 Request For Information (RFI)

A Request For Information (RFI) is a document submitted by the fabricators or the construction team and can be for any number of reasons, ranging from clarifications to the specifications, standards and IFC drawings, to material deliveries and transportation requirements.

The RFIs that are designated for action by you must be answered as soon as possible. Your response must be a clarification to the question asked and may have to include mark-ups to drawings that may become revisions to these same drawings.

5.17.4 Request For Change (RFC)

A RFC is a document submitted by the fabricators or the construction team to change or deviate from an IFC design. This is usually generated due to an inability to build according to the IFC drawings. Examples are an interference issue or difficult access.

As with the RFIs, RFCs that are designated for action by you must be answered as soon as possible. Also as with the RFIs, your response must provide clear instruction and include mark-ups to drawings that may become revisions to these same drawings.

An RFI and an RFC may trigger a trend or scope change and a DCN or FCN. Whether the document submitted to you is a DCN, FCN, RFI, or RFC, this is where your stick files will be of great value. Note the changes on the P&IDs, piping arrangements, and isometrics

stick files, with the number of the DCN, FCN, RFI, or RFC. Revise and re-issue the drawings in a timely fashion.

Going back to the need to maintain project documents, these are no different, and you must maintain a log of each for future reference.

5.18 PIPING JOB NOTES AND CAD JOB NOTES

Try as hard as we may, and for all the planning, there will be a need to issue instructions to your team of specific project requirements as the project unfolds. These will take two forms:

- PJNs are instructions written by yourself or a designate on piping matters.
- CJNs are instructions written by the CAD group on design and drafting software related matters.

These should be numbered and recorded, e.g., PJN-001, 002, etc., CJN-001, 002, etc., with a revision number. The following sections are example job notes, rewritten to give context from their original briefer more bulleted formats.

5.18.1 Locating field welds

5.18.1.1 Introduction

This instruction pertains to the shop spooling of butt-welded pipe, fittings, and flanges. Commonly the butt-welded piping is NPS 2 or NPS 2½ and above, depending on the company piping specifications. The goal of all projects is to do as much welding as is possible in the controlled environment of a fabrication shop in order to minimize the costlier field welding, and while it would be nice to be able to fabricate whole piping systems and ship them to site in one piece, this is of course impossible. Therefore shop-fabricated piping systems must be broken into convenient pieces (spools) for transportation to the field. This is accomplished by breaking the system down into multiple spools that will fit within a predetermined shipping box size for later field erection.

Natural breaks occur at all flanges, whereas breaks between pipe and fittings (field weld locations) must be selected. However, much more is required of the designer than just placing field welds that keep the spool sizes within the shipping box limit. The placement of the field welds also requires an understanding of the needs of construction. In order to undertake this task, designers must possess an additional knowledge that

will enable them to make sound judgment calls after due consideration of all factors.

This document is not all encompassing and does not provide all detail, but will serve as a guide for further thought and investigation during the exercise of field weld placement.

When in doubt, the designer should seek an experienced opinion from their lead, checker, or other senior piping team member. It is also recommended that a representative from Construction be consulted.

5.18.1.2 Spools and field welds

What is a spool?

- A spool is a part of a piping system prewelded in a fabrication shop. Commonly, spools are only fabricated for butt-welded piping systems NPS 2 or NPS 2½ and above. The components of a spool are the butt-welded pipe, fittings and flanges, welded on branch connections, i.e., WOL, SOL, TOL, and stub-ins, and welded on pipe support attachments, e.g., dummy legs, base supports, and shoes.

How and where are spools welded?

- A spool starts life in the fabrication shop where the spool components can be welded at floor level and rotated as the welder leans over and makes the weld passes. For obvious reasons these welds are called "shop welds."
- Once the spools arrive in the field, some can be welded together at grade, making larger spools to be hauled into place. This often takes place in a heated field-erected shelter with the spools supported on stands. Not quite as nice for the welder as being in a shop environment, but nonetheless, reasonably efficient working conditions. For obvious reasons these are called "field welds."
- After the spools are hauled into position, e.g., into pipe racks, the final welds are executed in place. This is the most expensive of the three locations due to the need to erect scaffolding and tarpaulins; additional safety measures; working in cramped quarters; exposure to hot or cold climatic conditions; and the higher incident of rejected welds. These welds are also called field welds, but are often more specifically referred to as "position welds."

Field welds, whether done at grade or in position, are categorized according to one of two descriptors:

- Field Weld (FW) or Field Fit-up Weld (FFW).

- The difference between a FW and a FFW weld is that a FFW has an additional 150 mm of pipe length added to the calculated dimension for a field trim allowance. No such allowance is provided at a FW. The construction personnel will do a dimensional field check and trim the extra 150 mm to the required length to suit the field measurement. The end of the additional pipe length provided by the spooling fabricator need only be a plain end cut because the final beveled end preparation will be done in the field.

5.18.1.3 Instruction

The primary considerations for field weld locating are as follows:

- Spools must fit into a shipping box size, the exact dimensions of which are a project decision based on the means of transportation employed, truck or rail for instance, and the jurisdictions passed through.
- Try to anticipate the best locations for the field position welds. A good example of this is at the branch to header welds in the pipe racks. While the position welds can be in horizontal pipes (vertical welding) or in vertical pipes (horizontal welding), it is best to avoid horizontal welding in a vertical pipe. Horizontal welding poses the most problems for the welders because the molten metal tends to drip necessitating enhanced welding practices and extra care to overcome this difficulty. Going back to the pipe rack example, instead of placing the field weld at the header branch fitting, consider placing the field weld at the first elbow of the branch line in the horizontal run. Also avoid field welds in a 45 degree plane.
- Look at the surrounding piping and steel. Avoid locating position welds in tight areas that will be difficult or impossible for a welder to maneuver in.
- Look at the pipe routing. Does the piping run through floor, wall, and/or platform penetrations? If so, more field welds may be required in order to create straight run spools without bends that can be threaded through the openings. Locate the field welds above the floor or platform.
- Likewise to the above bullet, consider how the spools will be fed into the pipe racks. This is particularly necessary when new piping is being added to an existing pipe rack.
- The exact distances calculated in the office are unlikely to be so precise in the field due to the possibility of foundations and steel being

slightly out and slight errors in the equipment fabrication. Therefore strategically placed FFW welds for a final hook-up should be considered in places where there is reason to believe field adjustment will be necessary. Common places where an FFW is beneficial are between exchanges, vessels, and pumps in parallel. Pumps in particular require this in order to ensure that the finished piping does not impose unnecessary loads on the nozzles. However, do not go overboard with FFW placement. Construction personnel would much rather have to cut apart the odd spool that does not fit and make adjustments as needed, than have to field measure and cut to suit in an overabundance of places where there would most likely have not been a problem.

- Field welds must be a minimum of 600 mm from any support centerline.
- Make field weld placement consistent for similarly run piping configurations.

5.18.1.4 Notes to figures

The following figures are provided for further clarification (for the purposes of example a shipping box size of 3 m × 3 m × 12 m or 10′ × 10′ × 40′ has been selected):

- Fig. 5.7A—All spools must fit into the established shipping box. In this example, imagine a box 3 m × 3 m × 12 m. This is referred to as the “SHIPPING BOX SIZE.” The 3 m × 3 m × 12 m dimensions are the maximum dimensions between centerlines and end of pipe or face of flange that the designer must work to in order to keep the spools within the allowable width, length, and height restrictions.
- Fig. 5.7B—Avoid small pup pieces. The 12 m length is a plus or minus convenient handling and shipping size derived from an expected utilization of nominal double random lengths of pipe. Exceeding the shipping box length limits by short distances is generally permissible. In this example, allowing that an additional 100 mm of extra pipe to the 12 m length of the spool eliminates one shop weld.
- Fig. 5.7C—Place field welds in the horizontal plane. This is preferred, not mandatory, but should be followed wherever possible.
- Fig. 5.7D—Always have at least one fitting attached to a pipe length per spool.

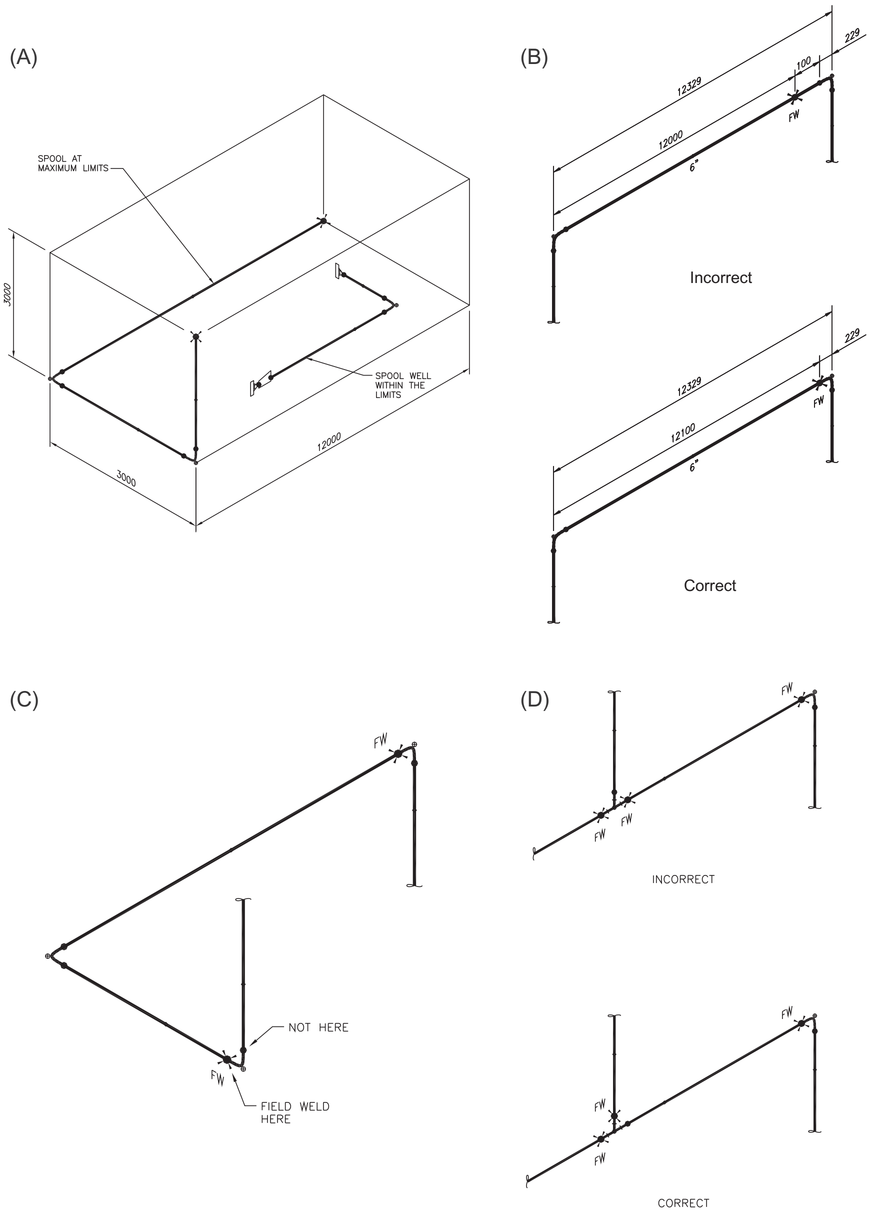

Figure 5.7 Pipe spool breaks.

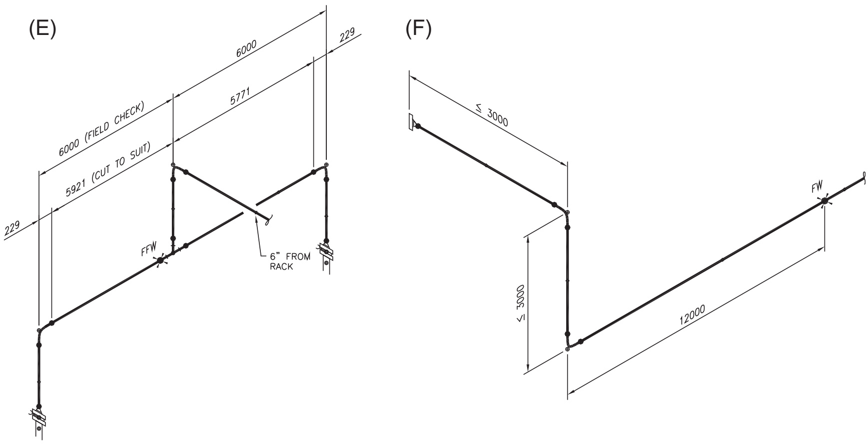

Figure 5.7 (Continued)

- Figure 5.7E—Consider placing one FFW for a final field measurement and dimensional adjustment in the horizontal piping between equipment in parallel, e.g., exchangers and pumps.
- Figure 5.7F—Maximize spool size whenever possible.

5.18.1.5 Summary

There is much more to the locating of field welds than is revealed by first impressions. It is an important value added project activity deserving of thoughtful attention. When done with forethought, this activity brings cost and schedule benefits to construction. A consistently applied approach that takes construction needs into consideration ensures that all spools will fit within the shipping box size and, when delivered from the spooling fabricator to the field, will be fit for installation with a minimum of rework.

5.18.2 Placement of vents and drains

5.18.2.1 Introduction

This Job Note will be used for hydrostatic vents and drains on piping. Process vents and drains on equipment and piping are to be as noted on the P&IDs.

The types of hydrostatic vents and drains, e.g., single block or double block, are specified in the piping classes. The correct type must be detailed in the model. Hand wheel orientation must be shown.

Ensure that the valve body is clear of the insulation and that drain plugs are 150 mm clear of grade, finished floor or platform.

5.18.2.2 Instruction

Process vents and drains

- Process vents and drains are commonly ¾″. At the discretion of the process engineer, for some commodities such as heavy viscous or slurries, it may be appropriate to increase the drain size to match hydrostatic drains per the NPS range listed below. Process will make their ruling during P&ID development.

  Hydrostatic vents and drains
- The size of all vents is ¾″.
- The size of all drains will be as follows:
  - Up to and including NPS 8 lines—¾″
  - NPS 10 and NPS 12 lines—1″
  - NPS 14 lines and above—1½″
- Hydrostatic vents and drains, used for the hydro testing of piping systems, are positioned by Piping. These vents and drains do not need to be added to the P&IDs. Whenever possible the vents and drains should be grouped together, i.e., on the same easting or northing coordinate, and at the edge of modules for ease of use by Operations. Vents are to be placed at all high points and drains are to be placed at all low points within a piping system. A piping system is defined as the complete routing of the line and any branches. See Fig. 5.8A.
- Any valved instrument connection at a high point, such as a PI, is an acceptable alternative to a vent. However, "cracking flanges" at vessel nozzles are not acceptable. In these cases a vent is required prior to the nozzle. In a fitting to fitting situation, i.e., elbow and flange, use an elbolet. It may be required to request the adding of elbolets to the piping classes databases by Material Control.
- Hydrostatic vents and/or drains are required on both sides of a spec break. See Fig. 5.8B.
- Hydrostatic vents and drains are not required on Instrument or Utility Air systems.
- Hydrostatic vents and drains are permanent installations. Valves are not removed and reused elsewhere after testing.

  Bleed connections

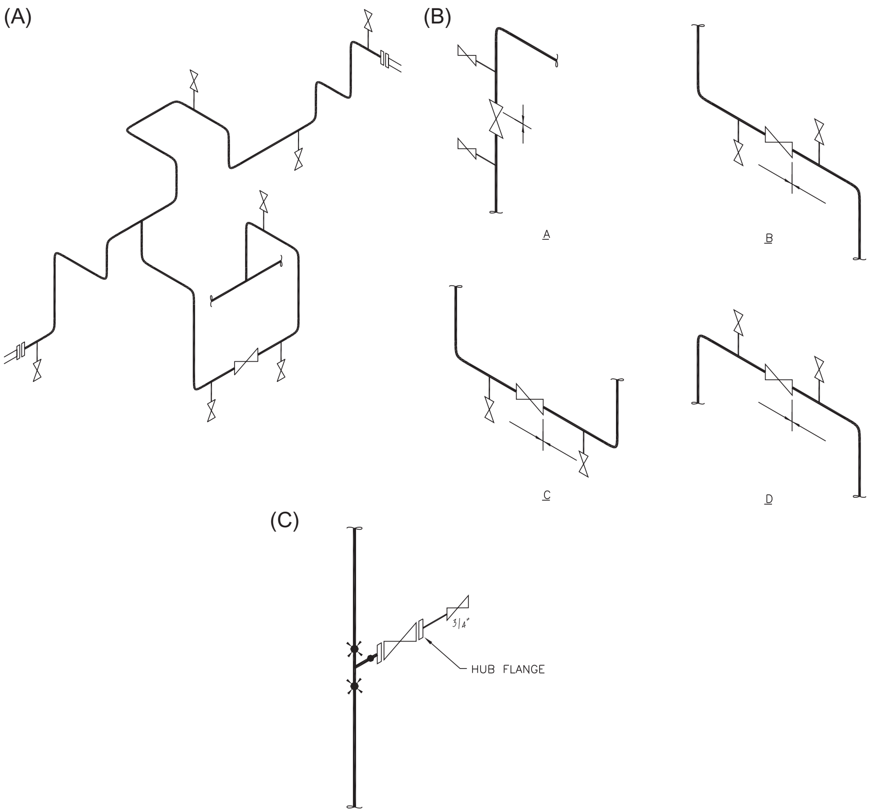

Figure 5.8 Vents and drains.

A type of vent is the "bleed connection," such as those used at a tie-point. These will be ¾″ in all cases. Do not tap blind flanges for bleed connections. Use hub flanges. See Fig. 5.8C.

5.18.3 Weld Diameter Inch reports

5.18.3.1 Introduction

The Weld Diameter Inch (WDI) is an industry recognized unit of measurement used to estimate and progress pipe spool fabrication. This unit of measurement is equal to the NPS of the welded joint. For instance, a butt-welded joint between a NPS 12 fitting and a length of NPS 12 pipe is said to have 12 WDIs. Total WDI counts are obtained by multiplying each NPS by the number of joints of that pipe diameter and then adding the results. Consider a spool with five NPS 12 joints and four NPS 8

joints. Five times 12 equals 60 and four times eight equals 32. Sixty plus 32 equals 92 WDI in total this spool.

WDI reports for bid purposes can be generated from the 3D model databases. However, in order to compare cost estimates between pipe spool fabricators, it is necessary to have a common format and approach to the extraction and application of the data. When done in a consistent manner, the results can be used by the engineering company to independently verify project fabrication costs. They can also be used for historical data comparisons between different projects.

5.18.3.2 WDI reports

The intent of this document is to provide a common methodology for WDI reporting. The simplest of the reports is the overall total WDI report. This report ignores the variances in the pipe wall thicknesses (WTs), types of welds and materials and is referred to as the unfactored WDI report. Due to the lack of detail, these reports are of limited value.

A more comprehensive report that does take into consideration pipe WTs, types of welds and materials is possible. This is referred to as the Factored Weld Diameter Inch (FWDI) report:

- The term "Factored Weld Diameter Inch Report" is a little misleading because it implies that factoring has been done, when in actuality factoring is a separate activity. A FWDI report is a WDI report that has been organized to be conducive to factoring.
- Just as is the case with other reports that are generated from the 3D model databases, the FWDI reports may be divided according to the desired project breakdown. Commonly this would be by EWP.
- As has been previously stated, reporting can be generated from the 3D model databases in a number of ways. For this instruction the FWDI reports are to be organized according to the accumulative total WDI of the welded joints segregated by pipe material, WT, and type of weld. Refer to the following bullets and Figs. 5.9 and 5.10.
- The welded joints are identified in the model database as follows:
    - Butt-welds [AT_BUTTWELD]. These are the connections between butt-weld fittings, flanges, valves, and pipe.
    - O'let welds [AT_OLETWELD]. These are the branch connection welds for weld-o-lets, sock-o-lets, and thread-o-lets on headers and main pipe runs.
    - Re-pad welds [AT_REPADWELD]. These are the branch connection welds for stub-ins with re-pads on headers and main pipe runs.

	Weld Inches (FWDI)				
File Name	Description	Field Weld Inches	Shop Weld Inches	ModYard Weld Inches	ModYard >12m Pipe Weld Inches
DET-NL1-A04-401-2-02-ZZ.DWG	BUTT-WELD	0.0	8.0	0.0	0.0
		8.0	0.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	0.0	8.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		8.0	0.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		0.0	8.0	0.0	0.0
		16.0	104.0	8.0	0.0
	PIPESMLS	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0
		0.0	0.0	0.0	24.0
		0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0
		0.0	0.0	0.0	24.0
	Total	16.0	104.0	8.0	24.0
Total	Total	16.0	104.0	8.0	24.0

Figure 5.9 FWDI report.

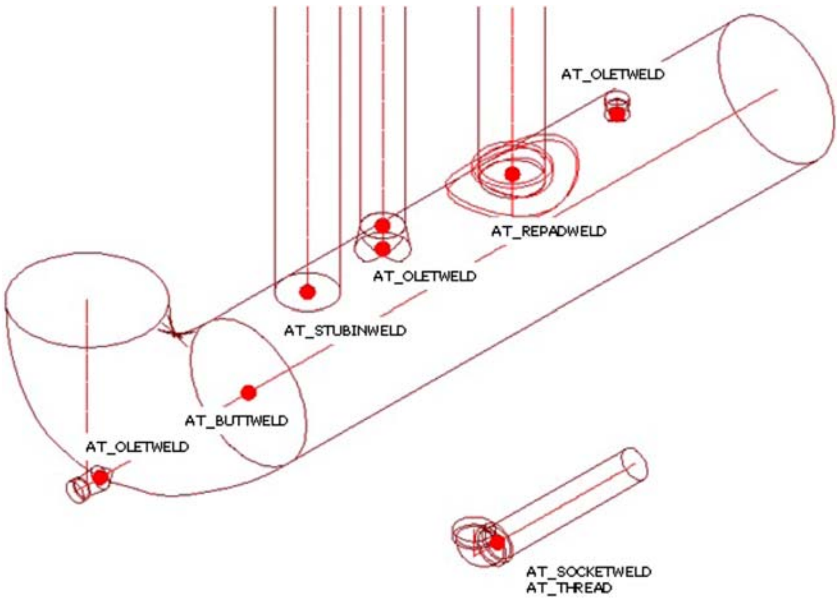

Figure 5.10 Welded joints.

- Stub-in welds [AT_STUBINWELD]. These are the branch connection welds for stub-ins without re-pads on headers and main pipe runs.
- Socket-welds [AT_SOCKETWELD]. These are the connections between socket-weld fittings, flanges, valves, and pipe.

- The pipe materials are collated from the piping classes, e.g., ASTM A106B.
- The pipe WTs are also collated from the piping classes, e.g., the WT for NPS 2 is XS wall and for NPS 3 to NPS 24 the WT is STD wall.
- The types of weld (shop and field) are identified in the models by the designers.

5.18.3.3 Factoring

Factoring is the multiplication of a benchmark to determine the cost and/or manhours required to complete similar work. For piping fabrication the benchmark is commonly 1 WDI of standard wall (STD) CS pipe with factoring applied to heavier pipe walls and alloys because these require more time to complete. As an example, a NPS 6 CS pipe with standard wall thickness (0.280″) requires 6 WDIs worth of work

PIPE SIZE	PIPE SCHEDULE										
(Inches)	20	40	STD	60	80	XH	100	120	140	160	XXH
2		1.0	1.0		1.2	1.2				1.6	2.1
3		1.0	1.0		1.2	1.2				1.7	2.1
4		1.0	1.0	1.1	1.2	1.2		1.4		1.8	2.2
6		1.0	1.0	1.1	1.2	1.2		1.6		2.2	2.5
8	0.7	1.0	1.0	1.1	1.3	1.2	1.5	1.8	2.1	2.3	2.5
10	0.7	1.0	1.0	1.2	1.3	1.2	1.6	1.9	2.3	2.6	
12	0.7	1.1	1.0	1.3	1.5	1.2	1.8	2.1	2.4	2.8	
14	0.8	1.1	1.0	1.4	1.7	1.2	2.1	2.5	2.8	3.2	
16	0.8	1.2	1.0	1.5	1.9	1.2	2.4	2.8	3.3	3.7	
18	0.8	1.3	1.0	1.7	2.2	1.2	2.7	3.2	3.6	4.1	
20	1.0	1.4	1.0	1.9	2.4	1.2	3.0	3.5	4.1	4.6	
24	1.0	1.6	1.0	2.3	2.9	1.3	3.6	4.3	4.9	5.6	
30	1.3	1.7	1.0			1.3					

Figure 5.11 Weld factor table.

to butt-weld, whereas a NPS 6 SS pipe with Sch. 80S wall thickness (0.432″) requires in the range of 14 WDIs to butt-weld. In other words, the latter weld requires a factor of 2.3 times longer to complete.

It must be noted that there are neither industry standards as to what work is included in 1 WDI of STD wall CS pipe nor the factors to be applied to heavier walls and alloys. The activities included and the factoring to be used has to be decided at a project level and captured in factoring tables to be applied by the estimators. Fig. 5.11 is an example of a Weld Factor Table for CS pipe. The following are the activities that may be included in WDI unit pricing:

- Labor for cutting, beveling, fit-up, and welding
- Handling charges for unloading materials; moving materials and spools around the shop; loading spools
- Hydro testing

Because of the differing testing requirements in the piping classes due to the differing pipe WTs, materials, and service, some of the activities that may not commonly be included in WDI unit pricing are as follows:

- X-ray and other NDE testing
- Stress relieving (PWHT)

Fillet welded on supporting attachments, such as shoes, dummy legs, and base ell supports, is not considered in the WDI reports. Reports for these are generated by item tag number and are best estimated by unit pricing from the standard fabrication details. These include the following:

- Base Ell Supports
- Dummy Legs
- Re-Pads
- Shoes
- Trunnions

Other factors that can have an impact on cost and progress are as follows:

- The complexity of the spools. Those with changes in direction and branches require more handling and more position welding (as opposed to roll welding) than straight run spools.
- The length and weight of the spools. Longer and larger diameter spools are less maneuverable and require more crane use. The terminology "longer" and "larger" are difficult to define, but longer than 6 m and larger than NPS 12 and above are a fair generalization.
- The capability and experience of the fabrication shop to handle the work.

5.18.3.4 Summary

While factoring itself may be somewhat nebulous, a consistent approach to FWDI report generation will aid in cost comparisons.

5.18.4 As-built mark-up procedure

5.18.4.1 Introduction

This procedure sets out the minimum expectations and requirements for as-built mark-ups which must be met by contractors:

- Drawings are delivered to contractors as assembled project drawing packages (e.g., plot plans, key plans, and LDTs) and construction drawings within the EWPs.
- All IFC drawings defined as critical by the project must be as-built.
- There are two possible turn-over conditions: "As-Built" and "As-Built No Change."
  - As-Built mark-ups are those drawings marked up to show changes that have been made to the IFC designs during construction.
  - As-Built No Change are those drawings where the completed installation is exactly as shown in the IFC designs.

5.18.4.2 Instruction

- Mark-ups must be done by personnel with discipline knowledge. This requirement is to ensure that the appropriate drafting symbols are used

for the drawing type and that unnecessary or irrelevant mark-ups are avoided.

- Mark-ups must be on the appropriate document type. For instance, mark-ups captured on a piping arrangement that belong on a P&ID must be copied to the P&ID.
- Do not use white out. Where needed, stroke out the design and draw a detail to one side with a leader arrow pointing to the area of change. Alternatively, draw the detail on a separate sheet as an attachment to the marked-up drawing. Make reference to the separate detail on the drawing and vice versa.
- When applicable, note the number of the RFC, RFI, or FCN that initiated an IFC change.
- Mark-ups must be clearly legible. Mark-ups that are smudged and/or weather-beaten are not acceptable and will be rejected. It is suggested that the initial working copy field mark-ups be copied to a clean set of drawings for turnover.
- All mark-ups must carry a red ink "As-Built" or "As-Built No Change" stamp with the following information:
  - The name of the company
  - The date
  - The name (block capital letters) and the signature of the person responsible for the mark-up
- The following colors shall be used for mark-ups:
  - Red—Information to be added or changed by the drafter on the revised as-built drawing.
  - Green—Information to be deleted by the drafter from the revised as-built drawing.
  - Blue—Notes or instruction to the drafter.
  - Yellow—Information that has been verified by the contractor as having been correctly installed per the IFC drawing.

This last job note is an example of the type of instruction that a piping lead may be required to write in support of construction, and is a perfect segue into the final two chapters.

CHAPTER SIX

Shop Fabrication

6.1 INTRODUCTION

During the course of the project a contractor or contractors will be engaged for shop fabrication of pipe spooling and, if also utilized on the project, module fabrication and assembly.

At many companies and on many projects a close working relationship between the piping lead and the shop contractors is a given responsibility of the lead. However, as each project and project manager have different requirements, the lead's services may vary from a minimal involvement, such as contributing to the Scopes of Work (SOWs) and responding to Requests For Information (RFIs), to a significant liaise role. Therefore, you will need to discuss the level of involvement that you will have with the contractors, with each project manager, and his/her expectations of you on a project by project basis.

In this chapter I will discuss the benefits to the project when a close working relationship exists between the piping lead and the contractors and the role of the lead in this process. Working closely with the contractors is required of all piping leads sooner or later.

You should build a rapport with all of the contractors, and if possible visit with them on a regular basis. A close working relationship will pay dividends to the project in terms of resolving problems and addressing potential problems.

As the piping lead, you will interact with and provide a number of services for the project management team in support of fabrication:

- Attend the kick-off meetings
- Provide fabrication and assembly SOWs
- Provide instruction to the contractors
- Respond to RFIs and Requests For Change (RFCs)
- Visit with the contractors at their place of business

Prior to the contract awards and these meetings you will be required to have input into the piping SOWs, if not write them entirely. You

The Planning Guide to Piping Design.
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should meet with the construction manager and discuss his or her requirements for shop fabrication drawings, and spool identification and module identification markings.

Based on your meeting with the construction manager, you should write an instruction for the spooling fabricator on the drafting aspects of the scope as a supplement to the SOW and explain what will be provided to them and what will be required from them. This will cover the drafting of spool sheets and will contain information not covered in the SOW. Later in this chapter is an example of an instruction given to the spooling fabricator.

6.2 KICK-OFF MEETINGS

Kick-off meetings will be conducted with every successful spooling fabricator and module assembler prior to the commencement of work. These meetings introduce the contractor to the project, the organization, the key contacts, the scope of the work, the expectations, and also allows for questions and clarifications. Generally these meetings will cover

- Introductions
- Content of the Engineering Work Packages (EWPs)
- The Scope of Work (SOW)
- Materials and services, i.e., client supplied and contractor supplied
- Quality Assurance and Quality Control (QA/QC) requirements
- Inspection requirements
- The schedule
- The request procedure, RFI and RFC
- Report requirements
- Contact information
- Expediting
- Contracts and administration

The common representation from your company will be the project engineer, QA/QC coordinator, contracts administrator, purchasing agent, construction manager, and shop inspector. Your company is the client to a contractor, and his/her manager, a project engineer, and other senior management types will commonly represent the contracting company.

It is not a sure thing that a contractor will bring his/her drafting manager. The drafting manager is the person responsible for receiving your drawings,

interpreting them, and creating the shop fabrication drawings, and consequently you will need to speak with him/her. Discuss the importance of the drafting manager of each contractor being present at these meetings with your project manager and have him/her request their presence.

In the meetings with the contractors you will need to explain any instruction and establish their drawing and model requirements:

- What CAD system are they using? Some contractors will have the ability to work with imported files from the 3D models to automatically generate spool sheets, just as your piping department has the ability to automatically generate isometrics.
- If the contractor cannot work with the imported model files, they may still be interested in receiving the models in a viewing file format for planning and information purposes.
- Do they have the capability to conduct a model walk-through? That is, do they have viewing software and a conference room set-up with a large screen monitor? This is useful for reviewing the EWP models when you visit.
- Should the contractor have the ability to work with the imported files and/or the models, you will need to secure the name of the individual that will be responsible for receiving them. You will have to establish contact between that individual and your own CAD support manager for issues surrounding the imported files and viewable 3D model files. Make sure that you will be copied on all correspondence between them.
- Confirm the contractor's requirements of size and the number of copies of the drawing packages. The ANSI B or ISO A3 reduced size copies of the piping arrangements are sufficient for reference, but many fabricators will want full size ANSI D or ISO A1 size copies for the shop to work with.
- Review the pertinent piping specifications and standards, and explain the requirements of your spooling instruction.

6.3 SCOPES OF WORK (SOWs)

The SOWs must describe in detail the work that the contractor is to do. It must also describe the work that is not within the contractor's scope. It

is apparent that the contents of a document of this nature cannot be decided at this point in the project. It is also apparent that in order to write this document you must have intimate knowledge of the construction and purchasing strategies. It is for these reasons that in the previous chapters we have discussed the importance of setting up and running your project according to the project execution plan, the construction execution plan, the purchasing plan, engineering work package boundaries, model boundaries, drawing boundaries, and shop and field material splits.

The SOW is the culmination of the work you have been planning and executing throughout the project. The contents of the SOW come from the decisions that were made at the beginning and throughout the project. It is most likely that your company will have templates for SOWs that have been used in previous projects that you will be able to modify to suit the requirements of your project.

The following are two examples of SOWs. One is for pipe spool fabrication and one is for module fabrication and assembly. You will notice that they reflect the same shop and field material splits and fabrication splits as discussed in Chapter Five, Detailed Design. They also discuss who is buying which materials. The projects you are involved in may or may not follow the same parameters.

6.3.1 Example of pipe spool fabrication Scope of Work

1. Scope of Work:

Work to be performed under this EWP No. ____________________.

Work includes the following items, all as set forth in the drawings, specifications, and other data:

- Fabricate welded spools of piping components NPS 2 and above in accordance with the attached drawings, line designation tables, piping standards, and specifications.
- Fabrication dimensions are to be taken from the isometrics.
- Field welds (FWs) are indicated on the isometrics. Spools are to be to a maximum shipping box size of 3 mH × 3 mW × 12 mL + or −300 mm as marked up on the isometrics. Should the contractor encounter FW positioning on the isometric that would result in a spool size beyond these parameters, an RFI must be raised.
- Additional FWs that the contractor may deem necessary must be approved first by way of an RFI.

- FWs have no trim allowance. Fabricate spools to exact dimensions.
- Contractor may assume his/her standard weld gap when calculating the cut length of pipe ending in a FW. A BE preparation is required.
- Field fit-up welds (FFWs) are to have 150 mm of additional pipe length for trim allowance. Finished BE preparation is not required.
- Fabricate and install the welded shoes.
- Fabricate clamped on shoes, guides, and anchors. Ship loose.
- Provide a stub for the base ell supports per the standard drawings. Fabricate the remainder of the support per the standard drawings. Ship loose.
- Fabricate the dummy legs, trunnions, and re-pads per the standard drawings. These are welded attachments to the spools.
- Pipe to be painted according to the line designation table requirements.
- Each shipment must be accompanied by a list of the spools and copies of the spool sheets.
- The spool sheets must be signed-off copies indicating the completion of each stage of fabrication and testing. All spool sheets are to include the material heat numbers and the weld mapping.
- Spools must have an aluminum tag (sized 25 mm × 75 mm) tightly wired with SS wire to them with the mark number stamped into the tag. As an additional precaution the mark number should appear on carbon steel spools by way of paint pen writing, and stainless steel spools by way of an approved marker (felt style marker with less than 50 ppm chloride content).
- Shipped loose shoes, guides, and anchors are to be identified by the standard tag number by paint pen writing.
- All documentation to be provided with piping material when released to site by the contractor.
- Method for the material requisitions by the contractor to be determined by contract administration in conjunction with the contractor.
- Excess materials to be shipped to site as determined by contract administration in conjunction with the contractor.
- Turnover package to be provided in whole and as defined by the QA/QC requirements.
- For shipping, arrangements are to be made between contract administration and the contractor.
- All ends of pipe and flanges must be protected for shipping.

2. Work Not Included:

The following items of work associated with this EWP do not form part of the scope of the EWP:

- Hydro-testing
- Assembly and erection of spools and nonwelded attachments
- Insulation and tracing
- Fabrication of heat tracing manifolds

3. Supplied Materials:

The following materials will be supplied for incorporation into the work:

NPS 2 and above:

- Pipe
- BW fittings (tees, elbows, and caps)
- WOLs
- Flanges (WN, SO)
- BW valves
- BW specialty items
- BW instruments

Except for those items specifically listed above, the contractor will be responsible for supplying all materials required to complete the work of this EWP.

4. Schedule:

Work of this EWP shall be performed in accordance with the following schedule:

- Work shall commence on or about _______________.
- Work shall be completed on or about _______________.

5. Drawings, Specifications, and Other Data:

Work shall be performed in accordance with the drawings (signed and stamped "Issued for Construction"), specifications and other data attached hereto and listed below:

A pipe spool is a portion of a piping system limited in its dimensions for ease of handling and shipping. The spools consist of the welded components in the piping system with naturally occurring breaks at the flanges and introduced breaks at fittings in the form of FWs. Fig. 6.1 is a photograph of an individual spool in a pipe fabrication shop and Fig. 6.2 is a photograph of multiple spools on a trailer loaded for shipment from the fabrication shop to the field.

Figure 6.1 Photograph of finished spool. *Printed with the permission of Pepco Pipe Services, Edmonton, Canada.*

Figure 6.2 Photograph of spools loaded for shipment. *Printed with the permission of Pepco Pipe Services, Edmonton, Canada.*

6.3.2 Example of module fabrication and assembly Scope of Work

1. Scope of Work:

Work to be performed under this EWP No. ____________________.

Work includes the following items, all as set forth in the drawings, specifications and other data:

- Complete fabrication and assembly of the piping systems and structural frames in accordance with the attached drawings, line designation tables, standards, and specifications.
- Spools that cannot be installed, e.g., expansion loops that would bring the module beyond the allowable shipping width, are to be shipped loose attached to the module.
- Installation dimensions are to be taken from the piping and structural general arrangements and isometrics.
- Verify shim height requirements as noted and install.
- Delicate instruments, as identified in attached documentation, are for preassembly only. These are to be removed and crated for shipment to site. Fill the gap with a temporary spool piece for module shipment.
- Should some bolted-in items not arrive in time for shipment, at the discretion of the contract administration, the contractor may be instructed to ship without these items. In this event fill the gap with a temporary spool piece for module shipment.
- Install pipe hangers and spring supports. Spring supports are to remain locked for shipping.
- Hydro-test per specifications and line designation tables.
- Pipe to be painted according to the line designation table requirements and attached specifications.
- Heat trace per the attached drawings, standards, and specifications.
- Insulate per the attached drawings, standards, and specifications.
- Prior to shipping, a final check must be conducted to verify the locations of the connections at the module edge. Should any connections differ in location from the dimensions as noted on the piping arrangements, an RFI must be raised. A decision will be made to either:

  Leave them as fabricated. Adjustments will be made to the connecting piping in the field.

  Adjust in the shop to avoid later field connection problems.

- The module steel must be marked at the base with the module number by way of 100 mm high white paint lettering using a stencil. The "DATUM POINT," as shown on the piping and structural general arrangements, must also be marked clearly on the module base.
- Contractors who create spool sheets must provide these with the final turnover documentation. Contractors who work to the isometrics must mark up a set of isometrics with any as-builting, material heat numbers, and weld mapping.
- Method for material requisitions by the contractor to be determined by contract administration in conjunction with the contractor.
- Excess materials to be shipped to site as determined by contract administration in conjunction with the contractor.
- Turnover package to be provided in whole and as defined by the QA/QC requirements.
- For shipping, arrangements are to be made between contract administration and the contractor.
- Temporary strapping, hold-downs, and bracing for shipping are to be determined by the client inspector in conjunction with the contractor. These are to be painted bright red for easy identification and removal at site.
- All ends of pipe and flanges must be protected for shipping.

2. Work Not Included:

The following items of work associated with this CWP do not form part of the Work of the EWP:

- Final erection at site

3. Supplied Materials:

The following materials will be supplied for incorporation into the work:

NPS 2 and above:

- Pipe
- Fittings (tees, elbows, and caps)
- WOLs
- Flanges (WN, SO)
- Valves
- Studs, nuts, and gaskets
- Specialty items
- Instruments
- Pipe hangers

- Spring supports
- Structural steel members.

Except for those items specifically listed above, the contractor will be responsible for supplying all materials required to complete the work of this EWP.

4. Schedule:

Work of this EWP shall be performed in accordance with the following schedule:

- Work shall commence on or about ________________.
- Work shall be completed on or about ______________.

5. Drawings, Specifications, and Other Data:

Work shall be performed in accordance with the drawings (signed and stamped "Issued for Construction"), specifications, and other data attached hereto and listed below:

A module is a completely assembled and tested unit consisting of all piping, equipment, steel, tracing (cold climates), instruments, instrument tubing, and electrical components allowed within a predetermined size. A module is built in a module fabrication shop and is shipped to the field for final installation. The dimensions of a module are limited by the type of transportation, e.g., truck, rail, barge, and the height, width, length and weight restrictions imposed by the transportation corridor and jurisdictions that the module will pass through. Fig. 6.3 is a photograph of a piperack module being loaded for shipment. Fig. 6.4 is a photograph of a piperack module starting the journey from the module shop to the field. Fig. 6.5 is a photograph of an equipment module ready for shipping.

6.4 INSTRUCTION TO THE SPOOLING FABRICATOR

SOWs outline specifically the "what" aspect of the work. There are times when it is necessary to outline the "how" aspect of the work. Each spooling fabricator will have his/her own procedures, and while the outcome may be very similar, the differences could cause some difficulties for construction. It would not be efficient to have different approaches to the mark numbering, the spool sheet drawing content, and the spool drawing package assembly. When you are dealing with multiple fabricators it is best to assert control over these details and provide guidance.

Figure 6.3 Photograph of a piperack module being loaded for shipment. Notice the temporary shipping steel at the front of the module.

Figure 6.4 Photograph of a piperack module being shipped. Notice the fire proofing and shipping beams to raise the module steel off of the truck bed due to the piping that exits below the lowest level of the module.

Figure 6.5 Photograph of an equipment module ready for shipment.

The written instruction to the spooling fabricator is to ensure consistency.

Instruction of this nature is not commonly required for the module fabricators because their scope includes complete fabrication and assembly, whereas the spools are often handed over to a different contractor for erection.

As with the SOWs, the following example reflects the same shop and field material splits and fabrication splits as discussed in Chapter Four, Deliverables.

6.4.1 Example of instruction to fabricator

1. Introduction:

This document is to inform pipe spool fabricators of the additional requirements beyond the SOW for spool sheet drafting, and to provide information on the drawing packages and the engineered piping drawings.

It gives instruction and guidance on expectations to ensure a consistent deliverable for QA/QC and field construction. While every attempt has been made to provide clarity to fabricators, it is likely that

the need for further questions or clarifications may arise. Questions and clarifications will be answered by way of an RFI. In the event that the information contained herein differs from the instruction in the SOW, then the latter shall govern.

2. Engineered Drawings:

Piping arrangements and isometrics are issued in the EWPs. Each EWP drawing package comes with a transmittal, a SOW, a drawing cover sheet, and a drawing index. Fabricators are responsible for reviewing the drawings provided against the transmittal and the drawing index to ensure that they have all the drawings at the listed revisions.

Issues arising during fabrication that require a change or deviation from the design must first be cleared by way of an RFI. Note that a EWP contains a complete set of all drawings required for the entire fabrication and erection of the piping systems, and may well contain drawings that are not part of the pipe spool fabricator's SOW. Primarily this would be NPS 1½ and below socket weld and threaded piping.

- There are piping plans only. No sections.
- Piping arrangements have minimal dimensioning for reference and are to be read in conjunction with the isometrics which are the governing documents.
- Fabrication dimensions are to be taken from the isometrics.
- Material is listed in the bill of material on the right-hand side of the isometric.
- Materials are listed as "SHOP" or "FIELD." These are a construction split, not a material purchase split. SHOP materials are those required in the shop. Some of the shop materials are client supplied and some are fabricator supplied. FIELD materials are those directed straight to the field for later completion/erection of the piping system.
- For complete instruction on client supplied and fabricator supplied materials see the SOW.
- The isometrics indicate the required FW and FFW locations.

3. Spool Sheets (Fabrication Drawings):

- Spooling only applies to NPS 2 and above butt-welded piping. The components of a spool are the butt-welded fittings and flanges, welded on branch connections, e.g., WOL, TOL, and SOL, and welded on attachments, e.g., dummy legs and shoes.

- Other than that noted in the following two bullets and within the SOW, ignore any isometrics of NPS 1½ and below piping.
- All NPS 1½ and below SOL and TOL branch connections are full penetration weld attachments to the NPS 2 and larger spools, and as such are considered part of the shop spooling.
- All swages NPS 2 and above times NPS 1½ and below require a butt weld at the large bore end, and as such are considered part of the shop spooling.
- It is not allowed to have multiple spools detailed on one drawing. Each spool must have an individual spool sheet.
- The mark number must appear in the drawing title block. Each spool sheet must have a revision number starting at Rev. 0.
- The drawing number and the revision number of the isometric that the spool sheet has been drawn from must appear as a reference within the title block.
- The project name must appear in the title block.
- A complete bill of material and heat numbers must appear on the right-hand side of the drawing.
- A "North Arrow" must appear in the upper left-hand corner of the drawing. Spool orientation and the north arrow (commonly up and to the left) must be drawn to the same orientation as the isometric.
- All components must be shown on the spool sheet and accurately located by a dimension from a reference point, e.g., from the centerline of an elbow or tee, or from face-of-flange. This includes all items that are welded attachments such as shoes, and shipped loose items such as guides and anchors. Do not show items that are not part of the spooling SOW, e.g., bolts, gaskets, flanged valves, and flanged instruments.
- Shipped loose items (e.g., anchors, guides, and base ell supports) will be identified with a leader arrow and the notation "FIELD WELD."
- Drawing continuation references to the adjoining spool sheets or to equipment is required.
- All QA/QC information, as has been determined by the QA/QC coordinator, must appear within the title block of the spool sheet.

4. Spool Mark Numbering:

- The spool mark numbering that is to be used by all fabricators is indicated on the isometrics. A control number may be assigned by the fabricator, but must be marked up on the close-out set of isometrics.

- Should a spool be added, as will be the case when an additional FW is added, the fabricator is to renumber the mark numbers on the isometric as an as-built.

5. Shipping:
    - Provide a list of the spools and a copy of each spool sheet of the spools being shipped.
    - Shipped loose items will carry the same mark number as the spool they are associated with, i.e., the spool sheet they appear on.
    - In addition to the other required QA/QC documentation, at the completion of each EWP the close-out must be accompanied by a spool sheet drawing list, the spool sheets and marked-up isometrics indicating the assigned spool mark numbers and any as-builting.
    - The spool sheets must be signed-off copies indicating the completion of each stage of fabrication and testing.

In order to check that the fabricators understand your instruction, you should request that they send you copies of the first few spool sheets that they produce for your review and comment. Fig. 6.6A, B are examples of a spool sheet.

6.5 REQUESTS

RFIs and RFCs must be handled as a high priority. Any delays in responding to the spooling fabricator or module assembler can be a cause for delay to the schedule. Occasionally a contractor may run into problems maintaining the schedule, and you do not want to become the target of a ready-made excuse for a delay.

6.6 VISITS WITH THE CONTRACTORS

6.6.1 The value of shop visits

Shop visits to the contractors are very beneficial to the project. There is nothing like face-to-face meetings to build rapport and trust. You will find that the contractors will have a whole string of questions for you each time you visit. While RFIs are a very needed and important

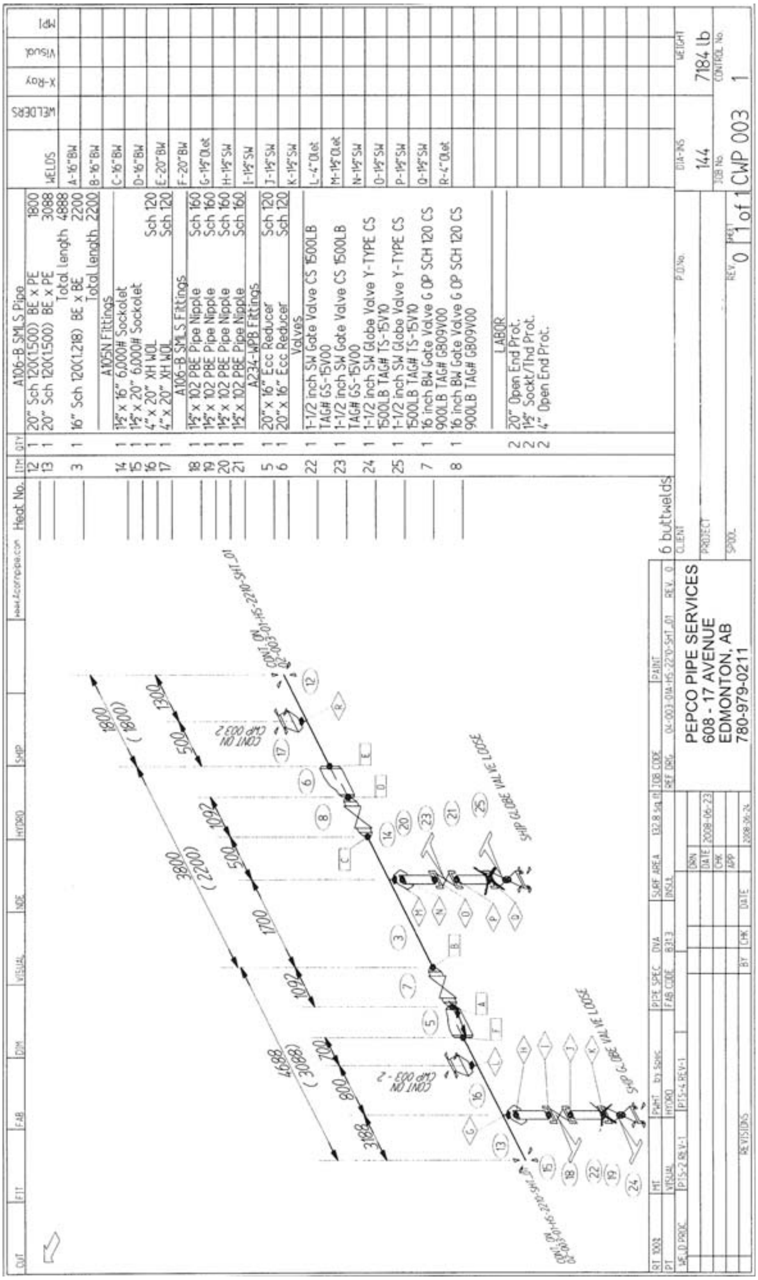

Figure 6.6 (A, B) Spool sheet examples. *Printed with the permission of Pepco Pipe Services, Edmonton, Canada.*

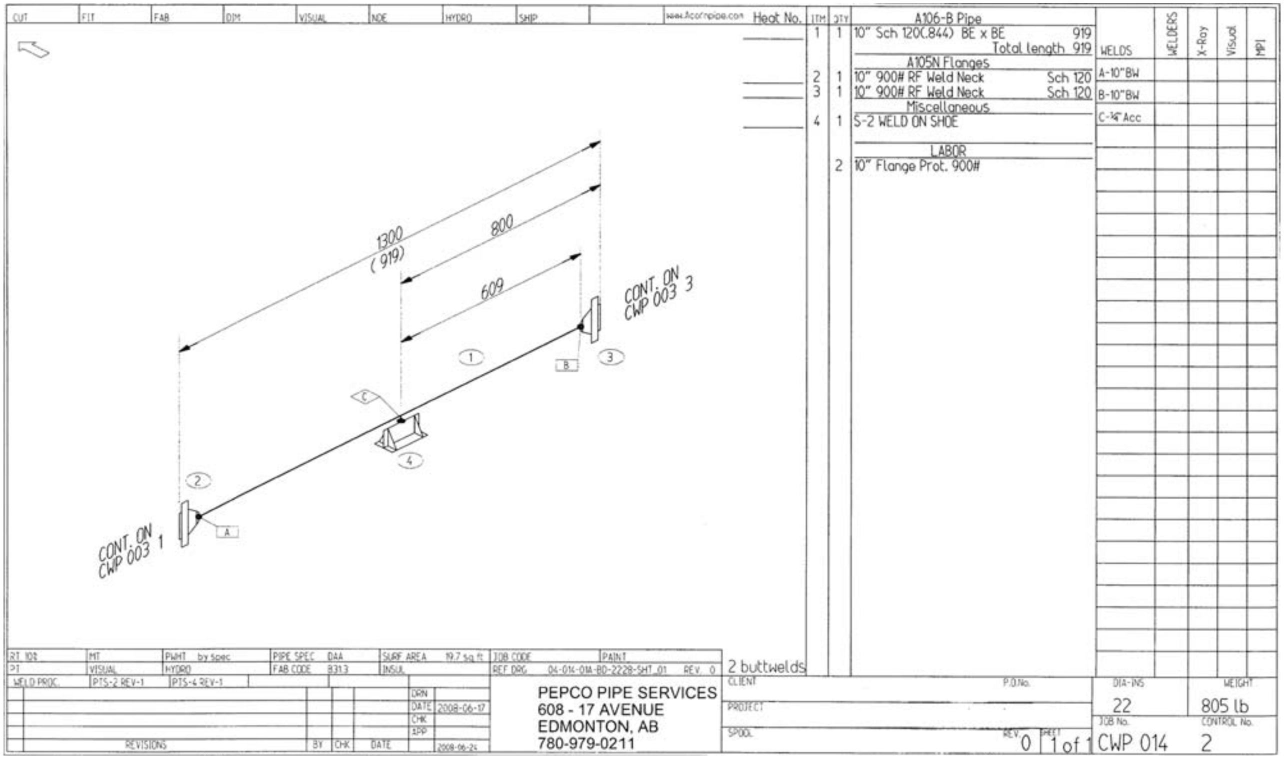

Figure 6.6 (Continued)

procedure, every question does not need to go through the RFI formality. Sometimes all that is required is a small clarification, especially when people are on the right track and are only looking for some confirmation. Without these visits and the rapport that allows for a quick phone call, the only option open to the contractor is the RFI. This can be time consuming for everyone, both on the contractor's side and the engineering company's side. Rather than going through the delay to get an answer, the contractor may be inclined to make an assumption.

You may wonder what you are going to talk about at visits, but topics will come up that would not have otherwise surfaced, or at the least not surfaced for some time to come.

Here are few stories for you:

> I accompanied a project engineer on the first visit to a spooling fabricator. The fabricator's project manager and drafting manager claimed in our meeting that the Material Take-Off (MTO) report received from the engineering company was deficient. The MTO report that the drafting group had compiled indicated that there was a substantial material shortage, and the project manager asked my project engineer to approve that the fabricator be allowed to purchase these deficiencies.
>
> We brought the fabricator's designer, who had compiled the MTO, into the room with the drawings he/she had used for this task. The drawings had both module and field erected piping shown on one set of piping arrangement drawings, and the reason became immediately apparent. This fabricator's scope was for spooling of the field erected piping only. Although there was a demarcation line indicating field on the one side and module on the other, the fabricator had missed this and had done his/her MTO for both module and field piping. The drafting group had also started to draw the shop spool sheets for all of the piping. Obviously, this would have been resolved through an RFI, but the fact that we were there on the spot resolved this quickly and without further time being wasted. It is for reasons such as this that I am so adamant about separate EWPs, models, and drawings.
>
> On another occasion at a module assembler's shop, I was walking around observing progress and I noticed what appeared to be some overly large fillet welds on gusset plates placed within the web of the wide flange steel columns and beams of a module. When I asked about them, I was shown the shop set of the engineering company's structural standards. A simple misinterpretation of a note on a standard

had the assembler's welders over-welding every gusset plate. Instead of an 8 mm fillet weld they were making the welds 16 mm, which in some cases were closer to 20 mm. I estimated that had this error not been caught it would have amounted to an extra $300,000 in time alone over the course of the EWP they were working on. As this was a time and materials contract, the client would have most likely ended up paying for it.

The structural engineer ordered that some NDE be conducted and everything proved to be acceptable. If repairs had been required it would have been at the assembler's cost; however, the potential schedule delays and the associated disruptions would have been borne by the project.

On yet another occasion, at the first visit with a spooling fabricator, I was informed that the fabricator had started the fabrication and I asked to see the first batch of approximately 30 spool sheets that they had created. Somewhere along the way the fabricator's designers had misinterpreted the isometrics and other information and were detailing every FW as a field fit-up weld with 150 mm of extra pipe. When I commented that this was an error the drafting manager was so sure of his group's interpretation that he disputed my words. There was no intent to raise an RFI for clarification on this.

Had I not been there to point out this error at an early stage it may have gone unnoticed and unchallenged until the inspector came. There would have been a schedule delay to bring all of the spools back through the shop to cut and prep the ends. I am not so sure that an inspector would have picked up on this, in which case the spools would have been in the field before the error surfaced. This error could have ended up being a significant dispute over back charges.

It is important to recognize that issues are often brought forth and resolved through an RFI, or are eventually caught through inspection or surface in some other way. The point is that you will have a history and working knowledge of the project that is very valuable in recognizing and heading off issues before they arise, but you will never know unless you are there to see the fabrication for yourself.

6.6.2 Supporting the contractors

The contractors will be well structured in the moving of spools and modules through their shop, and there is likely to be little that you can help

them with in this regard. Most of the people you will deal with come from a welding and construction background. The spooling and module assembly expertise of the contractor's lies primarily in knowing the construction side of the business, e.g., codes, regulatory requirements, welding procedures, materials, weld mapping and NDE testing, for which they will have procedures for managing and tracking.

Where you will be of benefit is with your knowledge of the history of the project and your experience as a senior piping designer in general. Just as you may lack the depth of knowledge in shop fabrication and assembly that they have, they may lack the depth of knowledge that you possess in the designing and drafting aspects. This can make for a very mutually beneficial relationship. You may discover and correct misinterpretations in the conclusions drawn by the contractors' own drafting teams that had they remained unnoticed, would have found their way into the shop causing rework for the contractor and delays for the project.

The first meeting you have should follow shortly after the kick-off meeting once the contractor has had a chance to digest the contents of the EWP. The chances are that you would not attend this first meeting alone. At the least, you will have the project engineer in attendance with you because many of the questions are going to be about schedule and material deliveries; questions that you should not be answering. For subsequent meetings that become more focused, you may be on your own.

Your role in the first and subsequent meetings is to gauge the contractor's understanding of the EWP and assist the contractor to resolve any difficulties they are having with interpretation of

- the engineered drawings
- the vendor drawings
- the standards drawings
- the piping classes
- the SOW
- MTO and other reports generated from the 3D model databases
- EWP and 3D model numbering convention

There will be other ways in which you will work with them, depending on need. Some may be mandated by the project, such as double checking the dimensional accuracy of the spool sheets of the more expensive piping. While it is not common, on some projects it is considered prudent that you have the fabricator's spool sheets checked independently by your piping group for such as high pressure and alloys piping.

Some ways of working with the contractors will occur naturally as a consequence of being there, and you may find that you start falling into a consultant role. Offering help outside of your responsibilities to the project will be a judgement call. For instance, you may be able to offer advice on a drafting or checking procedure to the drafting manager. While this would not be a requirement, it would be a friendly gesture that builds the rapport and helps the integrity of the project.

There will be times when you will have to go above and beyond the call of duty for the sake of the project. You will encounter contractors that are struggling for one reason or another, and in the interest of keeping the project on track you may feel the need to offer some additional help to a contractor that is falling behind, as long as those reasons are within your sphere of influence. This might be in the way of short-term help, for instance, checking to help move things along, or longer term help such as assigning someone from your team to work in the contractor's shop. This is extremely rare, but not unheard of.

The above is applicable to all contractors whether they are utilizing 2D CAD or 3D CAD. However, 3D software comes with other challenges, and if the contractor is new to the use of 3D, he/she may be struggling with your models and the software. In this regard, providing additional short-term help to assist the contractor in CAD support may be the answer.

6.7 AUTOMATIC SPOOL GENERATION

Many contractors utilize automatic spool generation. Just as engineering companies are automatically generating isometrics, likewise the contractors will generate the spool sheets from the same models as the isometrics are generated. This is a handover that makes perfect sense. When something is copied from one format to another, mistakes will happen. Working with imported files from the engineering company's models will negate the possibility of mistakes being made by the contractor's spooling drafters due to copying information from the isometrics. The fabricators will still have to add information to the spool sheets such as material heat numbers, NDE testing, and weld mapping, but utilizing automatic spool generation will save time and money just as automatic isometric generation has done for the engineering companies.

Having said the above, a consideration for the engineering company when handing over model files to a contractor is to ensure that contractually the contractor is still obligated to check their spool sheets against the IFC isometrics. This is to be needed in order to avoid any disputes over accountability should it surface later that there are discrepancies between the models and the issued isometrics. While there should not be any discrepancies, it is only correct that the engineering company protects themselves against any liability arising from the utilization of data they are providing as a convenience. Another consideration is for the engineering company to purchase the automatic spooling software and create the spool sheets as part of the EWP deliverables.

6.8 CONCLUSION

While the piping lead's involvement with contractors is highly beneficial to the project, you must be aware of the limitations of your responsibility and authority. There will be times when you will be drawn into discussions concerning topics that will go beyond your mandate, such as the schedule and cost extras or engineering questions. In cases like these you must refer the contractor to the appropriate party and remind him/her that for some issues he/she will have to use the RFI procedure. Never make promises or agreements to help that involve project hours without getting the approval of the project manager first. My previous examples of offering assistance of checking, assigning an individual from your team to assist them, and assistance from 3D CAD support would be such appropriate times.

CHAPTER SEVEN

Field Construction

7.1 INTRODUCTION

There are two aspects of the support provided by the piping lead to the construction management team during construction: the support from the home office and the support in the field.

7.2 SUPPORT FROM THE HOME OFFICE

As with the support that is required for the shop contractors, support from the office for the construction management team will be required to

- attend the kick-off meetings with the field contractors;
- provide piping erection Scope of Work (SOW);
- identify computers, 3D software set-ups, and maintenance requirements;
- respond to Requests For Information (RFI) and Requests For Change (RFC);
- update the drawings and the 3D models with the as-built information.

7.2.1 Kick-off meetings

The kick-off meetings with the field contractors are like the previously discussed meetings with shop fabricators, with the exception that your attendance will be on an as needed basis. This is due to the fact that the custody and responsibilities for the completion of the work have been transferred to the construction management team from the engineering team. Unless you are assigned to the field, your involvement in the issued Engineering Work Packages (EWPs) is more-or-less finished. This is not to say that a rapport with the field contractors is not every bit as beneficial as that with the shop fabricators, but due to the transference of

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responsibility you may have to be assigned to the field to have that same level of involvement.

7.2.2 Example of field erection of piping Scope of Work

We have discussed the SOWs for pipe spool fabrication and module fabrication and assembly. This last example is for the erection of the spools. It reflects the same shop and field material and fabrication splits, and material purchase splits as in the previous SOW examples.

7.2.2.1 Example of field erection of piping Scope of Work

1. Scope of Work:

Work to be performed under this EWP No. ____________________.

Work includes the following items, all as set forth in the drawings, specifications, and other data:

- Install the welded spools of piping components NPS 2 and above in accordance with the attached drawings, line designation tables, piping standards, and specifications.
- Install the lined piping and fittings, all NPS sizes, in accordance with the attached drawings, line designation tables, piping standards, and specifications.
- Field run all NPS 1½ and below piping in accordance with the attached drawings, line designation tables, piping standards, and specifications.
- The scope of the work is defined by the isometrics.
- Installation dimensions are to be taken from the piping arrangements and isometrics.
- Field welds (FWs) have no trim allowance. Weld spools to exact dimensions.
- FFWs have 150 mm of additional pipe length for trim allowance. Field check the dimensions on the piping arrangements and isometrics and cut-to-suit. Prepare the BE and weld in place.
- Install the vent, drain, and pressure connection assemblies.
- Install the shipped loose shoes, guides, and anchors.
- A stub has been provided for base ell supports. Set the piping at the required elevation and complete the installation as per the standard drawings.
- Verify shim height requirements as noted and install.

- Install the field supports (miscellaneous structural steel, "U" bolts, etc.) as detailed in the attached drawings and piping standards.
- Install all instruments not included in the spools. Primarily, these will be the inline bolted instruments.
- Install all specialty items not included in the spools. Primarily, these will be the inline bolted specialty items.
- Install all flanged valves.
- Install the pipe hangers and spring supports.
- Install the heat tracing manifolds.
- Hydro-testing will be performed by the installation contractor.
- Mark up a set of isometrics with any as-builts, material heat numbers, and weld mapping.
- Mark up a set of P&IDs and Line Designation Tables with any as-builts.
- Method for material requisitions by installation contractor to be determined by contract administration in conjunction with the installation contractor.
- Turnover package to be provided in whole and as defined by QA/QC requirements.

2. Work Not Included:

The following items of work associated with this EWP do not form part of the Work of the EWP:

- The repair of painting for any welds performed on painted pipe will not be required by the installation contractor.
- Insulation and tracing.

3. Supplied Materials:

The following materials will be supplied for incorporation into the work:

- Prefabricated spools NPS 2 and above
- Prefabricated lined pipe and fittings, all NPS sizes
- Prefabricated heat tracing manifolds
- Prefabricated anchors, guides, clamp-on shoes, and base ell supports
- Flanged valves NPS 2 and above
- Specialty items
- Instruments
- Pipe hangers
- Spring supports
- Studs, nuts, and gaskets NPS 2 and above
- Blind flanges NPS 2 and above

Except for those items specifically listed earlier, the contractor will be responsible for supplying all materials required to complete the work of this EWP.

4. Schedule:

Work of this EWP shall be performed in accordance with the following schedule:

- Work shall commence on or about ________________.
- Work shall be completed on or about ______________.

5. Drawings, Specifications, and Other Data:

Work shall be performed in accordance with the drawings (signed and stamped "Issued for Construction"), specifications, and other data attached hereto and listed below:

There are other mechanical SOWs that we have not discussed:

- Erection of equipment
- Installation of bridles and instruments on equipment
- Erection of modules
- Painting of field erected piping
- Tracing of field erected piping
- Insulating of field erected piping

Beyond issuing the EWP drawing packages, it is unlikely that you will have any involvement in these SOWs because they are field activities managed by construction, and in some cases require a specialized knowledge to write.

7.2.3 Computers, 3D software set-ups, and maintenance

It has become standard practice on 3D projects for the models to be utilized during construction. Therefore it will be required to have computers and the 3D software set-ups in the field with skilled designers able to run the 3D software.

You will be involved in the following discussions:

- How many computers will be required?
- How many licenses of the 3D software will be required?
- How many licenses of the 3D viewing software will be required?
- Will there be full time CAD support in the field or will the support be by remote access from the home office?
- The procedures that will be used to interface the models with the field. You do not want the field to have access to the live models. The

access that they have will be to copies of the models, commonly backed-up nightly to their server.

- How many and which of your designers will be assigned to the field to run models and provide the other needed support?

7.2.4 Requests

The RFIs and RFCs sent during construction may originate from the construction team or the field contractors. All will be funneled through the construction team and, as with the request from the shop contractors, all must be handled as a high priority. Any delays in construction can add up very quickly to a lot of money, or, conversely, can be saved by a quick response.

Significant problems will require your assistance to investigate and possibly redesign. The resources do not commonly exist in the field for the field personnel to become distracted by the time requirement of a single major problem. In these cases they may need your support so they can continue to focus their own efforts on the day-to-day activities of construction support.

7.3 SUPPORT IN THE FIELD

As the piping lead in the field, you and your team will support construction in a variety of ways. I have immensely enjoyed the times that I have worked in the field. There is an attitude that everyone can be expected to assist as required to get the job done, and you will gain experience in areas that you are not able to be involved in when working in the office. You will have a defined role, but you can also expect to do anything and everything within your capabilities that will help to solve problems and get results.

I am not suggesting that you or anyone else should ignore safety and be put in harm's way. I am saying that you cannot consider any task as menial and put yourself above it. You will get along famously with the construction team if you are willing to jump in and help wherever it is needed on any given day.

Primarily, you and your team will support construction in the following ways:

- Interpreting the engineered drawings, vendor drawings, standard drawings, and the piping classes and other piping specifications

- Reviewing the SOWs with construction and erection contractors
- Utilizing the 3D models
- Problem solving
- Compiling punch list and deficiency reports
- Compiling and submitting RFIs and RFCs
- Investigating back charges and extras
- Progress monitoring
- Maintaining the master stick files
- As-builting

7.3.1 Utilizing the 3D models

The 3D models will be utilized in a number of ways:

- Generating reports from the models
- Generating screen shots from the models
- Construction planning
- Problem solving

7.3.1.1 Generating reports

There are a number of reports that can be run from the model databases to aid construction. A few possibilities are the following:

- Lengths of pipe, number and types of fittings and valves in a line or system
- Number of FWs in a line or system
- Bulk field material to be purchased
- Number of shoes, anchors, and guides to be installed on a line or system

All reports are generated to assist in the construction planning and execution.

7.3.1.2 Generating screen shots

Screen shots are generated to assist the erectors in understanding the layout. You will find that contractors will come to you for help on the interpretation of the drawings. Sitting with them for a few minutes and going through the model of the area in question to produce a few hard copy screen shots that they can take with them will prove very valuable.

7.3.1.3 Construction planning

The 3D models are an indispensable tool for preplanning the construction activities. Models provide the capabilities to isolate individual structures and piping systems, to rotate, change colors, capture screen shots and

comments, and easily visualize the piping and equipment layouts. Several activities that the 3D walkthroughs of the models assist in are as follows:

- Identifying hazards ahead of time to create safe work plans.
- Communication between the operations start-up and commissioning team and the construction team
  - aids both teams to prepare for large scale shutdowns or unit outages to avoid unnecessary down time and/or costly mistakes;
  - gives both teams a chance to review the overall project scope and agree on the best path forward to constructing and commissioning the project.
- Planning the scaffolding. Scaffolding is a large expense for any project, and the models provide the ability to plan ahead to give clear direction to the scaffolding contractors. This avoids later costly modifications and rebuilds. The screen shots that can be supplied to the scaffolding contractors also have a lot of value.
- Planning of erection sequencing.
- Planning of hydro-test packages.
- Reviewing the piping system(s) to be punch listed.

It is hard to imagine planning and executing activities with the drawings alone and without the capability of conducting a walkthrough of the models.

A contractor may wish to have copies of the models to plan the work in his/her own time. There is no reason to not comply with this request. However, you should keep a record of which contractors you have given copies of the models to so that in the event of a model update from the home office, such as an FCN, you can give an updated model to the contractor as well.

7.3.2 Problem solving

All projects will have problems during construction ranging from the significant to the minor, not because the models are inaccurate, but because errors happen in the real world. For instance, spools may have dimensional errors or piling may not be exactly placed, leading to difficulty with fit-up and other problems.

Usually your notification that there is a problem comes in the form of a contractor walking into the construction trailer with drawings in hand. Your job is to listen to the explanation of what appears to be the problem, go with the individual to investigate for yourself, take measurements to identify where the problem lies, and solve the problem. This will take the

form of updating the model with the information gathered, e.g., a pump that is slightly out from the intended location, and creating an isometric sketch with the revised dimensions.

Issues that cannot be easily rectified must be addressed through an RFI.

7.3.3 Punch lists and deficiency reports

When a contractor claims to have completed a piping system it is necessary to walk the lines to inspect the work and create the deficiency reports. This exercise is called punch listing, or moaning the lines. The piping designers in the field are often called upon to assemble a package of drawings for the purposes of the inspection, and sometimes to conduct the inspection. The following is a common approach to punch listing:

1. Prerequisites:

   The following checks must be carried out to ensure that the piping systems have been correctly fabricated and installed. This procedure will ensure that all required rework will be carried out prior to commissioning and start-up.

   The inspector must use the latest revision of the following documents to carry out the inspection:

   - Piping and Instrumentation Diagrams (for reference)
   - Piping classes (for reference)
   - Piping standards (for reference)
   - Tracing standards (for reference)
   - Insulation standards (for reference)
   - Instrument standards (for reference)
   - Instrument vendor data sheets (for reference)
   - Specialty item vendor data sheets (for reference)
   - Equipment vendor drawings (for reference)
   - Piping arrangements
   - Piping isometrics
   - Tracing arrangements
   - Tracing isometrics
   - Tracing logs

   There are three stages of inspection:

   - Pre hydro-test: intended for the release of pipe system for hydro-testing
   - Post hydro-test prior to insulating
   - Post Insulating

2. Inspection Checks Prior to Hydro-Testing:
- All supports, shoes, anchors, guides, slide plates, and spring supports have been installed in the correct locations and orientations. Spring supports remain locked for the hydro-test.
- The material and rating stamped on all flanges matches the piping class.
- All bolted connections have bolts of appropriate length, i.e., two threads showing, and gaskets installed.
- All manually operated valve tags are correct and the valves are installed in the correct direction of flow where applicable.
- All manually operated valve bonnet orientations are correct.
- All check valves are installed in the correct direction of flow. Internal flappers are to be removed for hydro-testing.
- All control valves and instruments as required are not installed. Inline instruments are generally not installed at this time, as they are not tested through.
- All specialty item tags, locations, and installations are correct.
- All spectacle blinds and spades are installed in the correct locations and directions for hydro-testing, i.e., closed or open.
- All permanent or temporary strainers are installed in the correct locations and directions.
- All high point vents and low point drains are installed and comply with the standard drawings.
- All temporary shipping steel bracing or banding on modules (painted red) has been removed.

3. Inspection Checks Prior to Insulating:
- Hydro-testing is complete and witnessed for all lines.
- All manually operated valve hand wheels, stem extensions, and chain operators are installed. Chain ops and hand wheels will not necessarily be installed prior to hydro-testing.
- Check valves flappers are to be re-installed after the hydro test.
- All control valve tags are correct and the valves are installed in the correct direction of flow.
- All control valve actuator orientations are correct and instrument air tubing hook-ups are completed where applicable.
- All other inline instrument tags are correct and the instruments are installed in the correct direction of flow. Tubing to transmitters has been completed where applicable.

- Tagging and location of all online instruments are correct and tubing to transmitters has been completed where applicable.
- All spring supports have been unlocked.
- All spectacle blinds and spades are installed in the correct locations and directions, i.e., closed or open, or have been removed after the hydro-test.
- All painted pipes have been repaired at the field weld locations.
- All required tracing has been applied as per the tracing drawings and standards. Check that correct tube bending has been carried out with no flattening of tubing.
- For any lines that require electrical tracing, check that the tracer wiring has been applied and secured correctly.

4. Inspection Checks After Insulating:
- All lines and equipment requiring insulation, including partial personal protection, have been insulated to the correct thickness, and that cladding and banding is correct and sufficient.

The P&IDs and isometrics will be "yellowed off" during the inspections, and any discrepancies shall be clearly noted in red. The inspector is to prepare an itemized deficiency report at each stage indicating the corrective action to be taken. Submit these reports together with the marked up P&IDs and isometrics to the construction supervisor and QA/QC, and keep a copy for record.

The originals will be transmitted to the erector for rectification. Once notified that the deficiencies have been completed, the inspector will revisit the piping system and compile the final inspection report for the stage of inspection.

7.3.4 Compiling and submitting RFIs and RFCs

Clarifications may be required on a number of issues from the home office, and it may be decided to raise an RFI or RFC to log a permanent record of the discussions. But there are several occasions when an RFI or RFC must be used.

It is important to realize that neither you nor anyone in your team is in the field to redesign the piping. It is not within your mandate to alter an approved engineered design or tie yourselves up on any one exercise for an extended period of time. There are several circumstances where you may be requested or feel the temptation to do so:

- The client's operations personnel are requesting changes.

- There is a major mistake that requires a redesign. For example, a piece of equipment is significantly out from the intended location.
- The design appears overly complicated and a simpler, more economical approach seems possible.
- The design does not work. For example, access has been blocked.

You are in the field to assist the construction team to keep the construction moving, and you must stay focused on the immediate day-to-day issues of problem solving and recognize when you require assistance. There is a difference between problem solving that stays within the intent of the original design and making changes to an engineered design that will involve re-engineering, and may add to the scope and budget even though these changes may clearly be necessary. Small adjustments do not require a submission for approval from the project management team or the stamping engineer, whereas significant changes do. Once you start getting into areas where the changes to the IFC design involve re-engineering and redesign, manhours, scope, budget and possibly back charges and extras, an RFI or RFC is in order. This requires a judgement call at times. When you encounter situations that you are unsure of, you are advised to consult with the construction manager and the field engineer.

Gather enough information to explain the situation and offer a possible solution with a sketch, if required, and then submit the RFI or RFC to engage the assistance of the project management team. Only the stamping engineer has authority to approve changes to his/her designs and only the PMT have the authority to act on and initiate changes of this nature; to engage the necessary engineering and design team members in the office to make the design changes and re-issue the drawings.

All RFIs and RFCs must be logged along with the attached sketches and a record kept of both submissions and responses.

7.3.5 Investigating back charges and extras

A back charge is a charge that may be applied to a contractor to fix substandard work, incomplete work, or work that has errors. An extra is a charge from a contractor for an activity they claim was required to complete the work that is an addition to the scope. It is not likely that you will be involved in the contractual issues; however, you may have to investigate possible back charges and the claims for extras and compile reports to be used in discussions by those that are involved.

There are a number of reasons why adjustments may be required during the erection of a piping system so that everything will fit together:

- Spool fabrication errors.
- A module fabrication error, e.g., a connection is in the wrong place.
- Structural steel fabrication errors.
- Errors on the piling drawing or in surveying resulting in incorrect pile locations. Additional surveys may be conducted prior to equipment and module placement so that adjustments can be made via the pile caps, but this does not always happen.
- Errors in equipment manufacture, e.g., vessel saddles or nozzles may be out.
- Equipment is placed in an incorrect orientation. I worked on a project where a distillation column was placed 180 degrees out from the intended orientation.

  As an aside comment, equipment vendor plan drawings should always be marked up to include the Plant North. Additionally, tanks and vertical vessels should always have the 0-degree orientation at the top of the north axis with the angles for the tank/vessel quadrants and nozzles oriented in a clockwise direction.
- Incorrect information on the piping drawings. It is sometimes the case that firm vendor data, e.g., certified face-to-face dimensions for instruments, has not been received when a EWP is due to be issued. A calculated risk may have been taken to proceed with fabrication. If "HOLDS" were not placed on the drawings then the piping fabrication may be incorrect as a result.

It may take some time to identify the exact cause, but it cannot be assumed that because the piping does not fit that the piping is at fault.

7.3.6 Progress monitoring

You will not be responsible for the progress, but your assistance in maintaining accurate records of the progress will be necessary. While the construction management team will establish the progress parameters to be monitored, you may have to develop the procedure for this or manage the procedure that has been established. This may take the form of setting up stick files and models of EWPs. Adding highlighting and notation on the stick files, moving drawings from an ongoing to a complete status file, and copying models with the use of color coding to identify each stage of the established progress parameters may be utilized for this purpose.

Sitting in the construction trailer and waiting for the information to come to you will not be sufficient. Progress monitoring includes going out into the field and conducting daily updates from observation.

You will be responsible for organizing your team for these activities.

7.3.7 Maintaining the master stick files

Just as in the office where master stick files are maintained, master stick files are a requirement in the field also. All of the RFIs and RFCs sent and received back, the FCNs received, the resolutions to any field problems and the as-builts received from the contractors should be noted on the field master stick files.

7.3.8 As-builts

Maintaining a record of the as-builts will be an ongoing process as long as the construction is ongoing. As has been mentioned earlier, you can capture RFIs, RFCs, and FCNs on the stick files, but there will also be mark-ups from the contractors to be captured. Quite possibly there will be a number of contractors providing as-built mark-ups, and all of these must be captured in one location. The master stick files are the appropriate place to transpose the mark-ups from all the individual contractors. You may also receive the same drawing several times from the same contractor. Often the as-built P&IDs for a piping system will be turned over when the system is completed. Because the P&IDs involve more than one system, the same P&ID may be turned over several times.

As-built prints should be stamped "AS-BUILT" and signed and dated. As-built also applies to drawings where no changes are noted, i.e., there were no changes during construction.

As-builts of the master or live models must be handled outside of the construction support activities. Because construction support is the primary reason that you and your designers are in the field, maintaining models and databases may distract from this task. Field personnel require almost immediate answers. The designers must make changes per the field information and create sketches for resolution of the problems. It is best if they keep a record of the changes, but do not work in the live models where they have to be concerned about the integrity of the databases. If a model does become corrupted they can soon request a back-up from the live models.

Develop a procedure whereby copies of the master stick files are turned over to the start-up team and back to the head office for the drawings to be updated. Likewise, models must be turned over to the home office where they have the mandate and the time to copy the as-built information into the live models and ensure the integrity of the databases.

7.4 LESSONS LEARNED

All projects should end with a wrap-up of lessons learned for future projects. During the course of the project you will become aware of the things that have gone well and the things that have not gone well or were a hindrance to the project. If for no other reason than for your own future reference, toward the end of your project take the time to make notes.

Your project management team will likely want to conduct a day of lessons learned by all the disciplines, and your input will set the tone for the many projects to follow.

7.5 SAFETY

We will finish this book with one last personal story and a reminder of safety.

About 30 years ago I was working on the construction of a gas plant. Toward the end of my tenure I decided to take some photographs of the plant. I went to a good vantage point, a distillation column approximately 45 m high, and climbed the ladder to the top 360-degree platform. I stepped off the ladder onto the platform and was admiring the view while I got my camera out of my pocket. Placing the viewfinder up to my eye, I started walking while looking only through the viewfinder. I walked, took a couple of snapshots and walked again, all the time looking through the viewfinder. Then I stopped, lowered the camera and looked ahead at where I thought I wanted to go next. Right in front of me was one strand of "do not cross this line" yellow tape running from the top nozzle

to the outside handrail. Beyond the tape was the continuation of the platform steel frame but no platform grating. I was standing about a foot away from a very big drop. One more step and I would have fallen through. I could have become a statistic at the age of 30 leaving two young children fatherless. I went to the site safety engineer who immediately had the ladder roped off and "no access" signs erected.

That was a personal experience on how my life could change very quickly due to not paying attention to my surroundings. I trusted that if I could go there then it was safe to be there.

Industrial facilities of any kind are full of potential hazards and I know we all agree that safety is a serious matter. Follow the rules at all times to stay safe, but remember that you have a responsibility for your own safety. Always be aware of your surroundings and your egress. You never know what may happen.

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Abbreviations

A	
Above Ground	A/G
Anchor Bolt	AB
Anchors	A
B	
Bevel Both Ends	BBE
Bevel End	BE
Bevel Large End	BLE
Bevel One End	BOE
Bevel Small End	BSE
Bill of Material	BOM
Blind Flange	BF
Bolt Circle	BC
Bolt Circle Diameter	BCD
Bottom	BOT
Bottom Of Pipe	BOP
Butt Weld	BW
C	
Carbon Steel	CS
Center Line	CL
Chain Operated	CH OP
Complete With	C/W
Concentric	CONC
Coordinate	COORD
D	
Datum	DAT
Detail	DET
Diameter	DIA
Dimension	DIM
Discharge	DISCH
Double Extra Heavy	XXH
Double Extra Strong	XXS
Drawing	DWG

E	
Eccentric	ECC
Elbolet	EOL
Electric Trace	ET
Elevation	EL
Elevation (View)	ELEV
Existing	EXIST
Expansion Joint	EXP JT
Extra Heavy	XH
Extra Strong	XS
F	
Face to Face	F/F
Face of Flange	FOF
Far Side	FS
Field	FLD
Field Check	FC
Field Fit-Up Weld	FFW
Field Support	FS
Field Weld	FW
Figure	FIG
Finished Floor	FIN FL
Finished Grade	FIN GR
Fitting	FTG
Fitting to Fitting	FTG/FTG
Flange	FLG
Flanged	FLGD
Flat Face	FF
Flat On Bottom	FOB
Flat On Top	FOT
Flexible	FLEX
Floor	FL
Floor Drain	FD
Flow Line	FL
Foundation	FDN
Future	FUT
G	
Gage or Gauge	GA
Galvanized	GALV
Gasket	GSKT
Grade	GR
Grating	GRTG
Ground	GND
Guide	G

Glycol	GL
Glycol Trace	GT
H	
Hanger Rod	HR
Header	HDR
Heat Trace	HT
Heater	HTR
Heating, Ventilating, and Air Conditioning	HVAC
Heavy	HVY
Height	HGT
High Point	HP
High Pressure	HP
Horizontal	HORIZ or HOR
I	
Inside Diameter	ID
Instrument	INSTR
Instrumentation	INSTRUM
Insulation	INSUL
Iron Pipe Size	IPS
K	
Kilopascal (Gauge)	kPa(g)
L	
Left Hand	LH
Long Radius	LR
Long Radius Elbow	LR ELL
Low Point	LP
M	
Manifold	MAN
Manway	MW
Material Take Off	MTO
Maximum	MAX
Minimum	MIN
N	
National Pipe Thread	NPT
Near Side	NS
Net Positive Suction Head	NPSH

Nipple	NIP
Normally Closed	NC
Normally Open	NO
Nominal Pipe Size	NPS
Not Applicable	NA
Not to Scale	NTS

O

Outside Diameter	OD
Outside Screw and Yoke	OS&Y

P

Personnel Protection	PP
Pipe Support	PS
Pipeline	P/L
Pipeway	PW
Piping & Instrumentation Diagram	P&ID
Plain Both Ends	PBE
Plain End	PE
Plain Large End	PLE
Plain One End	POE
Plain Small End	PSE
Plate	PL
Platform	PLTF
Pound Per Square Inch (Gauge)	psi(g)
Process Flow Diagram	PFD

R

Radius	R
Raised Face	RF
Reducer	RED
Reference	REF
Right Hand	RH
Right of Way	ROW
Ring Joint	RJ

S

Sample Connection	SC
Schedule	SCH
Screwed	SCRD
Seamless	SMLS
Section	SECT
Sheet	SHT
Shoe	S

Short Radius	SR
Short Radius Elbow	SR ELL
Sketch	SK
Slip on	SO
Socket Weld	SW
Sockolet	SOL
Specification	SPEC
Stainless Steel	SS
Standard	STD
Station	STA
Steam	STM
Steam Trace	ST
Stress Relieve	SR
Structural	STRL
Suction	SUCT
Swage Nipple	SWG

T

Tangent	TAN
Tangent Line	TL
Thread or Threaded	THD
Threaded Both Ends	TBE
Threaded End	TE
Threaded Large End	TLE
Threaded One End	TOE
Threaded Small End	TSE
Threadolet	TOL
Top of Concrete	TOC
Top of Grating	TOG
Top of Steel	TOS
Typical	TYP

U

Underground	U/G
Underside	U/S
Unless Noted Otherwise	UNO

V

Valve	VA
Vertical	VERT

W

Water, Oil, Gas	WOG
Weight or Wall Thickness	WT
Weldolet	WOL
Weld Neck	WN

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About the Authors

Richard Beale has over forty years of plant layout and piping design experience on upstream, midstream and downstream oil and gas industry projects in the employ of engineering, fabrication, construction and producer companies. His career started as a junior piping draftsman in 1974, and over the years he has held the roles of piping drafter, piping designer, piping squad leader, project piping lead, design and drafting department manager, and technical support to fabrication and construction. He is currently employed by a major oil and gas producer in Engineering Information Management.

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