Piping Engineering Leadership

for Process Plant Projects

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James O. Pennock

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By J. O. Pennock

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Dedication

To My Father
Mr. Lloyd I. Pennock, Sr.
Oh, that someday I may be considered as fine a man as he.

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Preface

There are many books already on the market that address all the purely technical and mechanical aspects of the piping engineering and design profession (piping). There is also a long list of codes and standards that form the "rules" that govern the piping industry. This book is not about these technical aspects of piping nor is it intended to compete with or contradict any of these fine works. In fact, I have a number of these books in my personal library. I have found the need to refer to them on a regular basis during the course of my work. I also have used many of them as text or reference material when I teach the various entry levels and intermediate level design training classes. This book is also not about piping department management. There is no doubt that department management is complex, and the issues there are very important. Some department issues may even be similar to issues discussed in this book. However, I will leave any discussion of the department management area to others.

The focus of this book is the position of the lead, the person who is in charge of the piping effort on a process plant project. This position and the responsibilities of this position are not currently covered in any of these other technical books. This "lead in charge" is the person assigned to a project and held responsible for the successful execution of all the piping activities, both technical and nontechnical. This book is intended for the individual who may be at (or near) the top of the technical ladder and who will soon become, by choice or circumstance, a supervisor or "lead in charge" as a project piping lead. It may also assist those who are currently in this position of project responsibility by validating what they are already

doing. Hopefully, it may also suggest new areas where they can bring value to that project.

Let me start with a discussion that places you, the reader, in a symbolic scenario. You suddenly awaken and find yourself standing all alone in a strange place. You really don't know where you are or how you got there. You are in the center of a circle or cone of light. The light is shining down as from a narrowly focused spotlight. Everything you see inside the circle of light is recognizable and familiar to you. You have some level of comfort here. But beyond the cone of light, there is total blackness. You cannot see anything outside the light cone. You have an overwhelming sense of uncertainty about what may be out there. You can hear sounds, and you can see occasional flashes of light. You do not understand what is going on out there in the darkness. You are then told that this mysterious black outer area is now included as part of your world. You are also told that you must safely and successfully navigate it.

Does this scenario sound like some Hollywood screen plot? I assure you, it is not. This is how many people feel when they find themselves promoted to supervision and the lead position on a project. They may not have wanted to be promoted at all. They may have been the strong technical lead and second in command when the "boss" was not around. Then it happened. The "boss" quit, and they were the next in line. They were just in the wrong place at the wrong time. Possibly, they were due for a promotion, but they were never trained for it. There had been no money in the company or department budget for training. They may have been pushing for a promotion but never fully understood what they were wishing for. No matter how they got there, they are now the person in charge. This is a scary thing.

Back to the scenario. Now suppose that someone begins to turn on the lights. The darkness and the mystery go away. The purpose of this book is to help turn on the lights—the bright light of day to illuminate the piping engineering lead position and bring understanding to the four functional subgroups of piping. The light is then turned on for the next level, the engineering coordination position and the other peer-level engineering disciplines. We then turn on the lights for the management, administrative, and control functions. Next, the lights are shown on the many types of plants through a discussion of the breadth and depth of both new construction and modification projects. Light is then used to bring a broader understanding to the procurement and contracts area of a project. Finally, we turn the lights on to bring more understanding to the actual execution activities of project scope development, estimating, scheduling, staffing, directing, controlling, and final closeout. When all of the lights are turned on, you are

now better able to see what was in all of those dark surrounding areas. You can now begin to understand what is around you, what the hazards are, what is causing the strange noises and the strange flashes of light. Some of the things you see out there may be familiar, but others may not be. Now that you can see them, you can begin to form plans of action for dealing with each of these challenges.

The concept of illumination used in this scenario also works in understanding the position of leadership. Once the proper light is shed on all the fundamentals of the technical, administrative, and supervisory tasks, then the anxiety felt by the individual will be reduced. The person placed in charge as the leader will be able to function more comfortably in this new assignment.

This book is about the piping profession, specifically the piping profession as it applies to piping in the process plant industry. It has been written by a process plant piper. It was written about process plant pipers. It has been written primarily for the process plant piper who is, or will become, a piping engineering lead. What is the lead in charge of piping engineering on a project called? It would be presumptuous to assume that the "lead in charge" of piping in one company would be called by the same title in all other companies. This would just not be true. There are possibly ten or more different titles out there for this same position. With this in mind, this book will use a neutral, generic (made up for the purpose) title of "piping engineering lead" (PEL). The use of this PEL title is not intended to imply that it is the title that should be used by any company. On the contrary, each company should keep its current position title. It will be up to the reader to transpose his or her company title where appropriate. Discipline titles for the other group leads (structural engineering lead), or positions (project manager), when used, will also be as neutral and generic as possible.

One of the basic laws of physics is "For every action, there is an opposite and equal reaction." A similar "law" exists in the execution of an engineering project. The "action" of leaving out a necessary function or service from one part of the project means that the action must be added somewhere else. An activity required to complete the project that is not done by one entity must be added to someone else's scope. In this book, I have tried to point out some of these situations where alternate methods of execution, the leaving out of "action," may be appropriate. I have also tried to suggest the compensating action required in another responsibility area. Alternate execution options are necessary because the M. O. (*modus operandi*) of each company and each project is different. There is no such thing as a "duplicate" plant. No two regional offices of the same corporation will operate in totally

the same way. Concepts suggested in this book are just that, suggested concepts. The actual methods used on any real-life project will be dependent on the client, the company, type of project, and the project personality. Some of the concepts discussed here will fit only some situations for some people, some of the time. It is not the intent of this book to suggest that there is only one way to do this specific job. On the contrary, there are always lots of ways to do anything. The job or function of piping engineering lead is no exception. It will be up to each individual to determine where the book helps them and their situation at any given time.

Part I

Roles and Responsibilities

1

Piping

This chapter will define the terms used for the lead in charge of the piping effort. It addresses how people are selected for that position, defines the duties of that position, and defines the duties of the four piping subgroups.

Piping engineering lead (PEL) as a title, a function, and a position has a very narrow, industry-specific application. This position is not widely known outside the process plant engineering and construction field. The position of orchestra conductor also has a narrow, industry-specific application, but it is one that has wide public recognition. The title *welder* is not so industry specific and is also commonly known to the general public. The same can be said about *bookkeeper, accountant, cook, or lawyer.* You can find each of these names, titles, or professions in any dictionary. Each is also commonly known to the general public. The position *piping engineering lead* is not commonly known to the general public.

Over the years, people have asked me about my job. What is my title, and what are my job duties? I would then need to explain what it meant and what I do. If I were a plumber, I would not need to explain what I do for a living. So, how do we define this position?

The piping engineering lead is the person who is placed in charge of all piping-related activities on a major process plant project. A PEL is a technical expert/resource supervisor/production manager. He or she is responsible for the overall plant and equipment arrangement; for the technical definition of all the process system piping on the project; and for the supervision of a large group of people. The PEL is responsible for the deliverables from their effort and for the quality of that effort. The PEL

also manages the budget and schedules aspects of the assigned segment of the project.

The actual PEL responsibilities vary depending upon the engineering company, the client, the type of project, the project execution philosophy, and the construction philosophy. Some companies (U.S. or worldwide) have the piping function integrated with another engineering group or function. Some companies structure piping in some other fashion. The specific structure is not as important as the overall function.

To fulfill all the aspects of this functional definition, and depending on the company, the PEL may be involved in some or all of the following activities:

- Participate as a part of the proposal team in pre-bid meetings with the client for proposal development
- Define the physical scope of the piping effort for the project (see chapter 10)
- Define the piping execution method and the required piping deliverables (see chapter 10)
- Prepare a labor hour estimate for the piping effort (see chapter 11)
- Prepare a material cost estimate for all piping items (see chapter 11)
- Prepare a detailed piping discipline work execution schedule that is coordinated and compatible with the other engineering disciplines (see chapter 12)
- Plan all aspects of piping activities (see chapter 13)
- Organize electronic or hard-copy data files or data needs (see chapter 13)
- Oversee proper resource (people) requisitioning and utilization (see chapter 14)
- Recognize and report all scope changes or trends that may cause a cost impact to the project (see chapter 15)
- Be aware of labor budget expenditure, production, and productivity (see chapter 16)
- Prepare prompt and accurate status reports (see chapter 16)
- Manage project completion and closeout (see chapter 17)

If you are already knowledgeable about the engineering and construction business, this list of activities will speak volumes. If you are new to the business, it may tend to scare or confuse you. Rest assured that is not the purpose. The purpose is to provide a guide for the person who is new to supervision, the person who is just getting started as a lead. It is also intended to help the person who is already a supervisor and wants to

improve. The goal is to show who we are and what we do as piping engineering leads.

How does one become a PEL? People come to this position by a number of paths. A PEL may be a graduate engineer with a BSME (or other degree) who has been in the piping material engineering group or the pipe stress engineering group. The PEL may be a transfer from another discipline, such as a mechanical equipment engineer. In today's world, however, these would still be considered rare cases. Most PELs will be from the plant layout and piping design arena. They usually are the ones who have been in the business much longer than anyone who reports to them or much longer than any of their counterparts in the other disciplines. Most of these PELs are there because of the vast experience and the "gray hair" technical knowledge they possess. That depth of experience and the knowledge they bring to the project are invaluable.

Many of the PELs that I have been privileged to work with or have met through contacts over the years seem to have gotten their start the same way. They took drafting in high school or a vocational technical school, or they worked in a central drafting department in their first job. The ones that showed an affinity for piping stuck with it and grew. They moved up the ladder, becoming more and more knowledgeable as piping designers. If they were lucky, they worked for a company that developed and conducted piping-specific technical training classes. Some were fortunate to live in an area where a number of local companies would join together and sponsor programs like the Engineers Club in the Philadelphia, Pennsylvania. Over the years, they worked on bigger and more complex projects. As they moved up the ladder, getting on-the-job training and experience, they became better piping designers. Some of these individuals also gained or showed leadership traits.

For most people in the PEL position, the bottom line, education wise, was that tried and true: OJT. On-the-job training (OJT) was the only way to learn. Some PELs may have had the benefit of some type of supplemental college-level classes. Some may possibly have attained a degree in some related field. Many, however, will have only a high school education with some college or junior college-level courses in subjects that relate to the piping field. The lack of a higher level education in the piping-specific engineering and design field was not by choice. The fact is that until recently (see chapter 18) there has not been a formal program in academia to addresses this specific field. This lack of a formal education, however, has not been a significant issue.

Although the skills that a PEL must have in order to succeed are many, the traits the PEL should have are few and simple. Every PEL will have a different background of life experience, project type experience, and personal habits. Two PELs who may work together for years for the same employer will not be, or think, alike. However, the basic traits that identify them as the person in charge are the same. I refer to these traits as technical (T), administrative (A), and leadership (L). These three major traits create a triangle with one other trait, personality (P), in the center. Each PEL can be looked at and evaluated on the basis of this (T-A-L-P) triangle.

A manager who is thinking of promoting someone to the position of PEL would do well to consider the T-A-L-P traits of the individual first. The manager should ask these questions: Is this person being promoted solely because they have been here for a long time, and they are now at the top of their scale? Are they being promoted because of their technical skills? Does this person know about and accept the administrative aspects of the job? What type of leader might this person be? Does this person have the personality to be a good representative for the company? Will they be compatible with other discipline leads, project managers, and clients? The responsible manager knows that people should not be promoted for the wrong reasons.

Any individual who is currently at the top of the technical ladder and thus on the threshold of becoming a PEL should think about how they fit the T-A-L-P triangle. A person who is impatient or impetuous and is driven to become a PEL just for ego should also think about the T-A-L-P triangle. What is T-A-L-P?

The *T* stands for "technical." No two PELs will have the same knowledge base, and there is no single definition of exactly what the PEL needs to know from a technical standpoint. The best way to state this is that the PEL should know as much as possible. The PEL should have in-depth knowledge of what it takes to execute the piping portion of a project. The PEL needs to spend time in the plant layout and piping design group. The biggest share of the piping work effort and budget is concentrated in the design group. It would be good for the person to spend time in each of the piping subgroups. Another way to gain the required knowledge is to attend company training programs and seminars focused on these areas. Active day-to-day contact during the normal execution of a project is also a key element to the learning process. A person who is interested in moving up in this profession must have their eyes and ears open, show interest, and be inquisitive about the right things. There are ways to broaden one's

technical knowledge base outside of the company. You can go back to school and take courses like basic process chemistry, metallurgy, welding, or others that relate to the field. Another good way is to seek short-term job assignments that are industry related. These jobs may include work in a pipe fab shop, as an operator in an operating plant, or in field construction.

The *A* stands for "administrative." If you do not like paperwork, you will have a rough time in any leadership role. Becoming a PEL is no different. There is a lot of paperwork in the engineering and construction business. There are scopes to write and estimates to prepare. There are schedules to develop, personnel appraisals to prepare, and timesheets to approve. There are reports to read and write and budgets to monitor. The list goes on and on. The administrative duties and the paperwork can become tiresome and can appear to be overwhelming. Paperwork must not be overlooked or left undone. The PEL candidate must understand that the curse of paperwork comes with the position. The key is to learn what is required, get organized, learn quick and simple ways to do it, and then do it. Do not allow yourself to fall behind.

The *L* stands for "leadership." The ability to be a leader is not something you can completely learn in school. Some schools and consultants claim they can make you a leader. All of us have known people who have attended these classes and still are not leaders. The person must be endowed with some of the basics of leadership in order to succeed. The schools and consultants can and will teach what to do and how to do it. They cannot teach feelings. A leader must have feelings. A leader does not get behind people and push them to accomplish a goal of which they are not in sympathy. The leader will make sure that the goal is worthy, logical, and attainable. The leader will be in front, providing an atmosphere that makes people want to reach the goal. A leader will know what to do and when to do it. A leader will know whom to ask and what to ask. A leader will be thinking 2 to 3 months ahead of anyone else. Another aspect of leadership is the ability to organize the job—having the right tools, having the right answers, and having a place for everything and everything in its place. This can help to develop the leadership persona.

These three traits—technical, administrative, and leadership—form the three sides of the triangle. In the middle of this triangle is the fourth trait, the most important one of all. The *P* stands for "personality." It will not matter how much you know about the technical issues. It will not matter how good you are at paperwork, bookkeeping, and timesheet approval. It will not matter how clever you are at giving orders. If your personality is not suited for the job, then you will have a very hard time being a piping

engineering lead. I do not mean that a person cannot have a bad day occasionally. Everyone has had the occasional flub or uncontrolled outburst that could have or should have been handled in a more diplomatic manner. I have had my share, and I have regretted them all. However, the person who is always angry, consistently aggressive, or overly abusive is not a good candidate for the position of lead.

There is another sort of person who does not make a good lead. This is the person who got promoted by accident. They did not ask for the job and are not inclined to be a leader. There is a famous management book titled *The Peter Principle.* In this book, the author describes what happens to a person who gets promoted to a position that is beyond their capabilities. Prior to promotion, these people usually are doing a very good job. They are also very happy in that job. After the promotion, they struggle to do the new job. They are just not able to do the new job the way it should be done. The individual did not want the job, knew they could not do the job, and were not happy. The promotion turned out to be wrong all the way around. It is not good for the company, not good for the other workers, and not good for the individual.

When people fail after being placed in the wrong job, the cause is usually lack of knowledge. You cannot prevent an uneducated person from making mistakes. We are not talking about uneducated people here. We are talking about very intelligent, very smart people. Any individual who is contemplating a position as a leader should seek whatever information might be appropriate to help them decide. This goes for the PEL position in their current company or the one at the company across town that had the tempting ad in last weekend's newspaper.

What does being a PEL mean? The aspiring PEL might say: "I know piping; I know my job." "I have been doing this for 20 years." "We pipers do the piping plan drawings, piping section drawings, and sometimes piping isometric drawings." "Sometimes there are specifications and standards, but those are done by the engineers." Here, we have one of the main points of this book: Piping is NOT just piping plan drawings, piping section drawings, and (maybe) isometrics. Remember that first familiar circle of light mentioned in the preface of this book. Plans, sections, and isometrics are the items in that first circle of light for someone who came from the design side of piping. A materials of construction engineer who is assigned to the PEL position will be most familiar with piping material specifications. I have also met ex-construction field piping engineers who have moved back into the office and become PELs. These people were more familiar with the endgame part of piping. Each of these individuals

brings value to the position of PEL. Each, however, needs to have the lights turned on in as many of the other (unfamiliar) areas as possible. They and the people they work with, above, or below need to know the full scope of the piping discipline.

What is meant by the phrase “full scope piping engineering”? The process piping systems on a project really do have a cradle-to-grave (full scope) span of requirements that needs to be handled by someone. What is required to take a new pipeline from the process engineer first marks on the piping and instrument diagram (P&ID) to pre-start-up? For each piece of piping material required to make the finished plant work, there are steps that must be accomplished by someone. Some will say that is not done at their company: They might say they leave that up to the contractor. That may be true. I am not trying to define who should or should not be a part of the overall process. I am trying to help people recognize the all-encompassing aspect of the overall process itself. A part of that recognition of the (action) elements in the overall process will be the realization that someone makes the process happen.

Let’s look at this cradle-to-grave concept. For this exercise, let’s assume that process engineering has a change order to add a new exchanger (10-E-152) on the P&ID. A number of lines are required, including a new line from a vessel (10-V-101) to the exchanger. The line will be a large diameter (14 inch) high-pressure line operating at 650° Fahrenheit and will include a control valve with full block valves and a bypass, plus the normal vent and drain valves. The line has a temperature element (TE) and a pressure indicator (PI). The large block valves are long delivery items that become the critical path. The project is full engineering, procurement, and construction management (E, P, CM). (See appendix B for the detail listing of action.)

This line does not get added just because someone draws an isometric. Someone must prepare the design criteria. Someone must prepare the specifications and standards if the current project specifications are not adequate. Who were those mysterious engineers who prepared the specifications and standards on past jobs? Who were the people who did the material take off (MTO) and prepared the request for quote (RFQ) packages? We know they existed because we know the work got done. Let’s assume that they really did exist as a part of the piping department, but their relationship to the designers was not as clear as it could have been. Being a PEL means that it is clear to you, and you see the full picture. You know what your resources are; you are able to manage your resources. You understand the responsibilities, and you accept accountability for all the pip-

ing on the assigned project. At most companies, piping is considered a total responsibility discipline. You as the PEL and the people you work with need to recognize it as such.

Who do you work for? In this book, we will not discuss the pros or cons of being employed by a small company versus a large company. The size of the company is not important to the execution of the project or the actual PEL position. However, I do feel it is important that each individual understand whom they work for and what is a proper order of personal priority.

First, you work for yourself. The "you" is really you, your spouse, and your family. Each of us needs to understand that we should take care of ourselves and our families first. If we do not, then we will not be able to do a good and proper job for someone else. Second, your profession (at least at this time) is piping. You have an obligation to your profession. If you compromise your ethics or your technical integrity, then you hurt yourself and your profession. Doing a good job, a quality job, is what marks you as an expert in your profession. It is what allows you to be chosen for the next prime assignment or be promoted to the next higher classification. It marks you as someone who is wanted when people put together the next project team. Third, you are employed in the piping department of company X. While you are employed at X, it is the best and most important company in the world. You may not really like this company. You may not plan on staying there the rest of your life. That is okay, but while you are there, you owe the company your complete loyalty. Finally, you are currently assigned to a project for a client. This client deserves the best you have to give.

The biggest problem for most people is the apparent conflict of interest between the functional department with a department manager and a project with the project manager and the client. This is called *dual accountability.* What does dual accountability mean? It is very important to know and understand to whom and for what you are accountable. Accountability is another way of saying, "Who do I report to and why?" As previously stated, you are employed in the piping department of company X, and you are assigned to a client project. This means that there is a dual accountability. Is this a case of "whatever the client wants, the client gets"? No! Remember, clients come and go. Is this a case of "whatever the project manager wants, the project manager gets"? No! Projects and project managers also come and go. You are still employed by company X in the piping department. You are still a piper. Dual accountability means that you "render unto Caesar that which is Caesar's." Issues that relate to the project scope, project budget, project schedule, or project deliverables are items for which you are accountable to the project manager. What is done

and when it is done have a project focus. Issues such as staff utilization, piping code compliance, and product quality are items where your accountability is to the company/department manager. How things are done and who does them have a functional department focus. You are accountable to yourself for honesty and professional ethics.

Am I accountable to the client for anything? Yes! You are accountable to the client, but indirectly. You will have satisfied client accountability when you meet your obligation to the project manager. Being accountable means that you are held explainable for something (responsibilities) to the people you report to. The subject of reporting will be covered in more detail in chapter 16. Accountability has two sides. This is what we call middle management. The piping lead, as with the other leads, is in the middle. A middle management leader is accountable to those he or she reports to. They are also accountable for those who report to them.

The piping engineering group is traditionally the largest group on a task force project. Each of the piping subgroups specializes in a different piping engineering or design-related function. Henry Ford introduced and perfected the production line concept in the automobile industry. This method required people trained in different tasks to perform those tasks in the proper sequence. This concept allowed businesses to produce more for less. The heavy engineering-related business we are talking about here also uses a production line concept. We require people trained in different functions to perform all of the project tasks in the proper sequence. Some functions are a part of the traditional piping department and report to the PEL. Others are people outside the piping discipline or department (for example, structural engineers) and will be discussed in chapter 2.

Who reports to the PEL? In most companies, there are four major functions or subgroups that perform the traditional piping activities that will occur on a project. I want to remind everyone that this is a generic version: Your company may call them by some other name.

The functions or activities that report to the PEL are as follows:

- Piping materials engineering—Piping and piping-related materials of construction definition
- Piping design—Plant layout, piping layout development, and piping design documentation
- Piping material control—Material take-off, bills of materials, piping material RFQ, and purchase order generation
- Pipe stress engineering—Pipe stress analysis and specialty pipe support design

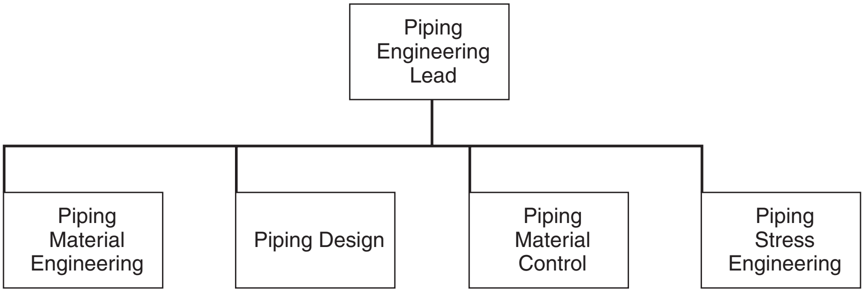

Figure 1-1

The piping materials engineer (PME) or the person who performs the tasks of the PME should report to the PEL. The PME may be the first member assigned to the PEL's team. This assignment may have occured during the proposal phase when there was a need to evaluate technical requirements for the bid. The PME is responsible for developing the master specifications covering materials of construction for all of the piping systems. Piping-related materials of construction definition would be included, also. Specifications for piping materials of construction include pipe, valves, fittings, flanges, bolts/nuts, gaskets, branch conventions, fabrication criteria (PWHT), and installation criteria (seal welding). Specifications for piping-related materials of construction include insulation, paint, and other special coatings. Using the data provided by the client and process engineers, the PME develops detailed specifications for the piping material. The specifications address each commodity with pressure-temperature ranges as allowed by the code.

The early definition of the required materials and the development of the project-specific piping material line class specification is a high priority for the piping team. With most projects, 75 to 80 percent of the piping material line classes will be easy to determine from the general scope data. Utility services such as steam, condensate, natural gas, fuel oil, domestic water, plant air, instrument air, cooling water, nitrogen, and others will be easy to identify and will normally use materials that are not long delivery. Process streams that include high temperature and/or high pressure could require systems with exotic materials that have restricted sources and long deliveries. Front-end coordination with process is an essential aspect of material procurement success. The material selection diagram (MSD) effort is required to properly define the types of material required on the project. If this important step is ignored or is performed too late, the project will suffer, and added cost may be imposed to recover.

In some companies, the PME may also be responsible for the proper selection of the line class for each line on the piping and instrument diagrams (P&ID). As a part of this line class specification exercise, the PME may also develop an initial listing of all lines. This document may be known by many names. It may be called a line list, line index, line designation table, or some other name. The choice of the name is not as important as the document itself.

Another important duty of the PME is the identification of and proper specifications for specialty items. It is not always prudent to write absolutely every piece of piping material into the piping material line class specifications. There are those odd items needing special handling by the PME. They may be items such as injection quills, pig launchers and retrievers, swivel joints, or loading arms. These are no doubt referred to by different names in different companies; however, they will simply be called specialty items in this book. The PME will need to work with the process engineer on the job to define the purposes, design, and operating conditions and then work with piping design and one or more vendors to satisfy the requirements.

The list of piping deliverables the typical PME will produce may include the following:

- Piping material line class specifications
- Piping material purchase specifications or technical notes
- Insulation specifications
- Pipe painting specifications
- Piping line list
- Specialty (SP) item specifications
- SP item list

The piping design group (PDG) reports to the PEL. The PDG is normally the largest single group on a process plant task force. The lead piping design supervisor (or squad boss) will normally be assigned to oversee the designers who will perform the detailed design stage of the project. The lead design supervisor should be available for the job kickoff meeting and should be deeply involved with the project from the beginning. The person who is assigned as the lead design supervisor is in a position similar to the vice president of the United States. That position is just one step away from the top spot.

This group is typically responsible for the overall plant layout. There may be some types of plants where another engineering entity may take the lead for the plant layout. Readers will need to recognize this and make

the required transition in their thought processes. Most major process plant projects in the refinery, petroleum, chemical, petrochemical, power, fiber, and many other businesses will have the fundamental plant layout and equipment layout done by the piping design group. The PDG will normally produce the project master plot plan drawing. The PDG will be responsible for the definitive equipment placement and layout. The equipment layout will be "fit for purpose" when considering the process requirements. The PDG will be responsible for all piping layout development and for working with other engineering groups to define physical plant needs and clearances.

The piping design group will route all piping. They will ensure proper support and flexibility of all lines. They will guarantee that all in-line instruments are properly accounted for and that all equipment and piping are in accordance with the project design criteria. They will consider criteria for operation, maintenance, safety, and constructability. One of the major milestone activities conducted on a project is that final confirmation that everything is done. There are various methods that may be employed by PDG to do this. The method I like is the piping design supervisor's P&ID isometric continuity, "yellow-off." With this method, the lead piping design supervisor yellows off every isometric against a set of up-to-date master P&IDs. After this activity has been completed, every pipeline and every piping-related item on every P&ID should be yellow. It is also not enough for that supervisor to simply yellow off the isometrics. When something is missing from the isometric or when something shown on a P&ID is not in the correct place (or orientation) on the isometric, then the supervisor needs to take action. I have spoken in terms of using piping isometrics for this activity. Piping isometrics are not the only documents that can be used for this. If the isometric is the primary piping design document to be released on a project for purchase, fabrication, and installation of process plant piping, then this is the document that should be used for the cross-check against the P&IDs.

The potential list of piping design documents is long. Not all jobs require all of the different document types. It is likely that some companies have never had a need to develop some of these documents. It is also possible that a document was, in fact, developed but was developed by some group other than PDG and, consequently, was known by another name.

The list of piping deliverables PDG will produce may include the following:

- Piping specifications (The term *specification* is used here and in other places in this book to define a document that will be a deliverable for use

by a vendor or a subcontractor. The information may also be formatted in a less formal manner and called *technical notes.*)
- Project plot plan (overall plant) and unit plot plan(s), also known as GAs
- Piping transposition (piping one line), also known as geographic schematic
- Piping standards and piping details
- Vessel orientation layouts and equipment layout studies
- Piping drawing indexes
- Piping plans and piping sections (elevations)
- Piping isometrics
- Heat tracing drawings
- Piping demolition drawings
- Piping tie-in drawings and tie-in list
- Demolition and removal drawings

Piping designers will also be required to go to the job site on any revamp project that includes piping. It is not advisable to gamble that the existing drawings might be current. The existing drawings must be checked against the actual physical plant, and the drawings must be corrected before any work can be started. Piping design on a major process plant project will also play a big role in the management of the computer-aided design (CAD) model. All disciplines must work together in one single CAD model just as they must in the real areas of the project. If one group does not participate in the CAD model, then the project might just as well not have the model at all. This is a case of everyone or no one, and coordination and communication are vital.

The piping materials controller also reports to the PEL. The piping material control (PMC) function is primarily accountable to the PEL for material requirements planning. Again, depending on the company, the PMC function may not exist or may functionally report to a different department. However, when required for the project, the PMC function is responsible for all piping material. This includes quantity take-off activities, production of bill of materials, piping material quantity summaries, piping material RFQs, piping order bid tabulation/summary, piping material purchase order generation, and required-at-site (RAS) date planning.

The list of piping deliverables the PMC will produce may include the following:

- Bill of material for each piping document
- Bill of material summaries

- Special take-off summaries (large diameter or long delivery valves)
- Piping material procurement request for quote (RFQ) draft
- Piping material procurement purchase order (PO) draft

The pipe stress engineer reports to the PEL. The pipe stress engineer (PSE) function is accountable to the PEL for all pipe stress analysis and specialty pipe support design. The PSE may produce specifications for any spring hanger supports, expansion joints, or piping stability strut devices. The PSE consults closely with the piping designers to review and approve selected pipe lines depending on the job type and project criteria.

The list of piping deliverables the PSE will produce may include the following:

- Spring hanger specifications
- Expansion joint specifications
- Piping sway strut specifications
- Formal stress calculations
- Deadweight, wind, and force and moment loading for pipe supports or equipment nozzles

At this point, one might ask, "If these four groups do all that, then what does the PEL do?" Good question. The PEL will be very busy. The PEL will traditionally be the first piper assigned to the project. He or she will be involved in the early planning phases of the job. The PEL will be responsible for drafting the piping scope of the work. The PEL will do all the initial estimates and schedules. There will be many, many meetings to attend, and there may be trips to the job site or client offices. The job execution will be completely thought out and planned. Later, as the job progresses, the PEL will review all work to ensure that it is in accordance with the plan. The PEL will also be responsible for making periodic reports. It is not unusual to have weekly and monthly reporting to both the project and the department manager.

No two companies will be organized in exactly the same way, function in the same manner, or use the same mode for project execution. Depending on the company, piping's project execution will typically fall into one of two traditional formats. These two formats are generally recognized as the functional department format and the project task force format. The size of the company does not have any bearing on the chosen mode for project execution. Most large engineering firms in the engineering, procurement, and construction (EPC) and engineering, procurement, and construction

management (EPCM) design-build business choose to execute projects in the project task force format. Small companies and a large company performing a very small project will use the functional department format. The functional department format has its good points and should be used by companies both small and large when it is appropriate. The project task force format also has benefits, the major ones being the gathering of all the people in one location for the duration of the project and the shortening of the lines of communications for everyone. The particular project execution format used by a company is not addressed in this book. Both have their merits and should not be judged as either positive or negative.

Because of long-standing industry tradition and the nature of the overall process plant design process, piping is a prime interface point for all other task force groups on the project. Piping is also a key factor in the proper and timely execution of many other task force work activities. The PEL needs to fully understand piping's role in the overall production line of the project. Piping is not now and never will be the only group involved. Piping is not the first group involved or the last group involved. Piping is surely not the most important group involved in the project. Piping is just one of the groups that make a project happen. In the next chapter, we will discuss the other engineering groups and their relationship to piping.

2

Engineering Management and Other Engineering Disciplines

This chapter will cover the interface with other disciplines and what is expected of the person in charge of piping for those relationships.

In order for a person to function properly as a piping engineering lead, he or she must know and understand the basics of the profession. These basics include the duties and responsibilities of the PEL position and the duties and responsibilities of the other positions on the project. The PEL needs to know the organizational structure and the peer-level leads on the project. The PEL must understand the relationship with the (peer level) project leads. Most importantly, the PEL must understand the concept of teamwork.

The word *teamwork* implies cooperative action by two or more people (or animals) or groups of people (or animals) toward a common goal. Cooperation and teamwork by the organization are exactly what is needed for the successful completion of any project. When we talk about teamwork, I would like for you to think about a very simple but special example of teamwork, a team of horses. I would guess that everyone today has seen the famous Budweiser Beer Clydesdale horses. You have no doubt seen them on television, or if you were lucky, you may have seen them in person. These remarkable animals portray the basics of teamwork. The Clydesdale horses can help us understand the concept of teamwork that is necessary for the execution of a major process plant project.

The Budweiser team is made up of eight very strong individual animals. Their common goal is to move a heavily loaded wagon from one place to another. These horses are connected to the wagon by the harness. The horses are guided by a driver. The driver is known as a *teamster*. The teamster does

not ride the wagon to dominate the team but to keep them focused on the correct path. You may now ask, "How is this relevant to engineering?" If you look very carefully at the Budweiser team example, you will notice some key points. The horses are all individuals that are working together. The horses are all pulling their own equal share of the total load. On any given day, any one of the horses may be the lead horse. The harness that connects the horses to the wagon helps the team stay together. The harness is not intended to be restrictive but is, in fact, a positive tool to channel the strength of the team to accomplish the common goal. Can you imagine what would happen if none of the traces were connected, and someone cracked the whip? Eight horses would all go in different directions.

You may question the relevancy of the Budweiser team to our subject. The horses represent the major engineering disciplines on a typical project. The teamster represents the engineering manager. The harness and traces represent the practices, policies, and procedures that keep us all pulling together. During the execution of a major EPC process plant project, all the engineering disciplines must work together. They must be ready, willing, and able to pull their own load. They must be capable of stepping up and being the "lead horse" when the need arises. They must also be willing to allow another to be the lead horse. If everyone on the project understood this team concept, things would run more smoothly.

The engineering organization on a typical process plant project is made up of various engineering groups. These groups are sometimes referred to as *engineering disciplines*. The engineering disciplines are normally made up of a designated discipline lead, along with the engineers and designers who perform that discipline's work. The leads for all the disciplines will usually report to one individual, who may be called the engineering manager. Other titles may include engineering coordinator, design manager, design coordinator, or other such titles. The title is not as important as the function. The engineering manager and the discipline leads would normally be shown on the formal project organization chart. Your company may not publish formal project organization charts. Whether published or not, formal or not, there is an organization structure on every project. The organization structure used in this book may not look exactly like your current company. Your organization structure may be more narrow or far broader than this. This one is only intended to show the major project disciplines. It is also intended to be as generic as possible so that you, the reader, can understand more easily.

Our generic project organization structure will have eight traditional process plant engineering groups. These eight groups will report to the project engineering manager. It is important that a point of clarification be

made on this subject. The eight groups listed here are not, in any way, intended to imply that these are the only engineering groups that exist. There are other engineering groups, some of which will be covered later. For now, we should concentrate on the majors. Our generic engineering organization includes the following primary disciplines:

- Process engineering
- Civil engineering
- Structural engineering
- Mechanical equipment engineering
- Vessel and tank engineering
- Piping engineering
- Electrical engineering
- Instrumentation or control systems engineering

Depending on the needs of the project, there are secondary disciplines that may be required to make contributions to the effort. Some companies may even have other discrete groups assigned full-time to some projects. Users of this book are encouraged to add or delete groups as required to fit the specific company or instructional situation. Each of the primary and secondary disciplines on a process plant project will have one person who is the designated (formal or informal) lead. This person is expected to answer the questions and solve the problems that relate to that specific discipline. All the discipline leads including the PEL will report to the engineering manager responsible for guiding the engineering effort. The secondary disciplines may include:

- Architectural engineering
- Plumbing and heating, ventilation, and air conditioning (HVAC)
- Fire protection
- Environmental engineering
- Technical document coordination

The project engineering manager (PEM) position will normally have eight major engineering disciplines but may have as many as ten disciplines reporting to it. The engineering manager position, in turn, will report to the project manager (or project director). The engineering manager is responsible for the overall coordination and productivity of all the engineering activities on the project. The engineering manager is the "teamster," the one who holds the "reins" and guides the "team." The PEM is typically an experienced individual who has been in the business for many years. This individual may come from any of the engineering disciplines. Key traits

for this position include the ability to see the total picture, understand the needs of all the disciplines, and be fair and impartial. The duties and responsibilities of the PEM include close interface with the client, the project management, the company management, vendors, contractors, and all the discipline leads. The tasks include the coordination of the development of the project scope, engineering estimates, project schedules, project engineering procedures, project quality procedures, and the production of the project deliverables. Perhaps the most important role of the engineering manager is to broker compromise and resolve interdiscipline conflict.

The PEM is also responsible for all sorts of reporting. There are weekly reports, monthly reports, special ad hoc reports, and the project completion report. The PEM does not actually produce any specific deliverables. The PEM position is a coordination function that is necessary on all but the smallest process plant project. Some very small projects may have one person acting as a combination project manager and engineering manager. A small project with one person filling dual roles does not change the duties and responsibilities of the function. Regardless of project size, there is a need to coordinate the project effort through the engineering disciplines. The typical engineering disciplines are described as follows:

The process engineering group reports to the project engineering manager and is typically the first group on the project. Under the leadership of the project process lead (PPL), process engineers begin the early engineering phase of the project. The PPL is responsible for converting the clients and/or licensor design specifications into various schematic diagrams [process flow diagram (PFD), P&ID, utility flow diagram (UFD)] required by all or most of the other groups. These schematic diagrams may be simple block diagrams or very detailed and complex piping and instrumentation diagrams (P&IDs). Process engineers may use one of the enhanced process-related CAD programs and develop the diagrams themselves, or they may operate through a CAD process graphics group attached to the process department. Some companies may have the process CAD work done in a central CAD group. It does not matter what hardware or software program is used, who actually does the drafting of the project schematic diagrams, or how it is done (manual or electronic). These diagrams ultimately define the process and, therefore, the ultimate success of the client's plant. They need to be recognized as the process engineer's deliverable. The process group is responsible for the format, content, quality, and production.

Process engineers will also produce a variety of downstream support documents for use by other groups. For the mechanical equipment group,

they will produce equipment data sheets that define the technical requirements of each piece of equipment. For the instrumentation/controls group, they will produce data sheets for all critical instruments such as control valves, flow meters, and relief valves.

The process group and the piping group are also closely aligned. Process will normally have full control of all line sizing and may take a strong advisory role in the selection of the materials of construction for piping. As piping begins to develop the initial line list, process will be asked to furnish required key information. This information includes the design and operating conditions for each line, the insulation requirements, and possible heat tracing criteria. Special conditions such as do not pocket, slug flow, slope, vacuum, and others also need to be included. Process and piping design need to work very closely as the P&IDs are developed to ensure that there is a complete understanding of what is required by the process.

The PEL should strive to guarantee a full understanding of the requirements of the process. This understanding extends to process-related requirements for start-up, normal operations, shutdown, and any alternative operating cycles such as catalyst regeneration or on-line de-coking. The PEL may need to offer alternative solutions to physical problems that are presented during the course of the project.

The mechanical equipment group is responsible for all of the equipment items (except vessels) that are required on the project. A mechanical engineering lead (MEL) will be assigned to the project and will have a number of specialists as part of the equipment team. The equipment team may include one or more of the following specialists:

- Rotating equipment specialist/pumps and compressors
- Heat transfer equipment specialist/shell and tube heat exchangers, cooling towers, and air fan coolers
- Fired equipment specialist/boilers and fired heaters
- Water treatment specialist/water treatment equipment
- Other specialist/filters, mixers, and miscellaneous equipment items

The equipment specialist will receive a data sheet containing the key performance criteria for each individual piece of equipment from the process engineer. The equipment group will produce detailed specifications for each piece of equipment or type of equipment. They, in turn, will work with one or more equipment vendors to finish the equipment definition process. The equipment definition process will identify some pieces of equipment with only one physical configuration. There are some pieces of equipment

having more than one physical configuration choice. The natural path for the MEL to choose might be the vendor (or configuration) that is the cheapest. This might be fine from the standpoint of the mechanical equipment budget. This selection, however, may result in extra costs for piping and structural. The piping, structural, and mechanical groups need to work together to find the most cost-effective solution for the overall good of the total project.

The PEL and the rest of the piping team need to review the equipment very carefully for issues relating to operation, maintenance, and constructability. When there is full procurement of the equipment on the project, piping needs to do a detailed review (vendor drawing squad check). This review will be done when the vendor-certified drawings are submitted. Piping does not need to see every vendor drawing. They only need to see the general arrangement drawing for each piece of equipment.

The vessel and tank engineering group is equipment related, but it is also different and in some ways more complex. For this group, two functional operation formats may be used. One format is for the company that does not have a strong in-house vessel group. For this type of company, the next step is to send the preliminary vessel data to a vendor and let the vendor do all the detailed design work. There is nothing wrong with this method. It works for some companies and even some projects. It does tend to give up a level of control over the design, and it may also introduce some delay to some of the downstream vessel-related engineering activities.

The second format is for the company that has the capabilities in-house to do all or most of the detailed vessel design work. For this format, the vessel vendor will prove certain pressure containment calculations and then build the paper. For this format, vessel engineering is responsible for all the engineering, design, and detail drawings for all tanks, drums, and trayed and nontrayed towers. The vessel engineering group will be under the leadership of the vessel engineering lead (VEL). The VEL will receive a data sheet from the process group defining the basic design and operating criteria for each vessel. On projects where a third-party process licensor is involved, this vessel data sheet may be a part of that licensor package. Detailed design of vessels requiring the involvement of piping includes the following:

- Tanks (tank-farm type with fixed roof or floating roof)
  - Orientation of all tank nozzles
  - Orientation and configuration of roof access stairs
  - Orientation of top- or side-mounted mixers or bayonet-type heaters

- Drums (horizontal accumulators)
  - Orientation of all nozzles
  - Orientation and configuration of all platforms and ladders
- Trayed towers (fractionation columns)
  - Orientation of internal trays
  - Orientation of all process nozzles and maintenance access openings
  - Orientation of all instrument nozzles
  - Orientation and configuration of all platforms and ladders
  - Type, orientation, and elevation of all pipe supports attached to the vessel (including deadweight loads)
  - Nozzle force and moment loading
- Non-trayed towers (reactor-type vessels)
  - Orientation of catalyst loading and unloading nozzles, and catalyst handling facilities
  - Orientation of all process nozzles and maintenance access openings
  - Orientation of all instrument nozzles
  - Orientation and configuration of all platforms and ladders
  - Type, orientation, and elevation of all pipe supports attached to the vessel (including deadweight loads)
  - Nozzle force and moment loading

There may be an inclination to ask, "Why is piping so involved in vessels?" First, vessels (on a per-equipment basis) have more nozzles, more operational issues, more maintenance issues, more constructability issues, and more complex access criteria issues than any other piece of equipment. Second, as stated in chapter 1, piping, specifically piping design, is responsible for the overall plant layout and piping design. For the purpose of our discussion, we are describing the operating scenario that exists in much of today's world. For those companies and projects where this operating scenario does not fit, then the group or entity responsible for overall plant layout should be given that role.

The PEL needs to recognize that there are two types of piping work. Some of the piping work has an internal piping discipline focus only. The output from one piping subgroup is input for another piping subgroup only. The second type of piping work activity has an external (outside piping discipline) focus. The largest share of the piping work has an external focus. The activities with an external focus are referred to as being piping dependent. These activities need to be done as early as possible in the project evolution. Early execution of piping-dependent activities allows other disciplines to meet their schedule obligations. Vessel orientation is one of the most important piping-dependent activities.

After the piping design group develops the tank, drum, or trayed tower layouts, these layouts are forwarded to the vessel group for an initial review. At this time, it may also be prudent to hold a formal review of these layouts that includes the licensor (when applicable), process (client and in-house), vessel engineering, plant operations, plant maintenance, and construction. The approvals that come out of this review will allow the total project to move forward in many areas. Later, after the vessel group has completed the in-house detailed design drawings, they will be issued to vendors and the project disciplines.

The vendor will send drawings for approval after shop detailing is completed. Piping would not normally need to do a detailed review (vendor drawing squad check) of these vendor vessel drawings. A detailed review should be done by the vessel engineering group to ensure compliance with the vessel group design drawings.

The structural engineering lead (SEL) reports to the project engineering manager. Under the leadership of the SEL, structural engineers and designers are responsible for the detailed engineering and detail drawings for all of the belowground and aboveground structures on the project. The structural group is heavily dependent on other groups for input as to the size, type, and location of items requiring support or "housing."

The key point of (piping) plant layout responsibility is restated here. As a part of the plant layout and equipment layout process, piping will conceptualize a design for all structures and pipe racks. The prudent PEL and piping design supervisor will have met with the SEL and other structural engineers and will have determined some basic design criteria for all structures. Key points to cover will include such items as concrete versus steel, stairs versus ladders, grating platforms versus checker plate, in-place monorail maintenance facilities versus mobile equipment, and others.

The detail engineering of structures and pipe racks is also a very important piping-dependent activity. The SEL and the structural group cannot move ahead on any of their work activities until piping releases the conceptualized design. As with the vessels, the PEL should push for a design review of all structures prior to full release to structural. The review should include process (client and in-house), structural engineering, plant operations, plant maintenance, and construction.

The civil engineering lead (CEL) reports to the project engineering manager. Under the leadership of the CEL, civil engineers and designers are responsible for the detailed engineering and detail drawings for all of the soil and paving issues, along with all surface and subsurface drainage for the

project. Civil normally handles all preliminary site clearing issues. Civil will also be responsible for roads and parking lots. A key point for the PEL to remember is that the first work to be done in the field is the civil site-related work. As part of the plant layout responsibility, piping also needs to remember that there are civil design considerations and civil code requirements that need be considered.

The electrical engineering group headed by the electrical engineering lead (EEL) is responsible for all of the project power, lighting, and communication needs. These responsibility requirements cover the normal and emergency systems, hardware selection (such as transformers and switchgear), and aboveground and underground distribution systems. There are also electrical design considerations and electrical code requirements that need be considered. Open lines of communication are important here, too.

The instrument engineering group (or controls systems group) headed by the instrument engineering lead (IEL) is responsible for the "nervous system" of the plant. These responsibilities include the layout of any control rooms, control system hardware, control system software, local indicators, sensing elements, and circuits. One of the major activities of this group is to define the physical hardware elements that constitute the in-line and on-line instruments for the project. The instrument engineering group will take the preliminary instrument data sheet originated by process and complete the definition requirements, including final sizing and vendor selection.

The architectural group will tend to have a minor role on most of the typical outdoor process plant projects, such as a refinery or chemical plant. If present, however, and depending on project needs, they will normally be responsible for the design development of only new (or revisions to) nonprocess-related buildings. These buildings may include the administration building, control house, laboratory building, warehouse, change house, and guardhouse. In the typical process plant or other large enclosed structures housing major process equipment, the structural department would normally be the responsible group.

Plumbing and HVAC will be involved in a process plant if there are occupied architectural-type buildings. Typically, when these services are required on the project, they may be provided on a part-time basis or be subcontracted. Piping may interface with these groups to provide utility services for heating, cooling, and domestic needs.

The fire protection group in most companies will exist as an autonomous group. This works fine if the primary product line of the company is

residential, commercial, or light industrial construction. It is not as appropriate for the process plant project. I believe that the complex process plants discussed in this book need a vastly different approach. Fire and other hazards, along with prevention and protection requirements, will exist on every project. The hazards and the provisions to satisfy the protection needs will vary from project to project. The organization structure for the execution of this work will also vary from company to company. The fire protection group is typically small; their involvement will be part-time and will occur in fragments spread over the life of the project. There will be a requirement early in the project to assist in the development of the project scope and design criteria. There will also be involvement in the permitting phase and in the detailed design of the actual fire protection and other systems. The designated lead for the fire protection work will normally report to the engineering manager. The PEL and the other project leads will need to interface with the fire protection lead and this group.

Like fire protection, environmental engineering may also be one of the smaller groups on the project. The mere size of this or any other group has no bearing on the importance of its contribution to the project. In fact, for most projects, if the environmental needs are not taken care of or handled properly, there may not be a project at all.

The final group for discussion here is the technical document control (TDC) group. There are two basic categories of documents associated with a project. One category is correspondence: client letters, job bulletins, meeting notes, and so forth. The other category is technical documents. Technical documents include internal documents such as specifications, data sheets, drawings, and other discipline deliverables like equipment lists and line lists. Technical documents also include external documents such as vendor drawings and data. All correspondence will typically (or should) go through the project manager. All internal and external technical documents should go through the technical document coordination (TDC) group. This group or function should exist on every project. It may be a separate and recognizable group at some companies. It may be nothing more than the additional duties assigned to the project clerk at others. The TDC can be called the “front door” for the engineering groups on the project. The term *front door* means that the TDC is the one and only conduit for all technical documents connected with the project. The TDC function, the TDC group, and the TDC supervisor should report directly to the engineering manager. In order to control the project properly, the engineering manager should insist that every project-related technical document that comes to the project or is sent out of the project go through TDC.

The groups listed here are not the only engineering groups that may be found in a company. Other specialty engineering disciplines can be found in companies that do very special types of projects. The ones listed in this chapter are the major engineering functions found in the process plant engineering and construction field. There are also some nonengineering groups and people who participate in the execution of the project. In the next chapter, we will discuss these very important nonengineering groups and nonengineering people who round out the total generic task force.

3

Nonengineering Groups

This chapter will cover the interface with management and other nonengineering entities. It will also identify what is expected of the person in charge of piping.

As previously stated, every company is organized differently. Many small companies have very simple corporate structures. Some medium-sized companies have more complex corporate structures. A few very large companies have even more complex corporate structures. The corporate structure itself does not normally influence the basic project organizational structure. The project's industry focus (power, petroleum, pharmaceutical, or manufacturing) will sometimes add an extra dimension to the project organization. The type of project (grass roots versus revamp), the scope of the project (E, E&P, or EPCM), and the size will have the greatest impact on the makeup of the team.

Every project is different. However, some organizational positions tend to remain the same for every project. For the purpose of our discussion here, we will classify the project positions as *internal positions* and *external positions*. The internal positions are defined as your company. The external positions are not your company and include the client's organization. Depending on the project, the external positions may also include the licensor's representatives, a third-party construction management entity, and others.

BASIC PROJECT ORGANIZATION STRUCTURE

The basic nonengineering-related project positions include the project manager assigned from your company; the engineering manager (see chap-

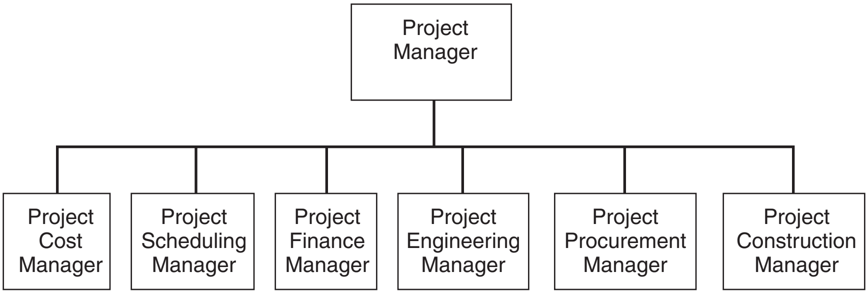

Figure 3-1 Basic Project Organization Structure

ter 2); the project cost controls manager; the project scheduling manager; the project finance manager; the project procurement manager; and a construction manager. Depending on the type, size, and complexities of the project, the following internal positions may also be present: area project engineers, a contracts manager, a validation engineer, a permitting coordinator, a project administrative manager, and possibly a project information systems manager. Every company will have different methods and needs. Some of these positions may never appear on any organizational chart and, therefore, may be thought of as nonexistent. This may not be so. These positions may be known by different names.

The project manager (PM) is the person assigned by your company to have primary responsibility for the total project. The PM is accountable to the company for everything relating to the project. He or she will be responsible for safety, quality, cost, schedule, profit, and loss. The PM will also have dual accountability, because he or she has an obligation to the client. However, this obligation to the client is not open-ended. The client looks to the company PM to correctly and completely convey all the project goals to the project team. This does not mean that whatever the client wants, the client gets. It does include meeting the mutually-agreed-to goals. It includes the moral obligation to protect the client from himself. The size and type of project will determine whether the PM takes an active role in the day-to-day project execution. If the project is small enough, the PM may also function as the engineering manager.

Regardless of the size of the project, the PEL has specific obligations that must be met with relationship to the PM. These obligations can be defined simply as doing the job right. Doing the job right will have a different meaning for different project managers, on different types of projects, in different companies. Some things will change from one job to another.

The PEL and the other leads should meet with the PM early in the project and ensure that everyone knows the project philosophy. Some things should never change. The things that should never change are safety in or at the workplace (office or site) and the quality of the deliverables. The PEL who allows horseplay in the office that results in someone getting hurt does not fully understand the PEL role or the potential legal ramifications. In simple terms, the PM will expect the PEL (and other leads) to:

- Be qualified for the position
- Be willing and able to fulfill the assignment
- Become knowledgeable about the project scope
- Be able to estimate the labor and costs required for the work
- Understand the requirements and relationships of the other disciplines
- Be able to develop and maintain a schedule for the execution of the work
- Be able to recognize potential problems and develop appropriate solutions
- Be honest and trustworthy
- Possess a pleasant, positive, and professional demeanor

These qualities should not seem unusual: They are very similar to the things we look for in the people who report to us. The project manager job may appear different from your perspective, but it is in fact very similar. The project manager is just another employee with a job to do.

The project cost controls manager is accountable to the PM for the project costs. The bottom line for a project is not a cost that is related to the number of hours: The bottom line is a cost expressed in dollars. The costs on a project will be generated in a number of categories. One of these categories is salaries for each employee. The employee salary covers the direct pay (including vacation and holiday), the indirect pay (local, state, and federal taxes), plus burdens such as health benefits. Other project costs are supplies that may include everything from paper clips to toilet paper. Project costs are also created by insurance, travel, special training (computer or safety), or by job-site requirements for special clothing. All of these generate costs on the project before a spade of dirt is turned or a single piece of equipment or material is purchased.

The PEL normally needs to do a complete labor and cost estimate for the project. In some cases, your company may not require an estimate, although this would be extremely rare. In a case like this, someone may have submitted a factored estimate, and that estimate will form the basis of the project. The problem with this is that you do not have a starting point for

your planning. You still need to do your own estimate, based on what you know to be the scope of work.

After the estimate, the PEL's next requirement is to generate a schedule of discipline work activities. It would seem virtually impossible to develop a schedule of activities if one does not know how long each activity will take. The PEL needs to work with the cost controller to ensure that all of the required categories are included in the estimate. The estimate also needs to be structured to meet the reporting and accounting breakdowns established for the project by the client and the company. The structure of an estimate is sometimes referred to as the *work breakdown structure* (WBS). The WBS may mean different things to different companies. Think of the WBS as a three-dimensional (length, width, and depth) matrix. This matrix is used for projecting (plan) and later reporting (actual) project costs.

The length refers to the geographic areas on the project (such as overall site, tankage, boiler plant, and feed preparation). The width refers to the disciplines (such as process, structural, piping, or electrical) and entities (such as construction, surveyors, or third-party inspectors) involved with the project. The depth refers to all of the costs generated in each area by each discipline or entity (such as home office labor, home office expenses, capital equipment, bulk material, field labor, construction equipment rentals, consumable materials, or services).

It does not make sense to put together an estimate that has a very complex WBS if the costs (labor, expenses, and material) are not going to be collected in a like manner. It is also a fact that you cannot wait until the end of the job and then decide that there needs to be a WBS or that the WBS needs to be expanded. It just can't be done! The PEL needs to find out early what the WBS is, what will need to be done throughout the job, and what will be expected at the end of the job.

The project scheduling manager is accountable to the PM for the project schedule, although saying this is somewhat inaccurate and unfair. The schedule is created from the input of all the participating engineering disciplines. The scheduler does need to know how to put this information together. The scheduler should know the proper sequence of all basic engineering and construction activities. All the activity element schedules will come from the various discipline leads.

The project scheduler as a single individual cannot keep the job on schedule. Maintaining the schedule is the responsibility of each of the individual engineering disciplines. When the PEL or any other lead recognizes the potential for schedule slippage, a red flag should go up. Communication

needs to be initiated with the engineering manager and any other discipline that might be affected. The main role of the project scheduler is to:

- Ascertain the client's project time line and critical milestones
- Prepare a master schedule
- Prepare a rough-cut engineering, procurement, and construction project level schedule (PLS)
- Collect schedule-specific detail data from all the disciplines
- Refine the PLS to reflect the actual project activities and duration
- Work with the various leads to develop their individual discipline control level schedules (CLS)
- Periodically collect progress and status data for reporting purposes
- Revise master or project level schedules, as required

No two projects are the same. The general activities of the project will be similar from job to job. However, specific tasks, quantities, volumes, and timings will vary from one job to another. The specific needs of the piping group will not be the same on every project. You must tell the scheduler if the schedule does not reflect the true nature of the piping needs. The project scheduler is not a mind reader. If the schedule is wrong or does not reflect the actual job requirements, it may be more your fault than the scheduler's fault.

The project finance manager is accountable to the PM for the accounts receivable and accounts payable relating to the specific project. The cash flow on the project needs to be managed in a proper manner. All legitimate costs incurred on the project should be posted in a timely manner. The receipt of payment needs to be monitored. All legitimate bills submitted on the project should be paid in a timely manner. To be cost-effective, only legitimate bills should be paid. The PEL will normally have little or no interface with project finance. However, the PEL needs to make sure that all unusual project-related piping costs are properly approved.

The project procurement manager is accountable to the PM for all project procurement activities. Some projects will not have any procurement activities required by the project scope. For projects that include limited or total procurement, someone will be assigned to oversee a wide range of procurement-related tasks. These tasks may include many of the following:

- Coordinating informal phone or fax quotes
- Establishing an approved vendors list
- Issuing and monitoring formal RFQs (request for quote)
- Conducting formal sealed-bid openings

- Preparing and performing (nontechnical) bid evaluations
- Issuing and monitoring formal purchase orders
- Preparing, maintaining, and issuing periodic purchase order status reports
- Coordinating and handling vendor or supplier expediting, inspection, and shipment delivery

Total procurement on a project means that all tagged equipment and electrical items, all tagged instrument items, all piping specialty items, and all bulk materials are purchased by engineering. Limited procurement on a project may mean that only the major equipment items are purchased by engineering. Limited procurement could mean that some special items in a discipline might be purchased by engineering.

When there is limited procurement by engineering, someone else will need to perform that service. It may fall to the client, a construction management firm, or the final installation contractor. No matter who does the actual purchasing, someone needs to tell them what to buy. For piping, you (and your team) must define in clear terms what piping materials are to be purchased for the project.

The construction manager (CM) is usually accountable to the PM for all project construction activities. The construction manager would ideally be assigned to and be present on the project during the early planning stages. This is not always possible due to the timing and location of the CM's current assignment. In cases like this, the company may have a construction coordinator who works with the project in that early planning phase. The coordinator would then hand off the job to the assigned CM when he or she is available. Most of the time, the key to making the job a success will be in the construction. It is possible to design something that, in fact, cannot be built. A simple thing like getting the CM to review the plot plan for constructability may save hundreds of thousands of dollars.

With a copy of the plot plan, the project scope of work, and the project schedule, the CM will start the construction planning. Most people in engineering do not have a good grasp on what successful construction means. Engineers and designers in the traditional office do not always get a chance to visit a job site. Because of this, we do not pay enough attention to what it takes to construct a major project. Here are just a few of the items facing a construction manager:

- Union versus nonunion labor
- Duration of current contract agreement (if union)
- Local work rules

- Worker quantity, quality, and availability
- Craft camps (if job site is remote)
- Job-site safety considerations
- Job-site security considerations
- Job-site weather conditions
- Job-site transportation access (barge, rail, etc.)
- Job-site construction office space
- Field office support services (toilet, water, and cleaning services)
- Equipment and materials receiving facilities and space
- Local availability of construction-related services
- Control and disposal of contaminated soils or controlled materials (for example, asbestos, lead paints, heavy metals)
- Assigned contacts for safety, operations, work permits, and security
- Construction management staff
- Living quarters for construction management staff
- Construction office procedures
- Construction office job file controls

Other potential company positions on a project include the area project engineer, the contracts manager, the permitting coordinator, the validation engineer, a project administrative manager, and a projects information manager. All of these positions may be stand-alone positions, or they may be secondary roles that are assigned to another person having one of the primary project roles.

An area project engineer is usually found on very large or megaprojects. These projects are too large and too complex for one person (the project manager) alone to manage. These area project engineers report to the PM and act, in effect, as project managers: They function much the same as a PM for their assigned areas. Some of the grassroots megaprojects of the mid-1970s had 10 to 15 major process areas or units. Each of these units was larger than most projects of today. Each of these units had an area project engineer that functioned in the same manner as the PM for any smaller project.

The contracts manager is usually assigned to a large project EPCM that has many construction work packages (CWP). This position is the focal point for the coordination of all the issues dealing with the packages. These issues may include:

- Quantity and the numbering of construction work packages
- Focus of each CWP (piling, geotechnical, surveying, mechanical, and so forth)

- Estimated value of each CWP
- Format of the CWP
- Schedule of all CWPs
- Development status of each individual CWP
- Issue for bid and award status of each CWP
- Post-award contract administration of the CWP

Permits and permitting activities for process plants fall into two areas: the permits required for constructing the plant and the permits required to start up and operate some types of plants. The first of these, building or construction permits, may not always be a company function or activity on every project. Obtaining building permits (or the equivalent on foreign projects) is a normal and necessary activity. In most cases, the burden of getting the actual permits themselves is handled by the client or a specialty legal firm retained by the client. There are, however, technical support documentation requirements for the permit process. On large, complex projects, a permitting coordinator may be assigned. This position would work with the client and the disciplines to ensure that all documents are defined, developed, and available in a timely manner.

The validation engineer is responsible for the second type of permit. These permits allow the client to start up, operate, produce the product, and make a profit. The validation function is normally present on any pharmaceutical-related process plant project that involves hygienic design criteria and FDA (Food and Drug Administration) approval requirements. The validation engineer may be involved throughout the project or may be part-time. The purpose of the validation engineer is to ensure that the plant meets all the requirements of the FDA or other licensing body.

A project administrative manager position is not normally a separate position on a small project. The duties may be shared by others or be a second "hat" for someone else on the project. Duties relating to an administrative manager position include:

- Supervision of clerical staff
- Office space coordination and security
- Office supplies
- Office hardware needs (printers, copiers, fax machines)
- Project procedures
- Project files
- Nontechnical project cost control (travel, lodging, and so forth)

Most projects today also have a project information manager. Any large project that is multidiscipline oriented and executed in an electronic (CAD) environment needs to have a person in charge of all the systems. Each company will have its own title for this position. This is the position responsible for the total project computer network. In a small company or on a small project, this function may be filled out of a central core group. On a large project, there should be a person assigned full-time to the project. An average project completed today does not look much different from the average project of 30 years ago. The big difference between then and nowis in the media and methods used in the office. The project of today will be constructed using the same field methods as those used 30 years ago and will look very much like that plant of the past. The big difference is in the way we design the plant in the office. There is also a difference in the way we communicate the design to the fabricators and the builders. The project of today depends on computers in every aspect of the work effort. Projects of today need hardware such as computers, servers, and printers. Projects need a wide range of discipline-specific software for technical documentation, design graphics, analysis, and records. Networks are needed to link all the local and remote users together. Databases, system security, periodic backups, and archiving of the finished records are also needed. The mission of the information systems manager is to make sure that the project has the right equipment at the right time and that downtime is as close to zero as possible.

This chapter has covered the various company-oriented positions that can be found on the typical process plant project. Client staff may also be involved in the project. Clients will not always place a full-time project staff in your company offices. If they do, then you (and your staff) should treat them with the same respect and courtesy you would expect if you visited their offices. You and your staff should make the client welcome. On the other hand, there are some things you should not do. You and your people are not an official line of communication for the project or for the company. When a client representative is in the work area, you need to ensure that random conversation is not detrimental to the project or harmful to the company. You should also try to direct sensitive questions (from the client) and the subsequent answers through your project manager.

It is more difficult to predict the size, shape, or configuration of the client organization. Being an operating company as opposed to an engineering company, their organization may appear different from your company. It is not your goal or role to change them. In most cases, the client structure will

be very close to that of your company. The typical client (external) positions may include the following:

- Project manager
- Process engineer
- Project cost manager
- Project scheduling manager
- Project finance manager
- Project procurement manager
- Construction manager

The client's staff from a functional standpoint will no doubt have the same basic duties and responsibilities as your internal (company) positions. In addition to these positions, the client staff may include the following on an as-needed basis during the evolution of the project.

- Plant operations representative—One or more people may be assigned to assist in the definition of plant operating criteria and review the design as work progresses.
- Plant maintenance representative—Maintenance criteria will be defined, and there may be reviews held for critical equipment, as required.
- Plant fire and safety representative—This is another area where design criteria will be needed early and will require one or more reviews to reach final design approval.
- Plant engineering representative—Plant engineering will usually be called upon to supply existing documentation, provide facility-specific standards or conventions, and define post-project records requirements.

These first three chapters have defined the typical players for the typical process plant engineering project at most engineering companies. The next three chapters will discuss the typical projects and some variations.

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Part II

Project Descriptions

4

Project Types, Terms, and Execution Philosophy

This chapter will be a discussion of various types of projects and some of the important aspects of piping's contribution to those types of projects.

In today's world, it would be rare to find a project of any kind that does not include some kind of piping. Every construction project requires some type of piping system. Piping systems for sanitation, fire protection, and HVAC (heating/ventilating/air-conditioning) are very important and are installed in a wide range of buildings built every year. Airports, factories, hospitals, hotels, jails, office buildings, and warehouses are being built every day. There are also projects where the piping is the method of transportation to move a gas or a liquid from one place to another.

These projects, although very important, would not be considered a process plant. The piping systems included in these projects for building support are not considered process plant piping systems. These types of systems are typically required only for space heating or cooling, for manufacturing support, and for safety. The piping involved in the pipeline project is also not normally considered a part of a process plant piping system. All of these piping systems do have their own complex technical and code criteria that must be met. The piping forms a vital part of these specific projects. The intent of this book is not to diminish the importance of these projects or these types of piping systems. This book is intended to focus on piping engineering leadership as it applies to the process plant project and the process plant piping systems.

A process plant piping system is a piping system that conveys the commodities related to the specific product of the plant. It is a product-related

system within a process plant. The process piping system tends to be a part of the purpose and function of the facility as opposed to being just a building heating or cooling system. Projects that include process piping systems typically have a wide range of pressures, temperatures, and materials of construction. Some projects require process piping systems to handle pressures that ranges from full vacuum to thousands of pounds per square inch. Some projects require process piping systems to handle temperatures at −300°F on the lower end of the scale to 1500°F at the upper end. Many plants have commodities so corrosive that they require special alloy or glass piping. Some process piping systems are so highly toxic as to require a special category (M) as defined in the piping code (ASME B31.3).

Process piping systems will also include the process-related support piping systems. These are commonly referred to as the process *utility systems*. Utility systems include multiple steam systems, condensate systems, cooling water systems, utility water systems, air systems, fuel oil and fuel gas systems, and nitrogen systems. These piping systems—both the process systems and the utility systems—are the responsibility of piping engineering and design and are found in the typical process plant today.

Process plants built as engineering and construction (E&C) projects require complex process piping. These projects include the following:

- Ammonia plants
- Aromatics plants
- Beer distilleries
- Benzene removal
- Beverage processing
- Butadiene plants
- Biotec plants
- Chlorine plants
- Cokers (delayed and flexi-)
- Crude oil refineries
- Cumene
- DOE nuclear waste calciner
- Ethylene steam cracking
- Fertilizer plants
- Fluid catalytic cracker
- Foods processing
- Fossil fuel power plant
- Gasoline blending unit
- Helium plants

- Hydrocrackers
- Light ends fractionation
- Nuclear power plants
- Liquified natural gas (LNG) plants
- Paint manufacturing
- Pharmaceutical
- Polyethylene plants
- Pulp paper mills
- Soap manufacturing plants
- Solvent deasphalting
- Thermo catalytic cracker
- Turbine generator Cogen power plant
- Urea fertilizer complex
- Vacuum/asphalt
- Vinyl chloride monomer plant
- Waste treatment
- Water treatment

And there are many, many more.

These projects and others in the process plant industry are often referred to in specific terms. The terms used include *lump sum* and *cost-plus*, along with qualifier variations that seem to add only confusion. These terms, however, are very important to both the client and the company. These terms deal with the primary method of payment and the framework of compensation for the work that will be done by your company. They should not have any bearing on how you do your work. Lump sum is normally equated to a more rigid concept of one maximum price: all or nothing. Most people, understanding that the job is lump sum, seem to make a more concerted effort to get the work done on time. With the cost-plus job, this seems to be different. Some people think it is okay to slack off on the cost-plus job. They tend to stretch out the work and make it last longer. This is wrong from a number of standpoints. Slacking off may not be illegal, but it is certainly morally wrong. Cost-plus carries a less rigid connotation. It tends to imply a less critical or a less-defined target cost. Cost-plus, when thought of in this light, is conditionally inaccurate. All jobs have a maximum cost limit that renders them not justifiable. Somewhere, to someone on the client side, there is a "one maximum price, all or nothing." Therefore, the attitude for all of the engineers and designers on the company side should be the same for both job types. Do your best all the time, every time.

For each of the plants listed earlier, there are variations for a potential project. The variations that might impact a project are discussed using certain industry-specific terms. Most of the readers of this book will already know and understand these terms. Some may have heard the terms but may not know the definitions as they relate to our profession. To understand the variations and the implications, one must understand the terminology. Two of the primary terms we have in our profession are *grass roots* and *revamp*.

Grass roots refers to a plant or project that is a totally new installation; it is literally built from the "grass roots" up, as a new facility. Another term that is also used to imply the same thing is *green field*. The choice of which to use in the future is left up to the reader. The term *grass roots* will be used in this book, when appropriate. A grassroots plant is one that may be built on previously vacant land. A grassroots plant may also be built on land that has been (or will be) totally cleared of all previous obstructions such as buildings, structures, and equipment. Because there are fewer constraints and obstructions, a grassroots project can be easier to execute. Chapter 5 will discuss the step-by-step process for piping of a grassroots project.

A *revamp* project is a modification of an existing facility. The reason for doing a revamp may be one (or a combination) of the following:

- Debottlenecking—Increasing the capacity by modifying existing equipment and piping or by adding new equipment and piping.
- Cost reduction—Improving the profits by lowering operating costs through the modification of existing equipment and piping.
- Changing product—Changing the process function by adding more, different, or larger equipment. It will also require the addition of new piping or the modification of existing piping.

A major process plant project does not just suddenly appear in an engineering company in-box. A project goes through a long process of conceptual planning and cost justification. Only when the client is convinced that a project is viable will that project move ahead to full execution. In today's world, there are a number of ways that clients choose to execute these projects. They may choose to give responsibility for the total project to one large multifunctional engineering and construction (E&C) company. Or, they may choose to unbundle the project and disperse the responsibility among two, three, or even more specialty companies. Some parts of project execution may be dispersed to these separate companies.

The commonly recognized terms for these project parts (and their meanings) are as follows:

Pre-FEED

In this part, FEED is an acronym for “front-end engineering development.” A pre-FEED project is one where someone is conceptually defining a proposed project. Many clients perform the pre-FEED part of a project with their own staff. Clients may also obtain the services of an engineering company to develop the pre-FEED project package. The objective of contracting out the pre-FEED package is threefold. First, the client may need the expertise of the engineering company to look objectively at the project goals and determine if the project is feasible. Second, the client will want a package that they can issue to selected contractors for bidding purposes. Third, the client will want the pre-FEED contractor to prepare a realistic estimate of total installed cost (TIC) for their internal requisition for funding.

FEED

The FEED part of a project is characterized as the first 20 to 30 percent of the engineering of a project. The FEED contractor has been awarded all or a part of the project. The contractor is now working with the client (and licensors, if applicable) to prepare the front-end requirements for the project. The heaviest workload during this FEED part will be in the process engineering group. However, some piping activities start at this time.

Detailed Engineering

This part of a project tends to have two results, depending on whether procurement is included in the FEED contractor’s scope.

- If the FEED contractor company has engineering only, then this part of the project is shorter in terms of time and does not lay the foundation for true fabrication and construction grade drawings and isometrics.
- If the FEED contractor company has both engineering and procurement, then this part of the project will take longer, but it does prepare the required basis for project drawings and piping isometrics that are ready for fabrication and construction.

Production Engineering

This part is the final preparation of the drawings and other documents required to define the final project. Here, again, there is a difference in the results.

- If the FEED contractor company has engineering only, then this part of the project is very short and can result in drawings that are only conceptual in presentation. Piping and other structures (platforms and stairs) can be fairly well defined and detailed as long as they are not around equipment. The piping and structural objects around equipment that will be purchased later by others cannot be defined or detailed.
- If the FEED contractor company has both engineering and procurement, then this part of the project will include the receipt of certified vendor drawings and the quality control dimensional confirmation.

Procurement

The procurement involved on major process plant projects manifests itself in as many different patterns as there are different types of projects. Procurement is a somewhat complex, multifaceted function that can be performed by various entities. The terminology refers to a whole list of activities that are included in the term *procurement*. Some people think that procurement is only purchasing. Not so: Procurement includes much more than just buying an object. Procurement includes all of the following functions that result in a piece of equipment or a quantity of bulk material arriving at the job site successfully.

Purchasing

This is a series of activities that include taking the requirements definition from the engineers, preparing the request for quote (RFQ), issuing the RFQ, monitoring the RFQ status, receiving the bids, preparing the bid tabulations, assisting the engineer in resolving vendor questions relating to the technical evaluation, preparing the formal purchase order, issuing the purchase order, and monitoring the vendor performance.

Inspecting

This is a series of activities that include the possible prequalification of any potential vendors; the post-purchase order award follow-up to ensure

understanding of purchase order requirements; the purchase-order-specific hold-point inspections; any random inspections; and the final release for shipment inspection sign-off with final reports and documentation.

Expediting

This is a series of activities that include the determination of how the vendor is performing on this purchase order, whether there are problems, what has caused the problem, what is the recovery plan, and what, if any, are the alternatives. This information is fed back to the project for decisions and action.

Traffic Services

This is a series of activities that would normally apply to shipments that are deemed special for some reason. Special reasons include size, weight, unusually high cost, critical schedule impact, or other. The services may include assisting the vendor/manufacturer with the selection of the shipment method, the routing for the shipment, the permitting of the shipment, and, if required, riding shotgun to monitor the actual shipment.

Procurement on projects does not need to be performed by the same company that does the engineering. Procurement can be (and is) performed by the engineer, the client, a third-party procurement contractor, the construction management contractor, or the final execution subcontractor. The procurement plan can differ from one discipline to another. The procurement plan for the project needs to be defined and understood at the start. Chapter 7 will present a more detailed discussion of piping material procurement.

Other terms relate to the execution philosophy of the project. These include terms such as *turnkey*, *design-build*, *E* (only), *E&P*, *EP&C*, and *EPCM*. The terms *turnkey*, *design-build*, and *EP&C* mean that one firm does everything. The other terms (*E*, *E&P*, and *EPCM*) mean that the project is broken apart and distributed among a number of different firms. Engineering (E) only projects relate to projects where the company has the responsibility for the front end of the project only. This company will not purchase any of the major tagged equipment, tagged instruments, or bulk materials, such as piping. Piping's responsibilities are somewhat restricted in this project execution environment. E or architect and engineer (A&E) projects place the responsibility for the purchasing of the major equipment with the owner or the constructor. The company doing the engineering part

of the project does not normally purchase any equipment. This limits the responsibilities of the engineer. When engineering does not purchase the equipment and does not get vendor-certified drawings, they cannot do detailed and dimensionally checked final design drawings. And, if the owner or engineering contractor does not purchase the equipment in time and furnish vendor-certified drawings in a time frame that is compatible with the engineering, then the engineering can only be conceptual in nature.

Engineering and procurement (E&P) projects relate to a project where the company has the responsibility for the full engineering and the procurement of some or all equipment and materials. The company will normally purchase all of the major tagged equipment, tagged instruments, and some or all of the bulk materials. Piping's responsibilities are increased in this project execution environment. E&P projects have the responsibility for the purchase of the major equipment. When engineering does purchase the equipment and does get vendor-certified drawings, they can do detailed designs and dimensionally check the final design drawings. When the engineer purchases the equipment, obtains the vendor-certified drawings, and completes the engineering, then detailed pipe fabrication drawings can be issued much earlier. Engineering procurement and construction (EP&C) projects relate to a project that is a single-entity project. The company that has the responsibility for engineering and procurement also has the responsibility for the construction of the total project. These projects are sometimes referred to as *turnkey projects* or *design-build projects*. Engineering procurement and construction management (EP&CM) projects relate to projects that have the responsibility for the engineering and the procurement provided by one company and the construction performed in a subcontract environment. The construction management of the field portion of the project may be the responsibility of the engineer, the client, or a third-party firm experienced in the management of large process plant construction.

At this point, we need to discuss the general work activities associated with the execution of the full EP&C project. As we all know, each year has seasons, and each of these seasons has its own personality. Insects have stages of life that they go through. The moth goes through three life stages, each with vastly different characteristics. This process is called *metamorphosis*. Projects also have distinct stages. With a process plant project, it is not always easy to recognize the actual transition between the stages. For the purposes of this book, the term *phases* will be used instead of *stages.* A brief description of the major phases associated with the engineering of a project follows. These will only occur after the client has made an award.

The initial phase of engineering is conceptual engineering (Phase I). This phase, which covers only the front-end engineering development activities on the project, is sometimes referred to as the FEED stage of the project. The percent of the overall project time line required for Phase I engineering varies depending on the type of project, the newness of the technology, and the methods and systems used to execute the project. Phase I normally begins with the contract award. It normally includes formal meetings where the client restates the project goals and objectives and provides the design basis and any licensor data (if applicable).

The deliverables at the end of Phase I should include:

- Client-approved plot plan for the project (overall and area/unit)
- Issued for (client) approval piping and instrument diagrams (P&IDs)
- Key discipline design criteria specifications
- Definitive home office labor and material estimate
- Definitive execution schedule

The second phase of engineering is detailed engineering (Phase II). This phase covers the middle part of the project time line. Phase II starts with the P&IDs issued for design (IFD). The percent of the project time line required for Phase II is longer and also varies depending on the methods and systems used to execute the project. During Phase II, those projects that include procurement define and purchase all the major tagged equipment. The detailed design activities of all disciplines are fully coordinated during this phase.

The products of Phase II should include:

- Final definition of all process streams
- Final definition of all utility streams
- Full hazop review
- Full constructability review
- Full operability review
- Full maintainability review
- Full company interdiscipline review
- Full interference check and issue for construction (IFC) for 3D PDS projects
- Client-approved final design

The final phase of engineering is production engineering (Phase III). This phase completes the major home office engineering activities on the

project. Phase III begins with the client's final design approval and ends with the issue of the last deliverables required to construct the plant.

The products of Phase III should include:

- All specifications issued approved for construction (AFC) from all disciplines
- All drawings checked, corrected, and issued approved for construction (AFC) from all disciplines
- All major equipment drawings certified for manufacturing or fabrication
- All applicable purchase orders issued
- All applicable subcontract construction work packages released for bid or awarded

The next phase of the EP&C project is the construction. Phase IV may have actually started back near the end of Phase I. After all, we knew where the project was going to be built, and we needed to start some activities such as soil borings and site clearing. As more and more work is done in the office, additional activities can be started in the field. One main advantage of the single entity, turnkey/design-build approach is the elimination of the package preparation and bid time required with the CM approach. Phase IV normally ends with the completion of the final construction activities and transfer of custody of the plant to the client.

Piping engineering and design, as well as some other disciplines, may be required to assign people in the field during the final construction. These assignments will vary in nature, depending on the type of plant, the location, the client, the construction manager, and the type of project (EP&C or EPCM). The primary reason home office engineers and designers are sent to the job site during the construction phase is to answer questions and solve problems. Having engineers and designers who previously worked on the project and who have prior job knowledge at the job site is a real cost-saving benefit to the project. A secondary benefit (this time, for the company) is the enhancement of the experience and knowledge of the employee.

5

Grassroots Projects

The purpose of this chapter is to define the generic piping activities that may be required for a typical grassroots project.

As stated in chapter 4, the term *grassroots* refers to a totally new installation. A grassroots project may be a completely new plant, built from the ground up, or it may be a grassroots addition to an existing facility. Our generic grassroots project will have the four phases described in chapter 4. We will assume that our grassroots project includes full engineering, procurement, and construction management. We will also assume that the procurement portion means that 100 percent of the equipment and bulk material will be purchased by the engineering contractor and supplied to the subcontractors at the job site. Being a grassroots project, our execution method will be the state-of-the-art multidiscipline 3D computer-automated design (CAD) system.

Let us assume we have a model project. Here are the steps you would follow for the successful execution of the project. During Phase I, conceptual engineering, the PEL is very busy trying to learn about the project while laying the foundation for all the task force piping groups. The PEL will be primarily involved in the following activities:

- Collect and read all the available information about the project. There is already a knowledge base to build on if the PEL was part of the proposal team. If the PEL was not a part of the proposal team, the proposal PEL should transfer all data, thoughts, and impressions.
- Get on the distribution list for future correspondence and technical data that is applicable to piping. This may be accomplished through a meeting

with the engineering manager to gain a clear understanding of what is important to the piping discipline. It may be best to get copies of all technical data that has been distributed and then weed out what does not apply.

- Formulate an initial piping execution plan. The type of project will suggest what you need to include in the initial plan. The plan should include what things need to be started in the office and what things, if any, need to be done at the job site.
- Determine the piping engineering organization. What does the job include? If it is an EPCM project, you will need all of the four major piping groups. If it is a grassroots project, you will need the services of the computer application and design systems (CADS) group. For a project of the size of this one, we will request that a piping CADS representative be assigned. You will need to meet with the piping department manager and determine who will be assigned to your team as subgroup leads. These leads are sometimes referred to as your *direct reports.* They report directly to you for this project. Some of the leads may be located on the task force and dedicated full-time to this specific project. Others may be located remotely in a core group area and may split their time between two or more projects. Regardless of their location or project time commitment, they are your direct reports, and they need to be treated as full members of the team.
- Initiate a piping discipline checklist of project requirements. If your company does not already have a checklist for the required topics applicable to typical jobs, then you should start one of your own. The checklist should be discipline specific and have the information grouped in a manner that is topical and logical to the way your company does business. If you already have a checklist, then start filling in the blanks. Record all decisions that will later assist in the drafting of the scope of work.
- Define the scope of facilities. You have been on the job for a month or more, and it is now time to produce the piping scope of facilities. You will need to review this with a number of people to ensure that your concept of the job is in agreement with the engineering manager, the project manager, and the client.
- Define the scope of services. After you have completed the scope of facilities, it is time to produce the piping scope of services. You will also need to review this with your department manager, the engineering manager, the project manager, and the client to ensure that your concept of the job is in agreement with theirs.
- Initiate the piping home office labor estimate. Estimating should be done after there has been an approval of the scope of work. With an approved

scope of work, you can do an estimate of the labor hours required to do the work defined in the scope of services. Try to avoid making the estimate before you have scope of work approval. This only wastes your time and leads to misunderstandings later when someone remembers a lower but premature number.

- Develop the job-specific piping files. Early in Phase I and throughout Phase II and Phase III, a project will be inundated with data and drawings. Knowing ahead of time what will be coming and having a place for everything will make your life a lot more simple.
- Establish communications with the client's authorized technical representatives. As the PEL on the project, you need to ensure that correct client sources are identified with regard to standard methods, plant prerogatives, and material selection. You will also need to ensure that proper communications procedures are followed and documented.
- Establish a method of communications with the piping team. The best method I have found for this is for the PEL to provide each engineer and designer with a preformatted book for the filing of authorized project data. This book is further described in chapter 13. A multibillion dollar or even a multimillion dollar project cannot tolerate inconsistency and unnecessary rework because people are using different resource data. On every job, someone does work and someone else checks that work. At least, that is what is supposed to happen. If the "doer" (designer) and the "checker" use different data during their part of the design effort, then there is no real check or consistency.
- Develop the piping total quality action plan. Many companies in the past few years have grown to appreciate the importance of quality. Many have applied for and received certification for ISO 9001. The ISO (International Standards Organization) 9001 certification has become a mandatory requirement for many European clients. Even if your company is not ISO 9001 compliant, a quality program will be in place. Each discipline will have a basic quality plan with minimum standards for each type of document.
- Develop the preliminary piping execution control level schedule (CLS). Scheduling is discussed in chapter 12. After you have determined what you will design (scope of facilities), how you will document it (scope of services), and how many hours it will take to do it (estimate), it is time to define in detail when you will do the work. Detail scheduling will determine many things, including level of experience needed for each task, the number of people needed, when the people will be needed, and for how long they will be needed. The key to front-end scheduling is to make sure that the number of hours on the schedule agrees with the estimate

and that the piping activities are properly integrated and compatible with the other disciplines.

- Establish the physical in-house space allowance plan for the piping staff. After the preliminary piping schedule has been established, there will be an indication of a staffing curve containing a peak number for space allowance planning. You must work with the engineering manager or the designated project space coordinator to define the needs of the piping group. The staffing plan will also be used by the CADS representative to requisition the required computer hardware and other related services.
- Participate in flow diagram review. The PEL needs to participate in as many of the flow diagram reviews as possible. The PEL and the piping team are responsible for interpreting the process engineer's design plan into physical reality through the design process. The experienced PEL will give final approval to the piping documentation of that design. If the piping is wrong, then the piping engineering lead will be held responsible. As the PEL on the job, you need to see, hear, and understand everything you can.
- Initiate project and departmental reporting. Reporting may be monthly, every two weeks, or every week. Whatever the timing, you should try to make one consistent report serve all. Meet with the engineering manager to determine the timing and the subjects that require reports. Do the same with the piping department manager. Then, make one report that includes both requirements.
- Establish the piping group deliverables list. The scope of services included a definitive list of the types of documents to be produced on the project and the quantity of each. You further did an estimate of the required hours and prepared a control level schedule that defined when the work would be accomplished. Now is the time to formalize the list of deliverables. You should make a list of all documents. For each category of documents, you should establish the following:
  - Document number
  - Document title
  - Document size (number of pages)
  - Document revision
  - Planned dates for key milestones (when applicable)
  - Internal review
  - Client review
  - Issue for approval (IFA)
  - Issued for bid (IFB)
  - Approved for construction (AFC)

- Establish a scope and estimate deviation control program. No matter what you do or what other people on the job say, there will be changes. You may have thought you understood the scope. You may have thought that what you put on your estimate was correct. The realities of life tell us that every time we think we know all the answers, the questions get changed. You need to have a program in place to identify and record all deviations from your original plan. A deviation is any change, up or down, to anything in the scope, estimate, or schedule.

These are all activities that you as the PEL need to take personal charge of during the Phase I part of the project. In addition to these activities and meetings, you will need to keep your direct reports informed about the project. You will also need your direct reports to be involved in certain tasks and activities.

The piping material engineering (PME) lead will be primarily involved in the following activities:

- Develop and issue the piping material line class specifications. The development of the line class specs should be considered the highest priority item for the PME during Phase I. This may be a simple task, or it may be a very complex effort due to the research required for a state-of-the-art process. The proposal package or the early project data may have included a list of the commodities, along with the basic design pressures and temperatures required for flange ratings. The proposed utility systems will also form a starting point.
- Prepare initial piping material selection criteria. The selection of the correct piping material for each pipeline on the project is the most critical activity for the PME. The method for doing this may vary from one company to another. Here is a simple description for the activity. The flow diagrams (PFD or P&ID) reach a point of development and level of accuracy that will enable material selection by the PME. A copy (manual or electronic) of the PFD or P&ID is designated as the material selection flow diagram. Each piece of equipment and each line is marked by the process engineer, indicating the available design and operating data (for example, commodity, design pressure, design temperature, operating pressure, operating temperature, flow rates, velocity limits, and corrosion factors). Using the previously developed piping line class specifications, the PME will assign a line class specification to each line on the material selection flow diagram.

- Perform necessary pipe wall and flange rating calculations. Some of the systems defined on the material selection flow diagram may be outside the envelope of the current material classes. Where necessary, calculations will need to be made to verify the selection of the correct pipe wall thickness or the correct flange rating. The PME needs to be vigilant for any unusual condition that will effect the piping system.
- Participate in P&ID reviews. It would be advantageous for the PME to attend the detailed process engineer's formal client P&ID review. During these reviews, the process engineer and the client will typically discuss the process to a level of detail that may expose the need to change a selected material. The PME is the only person to make that decision.
- Develop and issue for approval other key piping-related specifications. One of the key piping-related specifications is the piping insulation specifications. The project may have a requirement for one or all of the following typical insulation types: hot, cold, safety (personnel protection), or acoustic. Insulation, regardless of the type, will take up space and needs to be considered later by the designer in the piping layout.
- Line number and spec all P&IDs and UFDs; develop initial line list. As a result of the previous activities, the PME can now develop a detail listing of all known pipelines on the project. The choice to have or not have a line list is not a debatable issue with me. I believe the line list is mandatory. A line list can be developed in a variety of ways. It could be developed manually (by hand on a preprinted form); electronically off-line as a clerical function (using a spreadsheet or word processing system); or be generated as an output from the database of an intelligent P&ID program. Whatever the method, the line list should be fit for purpose, timely, and cost-effective.
- Develop initial specialty piping (SP) item list and SP item data sheets. Regardless of the format of the company or client piping material line class specifications, there will always be that item that is not covered elsewhere. There are two choices on handling the odd items. You can revise the line class specs to include them whenever they are found or added. Or, you can develop a separate listing with a data sheet for each. The second choice is recommended, because these items may be the long lead items that will be purchased earlier and from a sole source.
- Develop the project-specific piping material commodity catalog. The piping material commodity catalog is a full purchase description of each and every piping item. Our piping material specification is based on a specific item code number for each specific item of material. The item

code commodity catalog is a listing, by item code number, of the full purchase descriptions of all material required for the project.

- Prepare group input to the project piping home office labor estimate. The PME will be expected to review the scope of work for the project, along with the scope of services, and provide an assessment of the number of hours needed to accomplish the required tasks.
- Prepare group input to the project piping control level schedule. The PME will be required to review the schedule to ensure that the timing of the work is compatible with potential responsibilities. The PME may not be dedicated to this project full-time. In addition to these PME activities and tasks, in support of the project, there will also be periodic meetings to attend. These meetings keep everyone aware of current actions and future plans.

The piping design lead will be primarily involved in the following activities:

- Develop and issue the project plant design and piping layout specification. This is also a mandatory document for a piping project. This project will cost hundreds of millions of dollars, have six or more client representatives to satisfy and have 30 or more designers doing the work. How can you justify not having a plan? The plant design and piping layout specification should be developed by the piping design lead and approved by the PEL. This document will then be submitted for project and client approval. Once approved, this document defines the basic criteria for the plant layout design, including arrangement and spacing of equipment down to the definition and location of utility stations. This specification is issued to every plant layout piping designer and checker to convey the rules of the game for the project. We will assume that our piping department has a form that will be used as a starting point for this specification.
- Develop and issue for approval all job-specific standards and details. Standards and details are the definition of the repetitive assemblies that require client approval prior to the real design effort. We also assume that our piping department has frequently used boilerplate details and standards that will be used as starting points for each of the project standards and details. Once approved, these standards and details will be preloaded into the project CADS database for the designers' use.
- Develop the overall project plot plan. This is a process plant project; as such, the responsibility for the plant layout and development of all plot plans is a function of the piping design group. The overall plot plan is developed using the PFDs, any P&IDs that may be available, the approved plant layout specification, and all available site data. This document will

be routed to a long list of interested individuals who will sometimes request conflicting changes. The PEL will need to be an ambassador and a referee at times to gain plot plan approval from the client and still stay within the budget and schedule.

- Develop the individual area or unit plot plans. (This is the same as the overall plot plan, only smaller geographic areas.)
- Develop piping transpositions (overall plant and individual area/units). Using the overlay technique, the piping design group transposes all the large diameter, high-cost alloy, and critical process lines onto a plot plan. This will service a number of needs to the project, including the following:
  - Prove the plot plan as logistically correct from a pipe routing standpoint
  - Provide the ability to do preliminary material cost estimating
  - Form the basis for pipe rack and pipe support location and sizing
- Participate in P&ID reviews. It would be advantageous for the piping design lead and any area piping leads to attend the process engineer's P&ID detailed review. During these reviews, the process engineer will discuss the process at a level of detail that will impact the piping layout. The piping leads need to hear this discussion firsthand.
- Prepare design group input to the project piping home office estimate. The piping design lead will be expected to review the scope of work for the project, along with the scope of services, and develop input to the estimate for all the piping design activities.
- Prepare group input to the project piping control level schedule. The piping design lead will be required to develop the detailed schedule for the piping design activities.

In addition to these specific piping design activities and tasks, in support of the project, there will also be periodic meetings that the lead piping design supervisor will need to attend.

During Phase I of a typical project, the piping material control lead and the piping material control (PMC) group will not have much to contribute. There could be some functional activities, but there may be only the estimating and scheduling administrative tasks. The piping material control lead will be primarily involved in the following activities:

- Perform special take-offs for cost pricing. There may be a need for price comparisons of piping material to aid in the selection of design options. The PMC group will then prepare a special take-off for these purposes. The issue of the requests for informal pricing by vendors would be via the purchasing department.

- Perform (normal) preliminary material take-off. Near the end of Phase I, the PMC group will perform the full preliminary valve take-off from the P&IDs. This take-off will be used to generate a valve RFQ package. The PMC group will also do a full take-off of bulk piping material. This action would include take-offs from the piping transpositions and/or specifically developed line sketches. The preliminary take-off needs to be approximately 75 percent accurate. With this in mind, the take-off activity will be scheduled at the end of Phase I and will use the IFD P&IDs, the client-approved plot plan, and the piping material line class specifications. The completion of this activity and the issue of the formal RFQ packages will overlap into Phase II.
- Prepare piping material control group input to the project piping home office estimate. The material control lead will be expected to review the scope of work for the project, along with the scope of services, and develop input to the estimate for all the PMC activities.
- Prepare piping material control group input to the project piping control level schedule. The material control lead will be required to review the schedule to ensure that the timing of the work is compatible with other potential responsibilities. The material control lead may not be dedicated to this project full-time.

For our sample project, we will assume that there is no requirement for any other stress-related action during Phase I. The pipe stress engineering lead will be primarily involved in the following activities:

- Prepare and issue the piping stress design criteria and analysis specification. One of the important items required for proper piping design is the criteria for pipe stress and flexibility. The pipe stress lead needs to prepare the design criteria that will be used for stress analysis for the project. This specification needs to be approved by the client. Not all lines need to be submitted for formal stress analysis. To do that on all projects would not be cost-effective. Some projects may include the requirement defining that all pipelines and, therefore, all isometrics be reviewed by the stress engineer. This total review requirement may be dictated by company, client, code, or project type requirement. The piping stress design criteria and analysis specification would define which lines require formal stress analysis and what will be the basis for that analysis. Once approved, this specification forms the basis for the stress group labor estimate.
- Prepare pipe stress engineering group input to the project piping home office labor estimate. The pipe stress lead will be expected to review the

scope of work for the project, along with the scope of services, and develop input to the estimate for all the stress activities.
- Prepare pipe stress engineering group input to the project piping control level schedule. The pipe stress lead will be required to review the schedule to ensure that the timing of the work is compatible with other potential responsibilities. The pipe stress lead may not be dedicated to this project full-time.

We defined our sample project as grass roots. This means that we will be executing the project design in a totally integrated multidiscipline electronic environment. As such, we will need an extensive setup by the CAD department. Due to the size of the project and the tight schedule, a full-time CAD representative has been assigned to the project. This person will be shared with other disciplines and will handle all computer-related matters. The PEL and the other piping leads will need to coordinate with the CAD representative for the following activities:

- Define piping CADS-related requirements. The CAD representative will meet with the PEL and the piping leads to review the piping execution plan. During this (and subsequent) meetings, all piping CAD-related needs, along with the timing, will be defined. These CAD-related needs include the following:
  - Hardware—The number of stations, the type of stations, and the timing of the stations
  - Software—The design execution software system(s) and the correct versions for each discipline
  - Printers—The number, the type, and the timing
  - Plotters—The number, the type, and the timing
  - Servers, network, backup, settings, units (metric versus imperial), databases, and others
- Prepare CAD group input to the project piping control level schedule. The CAD representative will be required to review the schedule to ensure that the timing of the CAD capabilities is compatible with other project responsibilities. The CAD representative is not dedicated to piping full-time: He or she is assigned to the project, not the discipline.

Phase I of the project is primarily the realm of the process and mechanical equipment engineers. This is the time when there is a major push to define and approve the process scheme for the plant. It is during this time that the equipment specifications are developed, and preliminary discussions

are started with potential equipment suppliers. With the process definition and the preliminary equipment sizes, the major deliverable by piping is the plot plans for the overall plant and the individual areas or units. When client questions related to the plot plan(s) are resolved and the plot plans are approved, there will be a direct transition to the Phase II activities of the project.

Phase II of our sample project is the most critical phase for piping. This phase is the longest in terms of calendar time, and this phase is where the bulk of the labor hours will be burned. The optimum transition from Phase I to Phase II is based on the client's approval of various key design criteria documents. These documents include the P&IDs, the plot plans, the plant design and piping layout specification, and so forth. The approval of these documents will open a floodgate of activity that will require lots of people. It is a prudent PEL who has maintained close communications with the piping engineering department manager. These communications include the number of people needed, the type of people needed, and when they are needed.

The PEL is very busy during Phase II. There are meetings and reports that will be required. The most important thing for the PEL to do is to remain alert. The piping engineering lead will be involved in the following activities:

- Monitor the piping scope of facilities. This is very important for the overall control of the piping work, budget, and schedule. The PEL needs to have a nearly photographic memory when it comes to the piping scope of facilities. Little things have a way of cropping up that were not included in the scope of facilities. Any change potentially affects everything.
- Monitor the piping scope of services. The same can be said for the scope of services as was said for the scope of facilities. A change in the number and type of deliverable impacts the number and type of people needed to do that work. New deliverables and the new people required to produce them impact the budget and the schedule. The new people required to produce the new deliverables impact the in-house office space available. The PEL must know how change affects the scope of services.
- Participate in P&ID reviews. The PEL needs to attend and participate in all the P&ID reviews. This is driven by the need to ensure that the piping design lead fully understands the process engineer and the plant operating requirements and the need to identify any impact on other piping groups.
- Participate in project meetings. Project meetings are held for a variety of reasons including:

  - Information and direction. Think of the project as an automobile that is being manufactured and assembled. The piping group that the PEL represents produces subassembly parts that are used by other groups. These subassemblies are needed at specific times. The piping groups also use subassemblies from other disciplines. Information and direction meetings afford the opportunity to discuss who needs what, when, and why. The PEL needs to attend these meetings to make and keep commitments for the piping groups.
  - Status reporting. Meetings to report status or progress are viewed by most people as unimportant. It depends on your point of view. Status reporting is keeping the boss informed. The boss may be a different person at different times. Sometimes, the boss is the project manager; sometimes, the client; and sometimes, your department manager. The boss does not always like the information in the report, but at least they are informed.
  - Problem solving. Meetings are called to discuss or solve an isolated problem. Sometimes, it is not possible to know the subject of a meeting beforehand and be prepared. If you know the subject of the meeting, do your homework and be prepared. If no notice of the subject is given, then don't feel pressured to answer on the spot. The "too fast" answer that is wrong will cost more than the time to develop the correct answer.
  - Budget or schedule review. Meetings are called to develop and review both the budgets and the schedules. Schedules are more likely to have multiple review meetings. This is because schedules are so fluid and are affected by seemingly very small items, actions, or events. These small items have a domino effect on the rest of the design teams and the overall project schedule.
  - Combination meeting. Combination meetings have their good points and their bad points. The PEL cannot control the type or format of the meetings called on the project. With combination meetings and too many different subjects, there is a lack of focus. With so much being covered by each group or discipline lead, the other discipline leads will tend to get bored and shut down. The PEL should be prepared, be brief, stick to the point, and not try to solve every problem right there. Take notes and indicate when you will respond and to whom.
- Hold informational and activity-specific meetings with your piping leads. As the manager of your own segment of the project, you will need to communicate with your leads. You will need to establish a fixed time to meet with your direct reports to pass on information, give direction, and receive status reports. It is strongly recommended that the piping

department manager be extended an open invitation to attend your staff meetings. The manager's schedule may not always allow attendance, but the invitation should be extended.

- Monitor quality procedures. During Phase II of the project, the design is being developed, and other disciplines will be taking action based on piping outputs. As the PEL, you are responsible for the quality of the work of the piping effort.
- Participate in the final project schedule development. The PEL will need to work with the engineering manager, the project scheduling lead, and the other discipline leads to finalize a project schedule. Because our sample project is grass roots and EPCM, the project schedule will be extensive. The project schedule will require discipline schedules that are compatible. The project schedule will cover all the time from project kickoff to post plant start-up. This schedule will cover the functions of engineering, procurement, and construction management. This project schedule will control the timing of all the major piping milestones, the major activities required for them, and the other disciplines tied to them.
- Finalize and monitor the piping control level schedule (CLS). The CLS is a schedule that takes the piping milestones and the major activities and breaks them down to the task level. During the Phase II portion of the work, there are lots of activities that need to occur at the same time. This is true for both the piping groups and the total project. The PEL needs to finalize the piping CLS tasks so that all the piping activities are compatible, and the CLS is compatible with the rest of the disciplines on the project. Once the schedules have been accepted or approved, then the PEL needs to monitor the activities and the tasks to ensure a smooth-running machine.
- Review piping design development. The need to review the work as it progresses is obvious. Try to catch the mistakes as they happen. Don't wait until the end of the job and then try to make the desired changes. It is a wise ship's captain who makes course corrections on a constant basis and does not wait until they are totally lost to change direction.
- Initiate piping bulk material RFQ/purchase order (PO) activities. (See chapter 7 for a detailed discussion of what is required.) Our project includes the requirement to purchase and supply to the subcontractors all of the piping bulk material.
- Initiate piping specialty item RFQ/PO activities. (See chapter 7 for a detailed discussion of what is required.) Our project includes the requirement to purchase and supply to the subcontractors all of the piping specialty items.

- Initiate piping shop fabrication RFQ/PO activities. (See chapter 8 for a detailed discussion of what is required.) Our project includes the requirement to prefabricate the 2 inch and larger piping on a competitive bid basis. In order to do this, we will need to prepare and issue a request for quote to three or more piping fabrication suppliers. The information needed to issue this RFQ includes a definition of what materials are involved, what sizes are involved, how much of each size and material, when will the drawings be issued, and what is the required-at-site (RAS) date.
- Initiate piping construction work package (CWP) development activities. (See chapter 9 for a detailed discussion of what is required.) For this item, the PEL needs to know the number and description of the construction work packages. The information needed includes scope, schedule, and type (lump sum or cost-plus). The need for proper planning will become evident as the CWPs are developed.
- Review and approve all deliverables from the piping groups. One of the precepts we have for our model project is that a person cannot approve his or her own work. This means that the PEL cannot develop a specification and then approve it. The PEL is the discipline approver for all piping deliverables. A project engineer may also sign in that little box on the drawing with the "APP" at the top. That person is not considered responsible for the technical aspects of the piping work. And, that person will be the first one to point a finger at the piping lead if something is found to be wrong. If you are going to be the piping engineering lead then make sure that your team does the development work they are responsible for; you be responsible for the review and approval of that work.
- Monitor work activities against the budget and schedule. During the Phase II part of the job, there will be periodic reports from the administrative department showing who charged hours to your discipline. On a weekly basis, the PEL needs to check these reports for accuracy and review the burn rate of hours versus progress. When trends are detected, there should be an immediate notification to the proper manager.
- Prepare and submit reports as required. Reports are a fact of life in the E&C business. There may be some or all of the following:
  - Weekly discipline status—For presentation at the weekly project meeting
  - Monthly discipline progress report—For presentation to the client and company management at the monthly project progress meeting
  - Monthly department progress report—For presentation to the piping department manager

- Pipe shop fabrication status report—For presentation at the weekly project meeting
- CWP development status reports—For presentation at the weekly project meeting
- Piping purchase order status report—For presentation at the weekly project meeting

- Reports are a necessity of life, but sometimes they are pushed to the side and ignored. The responsible PEL will make the reports part of the job and will realize that there is a benefit. If reports are prepared accurately, in a timely manner, and retained, then the close-out report will be a much more simple task. Also, if you get sick, your replacement will have a much easier time.

All of these PEL activities and duties are full-time. There will not be a lot of time to rest or get bored. There will, in fact, be more of a requirement to invest extra time to stay ahead of the game.

The piping material engineering lead will be involved in the following activities during Phase II:

- Develop and issue other material-related specifications. Depending on your particular company or the needs of the specific project, there may be other piping material-related specifications that need to be developed. These may be the specifications for coatings, linings, special casting material, special cleaning, or testing. During Phase II, all piping material will be issued for quote prior to purchase. material that requires a detailed specification will be included.
- Participate in UFD (utility flow diagram) reviews, as required. The piping material engineer will need to participate in the reviews of the utilities for the project. The UFDs will come out of the reviews and then need to be processed for line numbering and material line class for each line.
- Maintain the piping material line class specifications. Why do we need to maintain the piping material line class specifications? During this phase of the project, new lines may be added. In some cases, new conditions may be added that require new line classes or the modification of the existing classes. Time needs to be built into the budget and the schedule for this activity. The PEL, the material lead, and the individual designers will need to stay alert to the possibility of change.
- Develop (or provide data to develop) the 3D CAD database. The project is being executed in an electronic environment, a "smart" system. We will assume that the company program is a database-oriented system that comes with the standard discipline-specific enhancements. What we

need to do is ensure that all the project-specific line class designations are loaded and that all the flange ratings required for the project are included. We will need to have the complete material property database for the project and determine that all the standard and project-specific dimensional tables are loaded and correct. The worst thing to have happen with a "smart" system is to work for months and then find an error.

- Develop and issue any required procurement-related specifications or technical notes. As stated previously, during this phase we will be issuing the request for quotes for all of the bulk piping materials. All of the material is described in the line class specification, but that description is a simplified version for the designers. For actual procurement and proper communications with the vendors or suppliers, we may need more. The procurement of piping material will require specific requirements and instructions that are "type" specific. Instructions to vendors for the supply of tees and elbows would be different from those required for a vendor who supplies gate valves. These requirements may be "as-is" company standards, or they may need to be a company standard modified to meet the requirements of the specific project. These documents may be in the form of true specifications, or they may be in the form of less formal technical notes.
- Maintain the line list and the line numbering activities. The project will experience changes to the P&IDs and the UFDs during Phase II. The piping material lead will need to keep up with all changes. Lines that are deleted from the P&IDs or UFDs will need to be removed from the line list. Lines that are added will need to have a number assigned and a line class selected based on the design criteria. Lines may also change size. Line size changes may void previous wall calculations and require new calculations. When line conditions change, the line class and material of construction need to be reevaluated.
- Maintain the SP item list. As the project moves forward into detailed design, more SP items may be uncovered. These items need to be properly defined; dimensional data must be given to the designers; item-specific data should be loaded into the CAD database; and a procurement quality data sheet should be created. These items are then issued for a vendor quote.
- Maintain the piping commodity code catalog. In Phase I, the item code commodity catalog was started. During the Phase II portion of the project, there will be additions, deletions, and changes. This catalog will need to be maintained because it will be used by many as the project progresses.

- Be responsive to the needs of the other piping and project groups. The piping material lead will be called on to provide technical services to the piping group and to other groups on the project.
- Monitor work activities against the piping scope, budget, and schedule. The piping material engineering lead will need to be watchful for any trend or change that affects the scope, budget, or schedule and notify the PEL when trends or changes are identified.

Depending on the type of project, the piping design group will normally account for 70 to 80 percent of the total piping budget. The bulk of the piping design work will be done during Phase II of the project. During Phase II, the piping design group will have the largest population and will burn hours at a higher rate than any other group. A long list of critical and complex activities must be accomplished. The piping design lead and the design group will be involved in the following activities:

- Develop and issue other piping design-related specifications. During Phase II, certain other specifications may be assigned to the piping design lead to develop. Depending on the needs of the project, these may include:
  - Shop fabrication specifications
  - Field fabrication and installation specifications
  - Heat tracing specifications
- To save time and project cost, most piping departments will have a boilerplate shell for each of these specifications that can be used as a starting point.
- Maintain the overall and area plot plans. At the close of Phase I, the client approved the plot plans. The plot plan forms the basis for the Phase II design work. However, there will be minor modifications to the plot plan caused by changes in equipment size, shape, or quantity. These changes will need to be incorporated in the plot plan. These changes will also be a trigger that activates a potential change to the scope, budget, and schedule.
- Develop and distribute all area-specific equipment location control plans (LCP). A location needs to be established for each item of equipment in each area. The method used for this is the LCP. Another document used by some is the equipment general arrangement drawing (GA). Not all equipment has been purchased yet, but there is a need in piping and in other groups to pin down the location of all items. Piping design will develop the document that locates all equipment and all space requirements, including permanent space and temporary space. This document will be a controlled document and be updated and reissued on a regular basis.

- Develop CADS model index and piping drawing index. Once definitive equipment sizes are known and the location is fixed, then the electronic model space can be defined. The lead design supervisor should coordinate this effort with all other disciplines to ensure compatibility.
- Participate in P&ID reviews, as required. The LDS and, if possible, the appropriate area design lead should attend any P&ID reviews. Reviews during this phase should only be for hazop or operations. However, there could be a review to discuss changes that would impact the ongoing design.
- Initiate vessel orientation layouts. With the P&IDs, the plot plan, the piping transposition piping design will develop the orientation layout drawings for all vertical and horizontal vessels. Our model project includes the procurement of all equipment. Vessels will typically be a critical design item and will also be a long delivery item. With this in mind, we want to define what we want the vessels to look like, and we want to do it early.
- Initiate critical equipment layout activity. Critical equipment would be items such as compressors, heater/reactor trains, large banks of air-cooled heat exchangers (fin fans), boilers, large high-temperature/high-pressure pumps, and so forth. These critical equipment layout activities will chew up a large number of hours and may include piping material that is long delivery. Getting this done early will be an important scheduling issue.
- Initiate general layout and design activities. The smaller, less complex equipment and the pipe racks would be the next order of priority.
- Prepare pipe stress analysis documentation. During the Phase II portion of the job, the formal or informal stress analysis of applicable lines will be completed. Piping design will define the proper routing and support of all lines. Pipelines that fit the category requiring analysis will be sent to the stress engineer via sketch or electronic transfer.
- Receive and squad check vendor drawings for equipment. During this period, the procurement process is moving ahead. Mechanical equipment is being purchased, and the vendors are sending in their drawings for approval. This is an activity that needs to have some control. (In chapter 15, we will discuss control.)
- Initiate detail design review and update procedures. Why do we need design reviews? There is a simple "answer" to this often-remarked statement: You do not wait until you serve the dish to find out you used too much salt in the cooking.
- Initiate electronic interference checking of the design model. At the appropriate times, all the discipline design models (for a specific area or

subarea) should be merged for an electronic interference check. All real and apparent clashes should be investigated and corrected.

- Obtain final client design approval. After all internal design reviews have been completed and after the successful completion of the interference checker, the model is ready for client review and approval. This approval by the client of the electronic model allows piping and the other disciplines to move on to Phase III.
- Be responsive to the needs of the other piping and project groups. Piping design, by nature, is both a supplier of data and a user of data. As a supplier, piping provides all other disciplines with information critical to their work. If piping does not recognize the needs of the other groups and execute the work accordingly, the project schedule will suffer.
- Monitor work activities against the piping scope, budget, and schedule. The lead design supervisor needs to be constantly on the alert for any hint of a change to the project as it is defined in the scope, budget, or schedule.

During Phase II, material control activities will increase. The detailed design will proceed to the point that preliminary material requirements can be quantified. Vendor or supplier selection along with price and delivery will be established. Initial purchase orders should be issued for all materials. The piping material control lead will be involved in the following activities:

- Prepare RFQ packages for valve purchases, for bulk material purchases, and for specialty item material purchases. All required RFQ packages are prepared and issued based on the take-offs done at the end of Phase I. After material control has completed their part of this activity, there will be a span of time before the next material control work. This time delay will include the following:
  - Time required by the purchasing department to formalize the RFQ with the proper terms and conditions
  - Time for company project management approval
  - Time for client approval
  - Time for the suppliers to prepare their bids
  - The actual bid closing date
  - Time for purchasing to prepare the initial pricing bid summary
- Assist in the process of bid evaluations. The purchasing department will normally handle all price-related bid evaluation issues. The MCL may be asked to coordinate the technical issues related to the bids. The suppliers may offer the specific material stated in the RFQ. This does not always happen. The suppliers will often offer a substitution that may or may not

be a true or "equal." The MCL will be asked to check all proposed substitution against a line class specification list of recognized, acceptable substitutions. When a proposed substitution is not on the approved list, the MCL will get the piping material engineer involved to approve or reject that offer.

- Perform intermediate material take-offs. During Phase I, various material take-offs were performed, and the RFQ packages were issued. The quotes have come in, the bids have been evaluated, and one or more supplier has been selected for each material category. In the meantime, the design has proceeded, and there have been changes to the type, size, and quantities required for the project. Prior to issuing a formal purchase order, an intermediate take-off will be performed to update the requirements. Depending on the degree of change, there may be a requirement to re-bid some materials. If there is no requirement for new bids, then we can proceed with the purchase orders.
- Prepare purchase order packages for valve purchases, for bulk material purchases, and for specialty item material purchases. The purchase order packages will not normally be mirror images of the RFQ packages. There have been changes to the types of material, sizes, and quantities. There have also been splits of the material between two or more suppliers within the same family of materials.
- Be responsive to the needs of the other piping and project groups.
- Monitor work activities against the piping scope, budget, and schedule.

Phase II is the busiest time for the pipe stress engineer. This is the time when the designers are developing the design and when the lines that require analysis will be submitted. They were not submitted during Phase I because the formal piping layout was not started. They should not be submitted during Phase III because then it is too late. In Phase III, the design is complete, and the production drawings are being issued. Phase II is the time for reviewing and approving the design from a stress standpoint. The pipe stress engineering lead will be involved in the following activities:

- Maintain the piping stress analysis specification. Revise and reissue as required for any changes.
- Develop and issue standard preengineered pipe support package. The standard preengineered pipe support package includes selection criteria and a complete set of details for anchors, base supports, guides, hanger supports, shoes, and other items that typically are used on a piping project. These details have been predrawn and prechecked to meet a need at

or below a specific maximum limit. The selection criteria drawings are used by the designers during the design process.

- Develop and issue any other required stress-related specifications. Other stress-related specifications include specs for spring hangers, expansion joints, vibration struts, and movement restraint struts. These items will be purchased, and the specification will define specific criteria the supplier will be required to meet.
- Perform all required formal and informal stress analysis. Stress analysis is the process of ensuring that the design the designers have developed will work. All the analysis in the world will not improve a bad design. The stress engineer should not see any design that does not stand a chance of working. The LDS should send only properly routed and properly supported lines to be analyzed.
- Prepare RFQ packages for all stress-related items. Spring hangers, expansion joints, vibration struts, and movement restraint struts specified by the stress engineer during analysis will need to be purchased. The process for the purchase of these items is the same as that for all other piping-related material.
- Be responsive to the needs of the other piping and project groups.
- Monitor work activities against the piping scope, budget, and schedule.

Phase III of a project is when the design work is completed and approved. The effort now is focused on producing all the documentation required to purchase, fabricate, install, test, and validate the design. The term *documentation* as used here would normally imply hard-copy, paper drawings. This will remain the default scenario for most projects in most engineering companies for a few more years. In the future, technology such as electronic document management system (EDMS) will be accepted that allows companies to handle more of the design documentation via electronic data transfer. For now, we will not try to define the method used to issue data.

During Phase III of the project, the PEL is still a very busy person. This is when we will finish the home office work effort. The piping engineering lead will be involved in the following activities:

- Monitor the piping schedule. How are we doing? Are we on schedule?
- Monitor the piping budget. The PEL will need to be watchful as the work moves into the final stages of the project. This is the time to be reflective about what has transpired. Did all of the changes get documented?
- Finalize the piping portion of the mechanical construction work packages (CWP). Review the CWP drafts that were prepared in Phase II. Have there been any changes? Has new work been added? Has any work

been deleted? The CWP was possibly issued for bid during the latter stages of Phase II. The bids are in, and this is the time to update the CWP package to the "For Award" status.
- Monitor the performance of the piping shop fabrication purchase order. The purchase order for piping shop fabrication has been awarded. The first piping documents to be issued will be piping isometrics for fabrication. During the balance of Phase III, the PEL will need to monitor the performance of this purchase order.
- Approve all final piping deliverables. This is one of the most important activities for the PEL on a project.
- Approve final piping purchases orders.
- Monitor the quality program.
- Participate in project-related meetings.
- Finalize the piping scope of work (scope of facilities and scope of services).
- Prepare the piping project completion report.
- Perform project close-out activities.

The piping material engineering lead will be involved in the following activities:

- Maintain the piping material specifications. There should be very little to do here; however, this document needs to be correct. It will be used by the subcontractors, and it will become a part of the client's records.
- Prepare hydrotest criteria package. There are many ways to prepare data for defining the hydrotest criteria. The method is not important. What is important is that the subcontractor and the construction management have the criteria.
- Finalize update of the line list. This should be a routine update at this point.
- Finalize update of the SP list. This should also be a routine update.
- Finalize update of the commodity catalog. This should also be a routine update.
- Monitor budget and schedule.
- Prepare input to piping final job report.
- Perform project close-out activities, as requested.

The piping design lead and the design group will be involved in the following activities:

- Complete any unfinished designs. Unfinished designs occur when there has been late definition from the client, late definition from a licensor, or late vendor data. Regardless of the cause, all unfinished design work must be given the highest order of priority.

- Complete corrections and resolution of all clashes found during (electronic model) interference checking. This is possibly the second order of priority. This and unfinished design can affect other disciplines and their downstream suppliers and subcontractors.
- Extract all shop fabrication piping isometrics. For home office piping, this is the culmination of the past 8- to 10-month effort.
- Perform supervisor's P&ID "yellow-off" and sign-off of shop fabrication piping isometrics.
- This activity:
  - Will confirm that all elements in a line or on a line are accounted for
  - Will identify any lines with a missing documentation
  - Forms a primary element in the piping quality control program
  - Cannot be delegated to anyone
- Extract all field fabrication piping isometrics.
- Perform supervisor's P&ID "yellow-off" and sign-off of field fabrication piping isometrics.
- Initiate and complete heat tracing design activities. Heat tracing is another activity that can be done in many ways. Again, the method is not as important as the doing. There must be enough information for the contractor to succeed.
- Submit isometrics to the PEL for approval and release. After the LDS has completed the yellow-off, then the isometrics are forwarded to the PEL for issue.
- Extract piping plan drawings for issue and submit piping plans to the PEL for approval and release.
- Initiate destaffing of designers in accordance with destaffing plan.
- Monitor budget and schedule.
- Prepare input to piping final job report.
- Perform project close-out activities, as requested.

Phase III is a busy time for the material control lead on a full EPC project. During Phase II of the project, all or most of the purchase orders for piping materials were issued. These purchase orders were issued based on material take-offs or electronic downloads from unapproved and unfinished designs. Now, the design is approved and is being finished. Now is the time to check the real material requirements and update the purchase order quantities. The piping material control lead will be involved in the following activities:

- Perform all final material take-off downloads. The material control lead needs to be in close contact with the design supervisor and the

PEL during this period. The issue of the final isometric drawing is the trigger that initiates the final material control activities. Once the final piping isometric drawing has been through material take-off (MTO) and issued, a complete material requirements summary should be pulled. A detailed review should be made to look for overages and shortages.

- Prepare overage and shortage report (O&S report). The O&S report would normally be an in-house tool; it is not intended for issue. This report will indicate one of the following: (1) There is a requirement for some item of material, but the quantity required exceeds the quantity purchased; (2) the quantity purchased now exceeds the quantity required. When overages or shortages are identified, a lot of decisions need to be made. The factors to consider for an overage may include the following: the job site location, the vendor location, the type of material, the restock policy, the quantity of material, the cost of the material versus return and restock cost, the potential for future use, and the client's policy or requirement for warehouse spares. The factors to consider for a shortage may include the following: the type of material, the quantity of material, the timing for delivery, the impact to the job completion and start-up schedule, the job site location, the vendor location, the possiblity of an alternate source, and the cost of expedited delivery. The decisions affecting the overages and shortages should not be made in a vacuum by the material control lead or the PEL. This is an area that needs an involvement and agreement across a wide spectrum of the project. The project manager, the client, and the construction manager may be the final decision makers here. Once there is agreement, then prompt action needs to be taken.
- Prepare final purchase order package supplements for valve shortages.
- Prepare final purchase order package supplements for bulk material shortages.
- Prepare final purchase order package supplements for SP item shortages.
- Monitor budget and schedule.
- Prepare input to piping final job report.
- Perform project close-out activities, as requested.

During the Phase III portion of the project, the piping stress engineering work will taper off. The detailed pipe stress analysis work was done during Phase II. The effort now should be limited to confirming that all the analysis requirements have been incorporated and that the final stress-related engineered items (spring hangers, expansion joints, and so forth)

have been purchased. The pipe stress engineering lead will be involved in the following activities:

- Secure final approval and sign off stress-related piping isometrics on issue.
- Prepare final purchase order package for stress-related item shortages.
- Monitor budget and schedule.
- Prepare input to piping final job report.
- Perform project close-out activities, as requested.

After the completion of the traditional technical and administrative activities for Phase III, there may still be other needs. The construction effort will always result in problems and questions that will need to be addressed. The client may also want ongoing support of some kind. You will want to be open to providing assistance wherever there is a need. When there is no longer a need, you may then be able to look forward to the next project.

6

Revamp and Rebuild Projects

The purpose of this chapter is to define the piping activities that may be required for the type of project that is intended to modify or rebuild an existing facility.

The term *revamp* is a fairly common term no matter how it is used in our industry. It refers to a project that is a total or partial modification of an existing facility. The project may include the modification of an existing process or utility unit by changing the existing equipment and piping. Revamp work may be included in a project along with some grassroots work. The rebuild project refers to the repair or reconstruction of all or part of a facility that has sustained major damage through fire or explosion.

The successful execution of a revamp project is dependent on many factors. The most important among these is an accurate definition of what is to be done. People often define the major points, but they sometimes forget or leave out some of the small or minor points. Other factors important to the revamp project include careful planning, proper scheduling, across-the-board teamwork, and the close coordination of all activities. The interaction between the client, the engineering contractor, the plant personnel, and construction management is even more critical on a revamp project than on a grassroots project. The application of experience, industry knowledge, and the lessons accumulated from past revamp projects should provide a foundation for effective project execution.

Engineering of a revamp project is vastly different from a grassroots facility. Engineering and design will be involved with existing equipment;

instruments and piping that may be modified, reused, reconditioned, and relocated; as well as new equipment, instrument, and piping.

Some of the issues that need to be considered on a revamp project include the following:

- To maintain maximum daily operations of the plant, construction activities may need to be divided into work periods, such as pre-shutdown, shutdown, and post-shutdown. To satisfy these work periods, all engineering and design groups must plan and expedite their work so that drawings, material, and equipment are available to meet these specific construction windows. The objective is to maximize the work performed during pre-shutdown and post-shutdown periods, thereby minimizing the actual shutdown time span. Downtime of the unit means lost revenue to the client.
- New and modified structural, piping, equipment, and electrical/instrument drawings, data sheets, and other engineering information are produced to accommodate the various activities and special requirements for each revamp project.
- Adequate numbers and types of engineering and design staff will be required in the field. The scope of the revamp project will determine the size of the field staff.
- Revamp projects may involve changes to units that were built 20 years ago, 30 years ago, or more. Units that are very old will not be in compliance with all current OSHA standards. If any modification is done to older existing structures—ladders, stairs, or platforms—you may be required to bring the total ladder, stair, or platform up to current standards. The designer must investigate the current local OSHA standards and policies. The decision to modify an object may have an unacceptable impact on the overall job schedule and job cost.

What are you (as lead) responsible for in the typical revamp project? The question of responsibility is the same on the revamp project as it is with any other project. Everything that directly or indirectly relates to the piping effort is your responsibility. The most important of the responsibilities is to understand the total project. This includes a complete understanding of the project scope. If you do not know where you are going or how you are supposed to get there, then you will always be lost. You must know what the project is about or you could be responsible for increasing the cost of the project.

One of the things you and the other leads should do early in the project is visit the job site. You and the others need to see the existing unit(s) that

will be upgraded by the project. What you see there may appear to be nothing more than a pile of junk. Don't be pessimistic and don't be critical. You will want to remember whom you represent. You will need to be discreet and control your comments. Be honest. You should answer questions about what you feel may be some of the challenges the project offers. You need to frame the responses in a proper tone. Remember, the client does not see this as a pile of junk. The client sees an opportunity to turn a nonproducing or low producing unit into a positive profit generator.

The revamp project will have some of the same piping tasks as the grassroots project. The revamp project will also have some piping tasks that are not done for the design of a grassroots project. The nature of the revamp project and these tasks will cause some differences in the planning of the project. Consider the following:

- On a revamp project, piping may be required to assist in the field by checking existing piping systems against existing flow diagrams. This will require a much earlier assignment of piping personnel to the project. If the job site is not local to your company office, then there will be expenses for travel, lodging, meals, and ground transportation. There will normally be some level of safety training involved for the people assigned. The people who do this work will no doubt acquire a level of knowledge about the job site and the project. Because of the timing of this early field-check activity, there is a risk of losing that knowledge pool. There may be a long gap between the field check and the normal design work, and the people who do the early fieldwork may be assigned to another project. If possible, keep track of these people so that you can get them back on the project, if necessary.
- On a revamp project, piping may be required to produce drawings for demolition of existing piping and make visual identification of removals by painting or other means. Review demolition plans and removal drawings with the client for approval. A number of risks are associated with this activity. If it is done too early, there may be a high degree of recycle required. This occurs because the P&IDs were not confirmed. Another risk is that the plant operations people assigned by the client may not have the right information. They should have a full working knowledge of the unit, and they should have full understanding of the new process. That is almost asking for the impossible.
- On a revamp project, piping may be required to prepare tie-in procedures, tie-in drawings, and tie-in lists and to review tie-in method and location with the client for approval. This is another activity that has the

risk of recycle if it is done too early. The tags may be damaged by the elements or hot lines. Tags can also be removed inadvertently by plant maintenance during their routine work activities.

- On a revamp project, piping may be required to make additions and changes to existing manual plan drawings and flow diagrams. With the advent of the computer, it is getting harder and harder to find people who can do manual drafting. The drafting style and quality of the new work will differ a great deal from the drafting done by the original designer.
- On a revamp project, piping may be required to produce isometric sketches of existing auxiliary piping for pumps that are to be relocated or reconditioned. This is done so that construction can reassemble this piping after dismantling. Converting photographs to photo drawings is a technique that may be used for this, if allowed. Some clients do not allow photographs of any kind for any purpose.
- On a revamp project, piping may be required to prepare pressure test flow diagrams to show the extent of testing required for each new and modified piping system. Separate test diagrams are sometimes required when there is more than one planned construction shutdown.
- Piping may need to assist the contractor in punch list and field pressure testing of installed piping.
- On a revamp project, piping may be required to prepare temporary installation drawings. This is sometimes required due to late equipment delivery or to facilitate construction. This activity is not shown on flow diagrams.

On a revamp project, special attention must be given to tie-ins of new piping to existing piping. Selecting the tie-in method and location is a very important design consideration and, whenever possible, should be made for the convenience of construction; however, the selections must account for operational needs. The following should be considered in determining the location and method of making a tie-in:

- Minimize the requirement to drain and safe (gas freeing) combustible liquid and vapor lines during the shutdown work period. This is time-consuming and hazardous if not done properly.
- Avoid cold cutting and welding on large diameter and alloy lines. Look for possible tie-in flanges on existing lines.
- Minimize pressure testing of existing piping. Add flanges wherever possible to carbon steel lines for tie-ins to be made during shutdown work periods. Where feasible and acceptable, use X-ray and dye testing of welds.

- Hot tap into operating lines during the pre-shutdown work period only when necessary. When hot taps are made, sufficient clearance is required for handling of hot tap equipment. Avoid hot tapping suction lines to pumps or other rotating equipment. If this is required and approved by the client, suction strainers should be installed before hot tapping. With agreement by the client and the contractor, consider using the following method in place of hot tapping:
  - With proper permits and precautions, tie-in branch connection fittings on pipe (or nozzles on tanks and vessels) can be installed and tested during the pre-shutdown period. This is done by welding the branch/nozzle to the existing line (equipment) without cutting it open.
  - The nozzle is provided with a temporary blind flange and pressure tested.
  - New connecting piping to the nozzle should be installed with a temporary blind flange and pressure tested during the pre-shutdown period.
  - During shutdown, the existing line is cut open at the tie-in nozzle, and the new line is connected.

The following list contains some of the typical engineering data and drawing requirements for a piping revamp project.

- CWP scope of work with description of work activities for various disciplines
- Engineering flow diagrams (P&IDs) for revamp piping. New piping may be shown wider and darker than existing piping. This subject is very important to a revamp project. Typically, it does not receive the attention it deserves. You will almost always be starting with out-of-date P&IDs, and the client will resist spending the money to "as-built" them. A way must be found to allow for a proper field check to ensure that the starting base is correct. When the P&IDs match the physical plant, then there will need to be an agreement on how to show the complex possibilities that may occur. Some existing equipment, piping, and instrumentation will remain as-is. Some existing equipment, piping, and instrumentation will be abandoned, but remain in place; some will be modified and reused; and some will be replaced. New equipment, piping, and instrumentation may be added. All of these possibilities cause complications for the process group and piping. To complicate matters even further, at the end of the job, the client will want this P&ID to look like any other.
- Material specification (piping line class)
- Pipeline list
- Tie-in list and tie-in isometrics

- Line removal isometric drawings (if applicable)
- Pipe fabrication isometric drawings of new piping with bill of material
- Plan drawing—revision of existing drawing to show new piping
- Additional engineering data by other disciplines
- Equipment drawings by equipment engineer
- Instrument specs and drawings by control systems engineer
- Foundation drawings, structures, and structural pipe supports by structural engineer

Preventing all piping fit-up problems on a revamp project is nearly impossible. All you and your team can do is try to reduce them to the lowest level possible. You will need the support of your company, your department manager, and your project manager. You will also need a dedicated effort by each and every piping person assigned to the job. Some of the issues that can help in the quest to minimize fit-up problems are as follows:

Team experience

The piping team should be selected with emphasis on prior field/revamp experience and knowledge of the industry. There is nothing wrong with having some apprentice-level people assigned to the team: That is how they will learn. The assignment will make them better for the next job. You just do not want to over staff the job with people who have no experience. Have at least a three-to-one ratio of experienced to inexperienced designers, if possible. The experienced designer also should be experienced in the type of plant that is the subject of the project.

Location of work

All design drawings and fabrication isometrics should be developed in the field. Set up some stand-alone computers in the job-site trailers and do the work there. This will permit:

- Accessibility to existing plant drawings
- Verification of existing facilities to ensure that obstructions are avoided; existing drawing are not always accurate
- Coordination with operations on tie-in location, type of tie-in, and test philosophy
- Field measurement
- A visual check for constructability of closure work
- Line routing approval by operations to minimize turnaround work

- Verification of existing anchor points and supports
- Quality control check of pipeline fabrication isometrics

Close-range photogrammetry (CRP). CRP should be considered to develop a 3D electronic model of portions of the existing plant. The electronic model can provide a reasonably accurate definition of structure and equipment location, size, and shape. Tie-ins requiring dimensional control should be surveyed. Some tie-ins, such as valve bypasses and valve additions, will generally not require surveying.

Fabrication check. All critical shop-fabricated turnaround spools should be dimensionally checked by inspection at the point of pipe fabrication. Closure spool pieces should also be dimensionally checked prior to the turnaround. Following shutdown and cooling/heating to ambient temperatures, field measurements should be taken and compared to the closure spool pieces prior to erection.

Fit-up control. Based on the actual configuration and operating temperatures, the piping designer should include extra final fit-up welds to allow for dimensional fit-up in the field.

Checking. All designers in the field should take into consideration the factors that may contribute to fit-up and constructability problems. Experienced checkers should be assigned to review each tie-in and closure with the objective of eliminating turnaround problems. This check must ensure that each fabricated pipe spool piece fits in and around existing piping or structures. It must ensure that field welds are located to facilitate constructability and that those spool pieces requiring field fit are not too short.

Constructability. The location of field welds, the line closure, and hydrotest philosophy must be reviewed with the construction team so that problems can be minimized. Consideration may be given to issuing a subcontract to remove existing insulation from pipe to ensure that existing welds are not located at proposed tie-in points. This will also validate insulation thickness.

Contractor construction personnel will (or should) participate in regular reviews of the design of any revamp project as it is developed. Specific items to be reviewed include:

- Plot plans
- Piping layouts and standards

- Electrical and instrumentation layouts
- Foundation designs
- Structural steel designs
- Grading/paving plans
- Equipment specs and arrangement drawings
- Vendor design information, as required
- Painting and insulation requirements
- Subcontract plan and contract scopes of work

Constructability issues will need to be addressed, with respect to the following:

- Access during construction and operations
- Rigging, preassembly, field erection
- Construction sequencing
- Safety during construction and operations
- Facility cost for construction labor and material

In addition to constructability, operability, and maintainability reviews, the PFDs and P&IDs should be reviewed in detail with plant personnel prior to issuing them for design. The client's standard practices for operations and maintenance should be included in the review process. Key to these reviews is the availability and participation of client representatives. Getting input firsthand from the operations and maintenance personnel is strongly encouraged. As always, the expeditious review and approval of the design will be mandatory. There are also recommendations for the planning and execution of revamp projects.

New piping and equipment should not occupy vacated spaces of items to be removed. New spaces or positions should be allocated. Though this may result in pipeway extensions and empty spaces on existing supports, it is acceptable. Placing new equipment in a new space provides the required construction flexibility necessary to a revamp project. It allows new equipment and lines to be installed during the pre-shutdown work period, with the final tie-ins made during the shutdown or post-shutdown work period.

Avoid any reuse of piping that has to be removed, cleaned, or modified. If you try to reuse existing piping, two things may happen. One, you may get lucky and discover that the piping is suitable for reuse. Two, you may discover that the existing piping is not reusable. Now, you have the potential for a costly delay to the construction schedule. Check flange connections on existing equipment to make sure it matches the specification

of the new piping mating flange. Thirty-year-old equipment may not have the same flange facing as similar equipment manufactured today.

Avoid using all the available space with piping valve assemblies, utility stations, and trap assemblies. The use of the available space needs to be coordinated with electrical and instrument installations. Remember, you are not the only discipline involved in this project.

Avoid excessive field routing of piping that may have to be defined and installed during a shutdown work period. As the old saying goes, "Prior proper planning prevents poor performance." Providing the construction contractor with a complete set of drawings showing all lines will allow for better planning and performance. Reference piping isometric drawings to the nearest equipment or pipeway column in addition to calling for coordinates.

Do not leave questions unanswered. Demolition drawings should identify any rerouting of piping, instrument, or electrical conduits. Demolition drawings should also identify any object that is supported by a line to be removed. Copies of demolition drawings must be reviewed with the appropriate plant operations group.

The typical revamp project will contain a measure of surprise and disappointment. There will be surprises that no one could foresee because they were buried underground. There will be disappointment because some part of the design may need to be changed on the fly to accommodate a problem. Remain flexible when you are working on any revamp project; each seems to have a personality of its own.

Another type of project is the rebuild project. The rebuild project will occur because of a disastrous event such as a fire or explosion. This project is neither a true revamp nor a grassroots project. The fire rebuild project will have unique aspects that will require new thought patterns and force change in the conventional execution plan. The first aspect of the fire job, and maybe the most important, is who is the client? If XYZ Industries had a major fire in one of its units yesterday afternoon, your company may be quickly awarded the contract to rebuild the burned-out unit. The client for this project may not be XYZ Industries. The real client will no doubt be the insurance company that covers XYZ Industries.

This insurance company will usually be responsible for two facets of the loss created by the fire. They will be responsible for the cost of rebuilding the plant, and they will also be responsible for lost revenue caused by the burned-out facility. The rebuilding cost for this burned-out physical plant will be very high. That cost of rebuilding the physical plant can be thought of as a fixed cost to the insurance company. There is very little anyone can

do to effect any real reduction in this cost. The cost of lost production is another thing. Lost revenue could easily be much more costly than the base replacement cost. The longer the plant is down, the greater the financial obligation and loss to the insurance company. With this in mind, the main goal of the insurance company is to reduce the downtime or nonproductive time of the plant. They are financially motivated to get this plant rebuilt and back into production as soon as possible. This monetary motivation may cause them to be very open and interested in anything that contributes to a shorter reconstruction period and the speedy completion of the rebuild project.

One of the common practices used in the traditional engineering and construction project is the competitive bidding process used during the procurement phase. This practice properly helps determine the lowest bidder for the purchase of the process plant equipment, fabrication, or installation services. As we all know, this process can take as long as 3 months just to select a qualified source. This competitive bid process brings value to those grassroots and revamp projects with longer traditional schedules. Nothing is intended here to suggest any change to this practice. However, for the rebuild project, this process will not normally deliver enough savings to offset the value of the production losses. The competitive bid practice may be the first compromise the insurance company and your engineering company will want to consider for this fire rebuilding project. The question, then, is who do we select to provide the required services? The answer to this question not only affects piping but the other disciplines, also. The number-one candidate and best choice to replace an item is the company that manufactured or fabricated it the first time. One reason for this is that they, like other companies, will have kept records of their past projects. Is this company still in business? Do they have records, including financial records, from the original project? If they have these records, then there is a potential time reduction because shop drawings will not need to be created. The cost for replacement at today's cost can be a simple formula based on accepted escalation factors.

The insurance company, as stated, is responsible for rebuilding the plant. This usually means rebuilding the plant just as it was before the fire started. The insurance company will not be responsible or willing to pay for any improvements or changes that the operators may now want to include. The insurance company, however, will be responsible for any and all upgrades or modifications made to the plant that existed before the fire. Hopefully, all of these upgrades and modifications were legal, authorized, and well documented.

The first place to start on a fire rebuild project is the client files. Do they have the files from the original project? Do they have records of any additions or modifications? If so, copy everything, including the purchase orders. You will need one copy as your working copy. The insurance company will no doubt want a copy. You will want a copy for material take-off to get the procurement started and a copy for the project files. You will save time if you have a minimum of seven copies. If you run only the minimum number of copies, someone will always want an additional copy.

The next activity is the site walk. The site walk cannot take place until the fire has been put out. The unit must then be declared safe. The site walk must take place before any demolition and removal are started. You and the rest of the team must be able to see the extent of the damaged area clearly. The most important item here is safety. Before you or your people enter the unit, you should personally check with the site safety manager to ensure that it is safe to enter the area. It may even be wise to do this more than once a day. Safety is stressed here because liquids and vapors will be trapped in that collapsed pile of fire-blackened equipment and piping. Liquids may collect in what are now plugged drain and sewer systems. When the demolition crew starts cutting and removing the burned piping and equipment, all access to the unit should be restricted. A cutting torch or even a portaband saw could ignite a new fire.

During the site walk, the objective is to determine the extent of the damage and the amount of piping that must be replaced. This damage assessment period needs to be long enough to cover all the disciplines needs, but it should be as short as possible to expedite the rebuilding process. Experience and good judgment come into play here. piping does not need to be replaced just because it was near the fire or actually in the fire area. Insulated piping may not have suffered any real structural damage just because it was exposed to the flames. This piping may only need to have the insulation replaced. For the damage assessment site walk, the piping team needs to have the walkaround copy of the piping plans or, as a bare minimum, a copy of the plot plan.

The walkaround for piping will soon show three zones. The white zone will be that part of the plant or unit that was outside the fire area. The piping and equipment in this area will not require any replacement. The black zone will be that part of the plant or unit that was totally engulfed in the fire. All the piping and most of the equipment in this area will need to be replaced. This is the area where the fire damage to the piping will be really obvious. This piping has deformed and, in most cases, has fallen to the ground. The piping fell because the support structure failed because of the

intense heat. The third zone is the gray area, where there may or may not be real damage to piping. This piping may need to be examined through Brinnell hardness testing or other methods for heat inbrittlement. A qualified third-party metallurgical testing service should perform the required tests. The objective is to find the extent of the fire damage and the limits of the piping that truly needs to be replaced. Try to keep the replacement cost down, but you must remember: "When in doubt, rip it out."

An important issue that may appear with any fire rebuild project is the age of the facility and the potential for true replacement in kind. Piping we buy today will conform to the same standards and mate to piping from 50 years ago. However, piping does not connect just to piping. One end or the other of almost every pipeline in every process plant connects to a piece of equipment. If this facility is an older unit, there could be a problem replacing the equipment with an exact match to the original. The original equipment manufacturer may not exist today. There may also be recent code changes that prevent an exact replacement. This can and will cause modifications to the piping to match the new configuration. Close contact and coordination with the mechanical equipment group is required to prevent costly delays.

The next step for piping is to sort all the piping fabrication documents for the three zones. Those for the white zone do not need to be refabricated. Those for the black zone should be sent off as soon as possible for refabrication. The first choice for fabricator would be the fabricator who did the original project, which you know from the client files. Select a competent fabricator, and get these piping drawings into the hands of the fabricator. Those for the gray zone will be where you can spend some time. If the majority of a line shows real fire damage, then replace the whole line. If there is little evidence of fire damage or serious heat exposure, then run some quick hardness tests on the pipeline. Get the test results, make a decision, and then move on. Any gray zone pipeline judged a candidate for replacement must also get to the fabricator as soon as possible.

Identifying and sending the pipe spool pieces to a fabricator for replacement are only parts of your overall piping effort. Piping assembly material must also be identified, purchased, and delivered to the job site. The piping assembly material includes all the replacement valves, bolting material, gaskets, strainers, field supports, hanger rods, pipe shoes, guides, and any other miscellaneous piping item. Special-engineered piping items will also need to be replaced. The special-engineered piping items will include all spring hangers and any expansion joints or strut devices required in the original installation. The material take-off activity can be started

very early, soon after the site walk. During the site walk, it should have been obvious where the black zone was. Your piping material control or material take-off people should already be identified and available. They should also be primed and able to give this fire rebuilding project the highest priority.

With a fire rebuilding project, the objective is to get the plant back on stream in the shortest period of time and at the lowest cost. The plant cannot start up until all of the piping systems are installed and tested. The piping systems cannot be installed and tested until all the piping is fabricated, and the required assembly material is purchased and delivered. The material cannot be fabricated or purchased until it is identified and quantified. You must have experienced people who are motivated to put in extra hours and willing expend extra effort to make this type of job a success.

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Part III

Procurement, Pipe Fabrication, and Contracts

7

Procurement Responsibilities

The purpose of this chapter is to present a list of issues that may be involved in the procurement of the bulk piping materials required for the E&P, full EPC, or EPCM project.

Who is responsible for purchasing all the piping material that is required for a project? What are the implications and responsibilities that go along with the purchasing of the piping material? What is required of the PEL when there is a “P” in the project execution formula? Are purchase orders required? If your project is an E&P project, an EPC project, or an EPCM, then the answer is “yes.” Your company and you, the PEL, will have procurement responsibilities and purchase orders for some or all piping materials. The “P” may not be a full “P.” The project may have the procurement divided between a number of entities. The client may decide to do some purchasing. Some of the purchasing may be assigned to the engineering company, and some may be handled by the installation subcontractor. In the scope, you will list the requirement for all the piping purchase orders. To do that, you must know that purchase orders are required, the number required, and the type.

The first thing to do is fully define what piping material will be required and who will be responsible for what in the total material requirement process. Such a document might be called the *procurement responsibility matrix*. To create this document, a definitive listing of all potential material categories and a structured list of the major steps required to purchase those materials needs to be created. The vertical and horizontal tabulation of this data creates one or more pages of boxes. All of the entities involved

in the project need to be identified and given a simple identifier, such as an initial (for example, E = engineering, P = purchasing, C = construction, and so forth). The procurement responsibility matrix document should be initiated by the procurement group at a very early stage of the project. The project PEL needs to ask about all procurement planning and be involved in the development of the piping portion of the responsibility matrix document from the start.

The procurement responsibility matrix document should define all the various types of the piping material categories required for the project. It would be good to have a preexisting generic company or piping department document as a starting point for a specific project version. This company/department-specific version should list all of the normal industry material categories. These material categories may include:

- CS pipe, flanges fitting 2 ½ inches and larger (shop fab)
- Alloy pipe, flanges fitting 2 ½ inches and larger (shop fab)
- Lined pipe, flanges fitting 2 ½ inches and larger (shop fab)
- CS pipe, flanges fitting 2 ½ inches and larger (field fab)
- Alloy pipe, flanges fitting 2 ½ inches and larger (field fab)
- Lined pipe, flanges fitting 2 ½ inches and larger (field fab)
- CS pipe, flanges fitting 2 inches and smaller (field fab)
- Alloy pipe, flanges fitting 2 inches and smaller (field fab)
- Lined pipe, flanges fitting 2 inches and smaller (field fab)
- Nonmetallic (plastic) pipe, flanges fitting 2 inches and smaller (field fab)
- Valves—2 ½ inches and larger
- Valves—2 inches and smaller
- Bolts and gaskets
- Specialty items
- Spring hangers and struts

Although some material may not be listed in this or your own generic list, it does not mean that it does not exist. Other piping materials may be needed for a specific project. It is better to have too many materials on the starting generic list than only a few. Seeing a type of material on the list may trigger the memory of an actual requirement.

The procurement responsibility matrix document will also define the three major steps relative to the procurement of piping materials. Included in each of these three major steps are a number of broad, functional activities. Responsibility assignments need to be defined for each as a part of the project procurement responsibility matrix document.

Step 1 is the material requirement definition. Who is responsible for:

Specifications and Data Sheets

Each piece of bulk material installed in this process plant project, like every piece of equipment, has specific technical requirements. All items will have either an individual specification or will fall into a group general specification. Most items that are for a specific function, location, or condition will also have an individual data sheet. The responsibility for the preparation of these items should be defined in the matrix.

Fabrication or Construction Drawings (When Required)

Valves, bulk pipe, and field assembly materials do not normally require drawings for the procurement activities. However, prefabrication of pipe spools for later installation in the field will need fabrication drawings. On some projects, the engineering company produces the piping fabrication drawings. Such drawings have also been the responsibility of the piping subcontractor or the fabrication shop on other projects.

Material Take-Off (MTO) or Quantify Definition

This is another very important activity that can be done by a number of different entities or players on the project. The MTO activity can also be done by more than one of the players. The engineering company may need to perform MTO activities to determine the full material cost of the project or purchase all or part of the materials. The client may choose to perform an MTO to validate the overall cost estimate. The installation contractor may need to perform a piping MTO to qualify the bid or to actually purchase the required materials. It does not matter who does the MTO; it needs to be done, and the responsibility for doing it needs to be defined.

Step 2 is procurement. Who is responsible for:

Purchase

This may seem obvious, but every time you assume you know the answer, there will be an exception. Designate in writing who has the purchasing responsibility for each type of material. There have been cases where the engineering company did most of the paperwork, such as RFQ preparation, but the client did the actual purchasing.

RFQ (Request for Quote) Preparation

This is normally a shared responsibility between the technical disciplines and the purchasing department. The hours need to be put in the estimate/budget, and the proper people need to be made available at the proper time.

Bid Summary

The discipline, purchasing, the client, or some other third party may prepare the bid summary.

Purchase Order Performance Monitoring and Expediting

This is another activity that can be done, and is done, by various entities on a project. This function could be performed by the discipline, purchasing, or the client.

Inspection

All materials purchased for a process plant project should be subjected to inspection. How much inspection is required? What type of inspection is required? When is the inspection to be done? Where is that inspection to be done? Who is best qualified to do that inspection? These are the basics of all inspection programs. However, there are a number of project specific issues that will have potential impact on these basic inspection questions. Project specific issues include the criticality of the material, the job site location relative to the source of the material, and the potential time required for replacement if the material is damaged or inoperable. The more critical the material, the more remote the job site, and the longer the replacement time would suggest more emphasis on proper inspection. The actual inspection can be done by a number of different groups or entities. Any one or combination of the following can do inspection:

- The piping material engineer who specified the material
- The engineering company inspection group
- The client organization inspection group
- A third party inspection company

There are a lot of factors and there are a lot of choices. There is no single best answer that fits all materials, all situations, or all projects. These issues must be recognized, discussed, and provided for or the project goals will not be met.

Vendor Data and Drawing (Identify, Track Status, and Expedite)

In engineering, some parts of a job cannot start until the paperwork is completed. For some equipment and materials, the finished drawings from the supplier or vendor are required to complete the detailed design. Someone needs to be assigned to ensure that all the required documents are obtained and obtained on time.

Traffic

The term traffic as used here refers to the planning and execution required making sure materials or equipment get from the point of manufacture to the point of use, the field. This is an extremely important, expensive, and high-risk activity. The choice of who does this service is not important to the PEL. The important issue is any requirement for special handling. Any material that requires special handling due to size, shape, or materials of construction may require special carriers or routing. The PEL needs to be aware of any item that is out of the ordinary.

Step 3 is the field or job site. Who is responsible for:

Receiving

Here, again, we have a wide choice. We could have the activity of receiving performed by the client, the construction management entity, or a subcontractor. Equipment can be received by the responsible discipline engineer at the engineering company office. Define it, so everybody knows.

Storage and Issue

The choices here include the client, the construction manager, the subcontractor, or someone else.

Installation

For most items, this will be obvious. A subcontractor is normally responsible for the installation of all equipment and materials in a designated area. However, there are also instances where some odd or special item will need to be installed by the client or a specialist.

All of the activities listed in the preceding steps take time and manpower. Time is schedule, and manpower is labor. Both are costly to the project.

The more action that is defined as being the responsibility of home office engineering (piping), the higher the home office labor hours. The more action that is defined as being the responsibility of the contractor, the higher the potential risk. The procurement matrix should be prepared for the project during the early project scope definition phase. If this document is not filled out at that time, then the scope is not complete, and the estimate will not be correct. Once the procurement matrix is filled out (and approved), there needs to be a complete schedule review. There should be a review of the timing for the following milestones and their effect on all equipment and material.

P&ID Availability and Status. The timing of the P&IDs for a project is tied to the ability to identify and order the right materials and equipment. The P&IDs define what you are trying to build. If you do not have the P&IDs, you cannot determine what you are going to build or what it takes to build it. The P&IDs also need to be as complete and as accurate as possible to be of any value to the procurement effort.

Preliminary MTO. The requirement for, the purpose, and the timing of any preliminary MTO needs to be reviewed and understood. Why are we doing this? Do we have the right information? When is the right time?

RFQ issue, bid closing, and purchase order issue. All of these events need to be thought about and properly programmed into the project schedule.

Lead times on custom-engineered or nonshelf items. This is an issue that can sink a project. A shelf item is normally already made and available for shipment within a matter of hours or days. The nonshelf item will have a lead time from receipt of order to ship date. The lead time will normally include many activities. These activities include order entry, release to engineering, engineering, drawing transmittal for approval, question and conflict resolution, engineering revisions, material order or requisition, production scheduling, release to production, actual production, inspection, testing, packing, and release for shipping. You may think that all of these steps apply only to a vessel or a major piece of equipment. However, some engineered items and some catalog piping items could fit this profile. Special alloy, high-temperature and high-pressure expansion joints are not considered shelf items. Some large bore (size), high-pressure, high-temperature valves may be shown and listed in the vendor catalog, but they should not be considered shelf items.

RAS (required at site) dates. This is the key. The RAS date does not mean sitting on the dock at the vendor shop. The RAS date is when you need to have that material at the job site, in the hands of the construction group.

The cost of equipment and bulk material is also an important issue to both the client and the engineering company. The PEL should review the requirements for and determine who will be responsible for the following:

Total budget for piping material cost. For some projects, the PEL may only be responsible for estimating and controlling the cost of home office labor hours and expenses. For other projects, the PEL may be responsible for estimating the full cost of all piping materials. You need to know what will be expected and then do the necessary planning and organizing to succeed.

Budget breakdown (total job, WBS, code of accounts, and so forth). This is part of the overall project planning, and it is very important. If you do not know about this requirement at the outset, you will cause recycle and added cost to recover.

Piping material dollar commitment status and purchase order commitment trend reporting. These are the reporting requirements that are related to the two previous items. The piping material dollar commitment status report indicates the value of actual orders placed. The purchase order commitment trend report indicates the estimated value of the orders yet to be placed.

Coordination with groups outside of piping will be required for the following procurement-related activities.

- Process engineering—Timing of initial issued for design P&ID development plus the control and coordination of P&ID revision cycles
- Equipment engineering—Timing of vendor data and communication of delays and risk
- Civil/structural/architectural—Material take-off and purchase of any piping materials
- Control systems—Material compatibility and interfaces with instruments
- Technical document control—Issue and control of specifications and drawings
- Construction—Geographic area color code criteria (very large projects) and RAS dates

Coordination with groups inside of piping will be required for the following procurement-related activities. Everyone on your team has a contribution and a responsibility for the success of the project.

- Piping material engineering—Specification development
- Piping design—Preliminary MTO sketching, change control, schedule
- Piping material control—MTO and database coordination
- Pipe stress engineering—Specifications and needs definition

Management-level reporting is required for all discipline procurement activities. Projects will normally require some form of periodic reporting and a standardized list of reports. There are some projects, due to their type or location, that may also require additional control and special reporting.

Standard reporting may include the following:

Material take-off status. A definitive list of take-offs, the purpose of each, the scope of each, the proposed timing of each, and the incremental status (started, partial complete by percentage, and final) will be required.

Requisition issue and status. A complete listing of planned RFQ packages with the incremental steps monitored for preparation, in-house review, client review, approval, issue, and bid return will be needed.

Purchase order issue and delivery status. A complete listing of actual purchase order packages with the incremental steps monitored for preparation, in-house review, client review, approval, issue, and vendor performance will be required. Some may question the need for two separate reports. Your company or a specific project may elect to have one combined report per discipline. Combined RFQ/purchase order reports tend to become very complex and confusing. Some additional reasons for not having combined RFQ/purchase order reports include the following:

- Your company is only doing the RFQ stage; the client will issue the actual purchase order.
- Some RFQ packages will be split into multiple purchase order packages after the bids are evaluated.
- Company confidentiality policies regarding RFQs and actual purchase orders.

Problem and resolution report. No matter how hard we try or how well we plan, there will always be problems. The vendor lost the order; the vendor

plant burned down; the material failed to meet specification; the truck transporting the materials from the vendor to the job site was hijacked. Ships sink; planes, trains, and trucks have accidents. All unplanned events cause costly delays to the project.

There are always reports for special purposes. Most of these special reports are prepared by people or groups outside of piping. The PEL and others in the piping group should know what special reports are available and what they mean. Special reporting may include the following:

Supplier qualification status. This would be a comprehensive listing of all the proposed suppliers for the project. The report would indicate the key steps required to investigate and approve each supplier. This report would normally be prepared by the purchasing department. The piping group (or other discipline) would use such a list when selecting bidders for a specific RFQ package.

Bid summary status. This may be a report listing each RFQ, the number of bidders, the bid due date, the return bid status, the summary steps, and the status of each step to final selection and approval. This report is sometimes prepared by the disciplines and sometimes by purchasing. The piping group would use this report to indicate progress and to identify scheduling problems.

In-transit processing status. This is a potential risk area for a project. In-transit processing occurs when materials or goods from a vendor or supplier are shipped to another company for additional work before being shipped to the next point. Pipe is sometimes ordered in large quantities direct from a mill and then sent to a production paint operation in another location. The painted pipe is then shipped to the job site. This type of order takes a lot of coordination to succeed. The original supplier, the in-transit processor, two transportation situations, and job site receiving are all involved in this process.

Expediter's status report. An expeditor is a person who visits the vendors and suppliers and makes an eyeball, hands-on evaluation of the performance of each order. The expediter's report is intended to be informative and factual. The report would not normally be the responsibility of the PEL. The PEL may need to take responsibility for the action required to solve a problem identified in a report.

Inspection reports. These reports are very much like the expediter's reports, except they are prepared by an inspector. This report would also not normally be the responsibility of the PEL. Again, the PEL may need to take responsibility for some form of action required to solve a problem identified in a report.

Traffic reports. Traffic reports indicate everything that is on the move at a given time. This report would normally be prepared by the people or group assigned to coordinate the shipping of equipment and materials. Like other reports prepared by people outside of piping, this report is intended to contain information. If the information is good, then no action is required. If the information is bad, then someone needs to take some kind of action.

These special reports, and there may be others, all have a purpose. The PEL needs to understand the extent or scope of his or her responsibilities on the project. He or she needs to understand what reporting tools are available and what to do with the information they contain. The worst thing of all is the person who says, "It's not my job."

The PEL needs to be forward-looking at all times and in all areas. The piping plan for an activity or action will need to be well thought out, and the proper instructions need to be in place. Wherever possible, the existing company procedures for an activity should be the starting point. Modifications to these company practices may be required to meet specific project needs, but these modifications should be held to a minimum. Procedures specific to the piping group that should be reviewed for application on the project may include:

Material take-off methods. Factor take-off from P&IDs, line sketch take-off, and electronic downloads. There are a number of reasons for a material take-off. The purpose, scope, timing, and design development status will influence the method of the take-off.

Sketch procedures and sketch control. In spite of the advancement of CAD systems and other electronic tools, there will always be the project where manual sketches are used for material take-off. Make sure you have a plan for making, identifying, and controlling these sketches.

RFQ and purchase order division and numbering. This may seem like an issue that does not matter very much to piping. However, this has caused real problems on projects because of poor foresight and planning. Any project with multiple job sites and/or multiple contractors is one where you

want to consider separating purchase orders by location or responsibility. There have been cases where the vendor said that material was shipped, and the job site said they did not have the material. Both were right. The purchase order included all the shipping instructions and destinations. The material just went to the wrong place. The people who had it did not know that they were not supposed to have it.

RFQ and purchase order development and approval. What are the steps required to properly prepare and issue a request for quote package or a purchase order package? What technical data needs to be included? Who needs to supply the technical data? Who needs to review and approve each RFQ or purchase order document? This RFQ and purchase order preparation process will take time. That time will affect both your labor hour estimate and your schedule.

Policy for supplementing purchase orders. Purchase order supplements are required and used to delete an item from the purchase order, to reduce the quantity of an item on the purchase order, to add a new item to the purchase order, to increase the quantity of an item already on the purchase order, or to change some condition or instruction in the purchase order. Two items seem to cause the biggest share of problems when purchase order supplements are required. The first is the method of numbering a supplement. Some people and companies insist on a very complex numbering method. You may not be able to influence or control the method, but you do need to understand and use it. The second major problem area is having to increase the quantity of an item already on the purchase order. One method is to add a new line item with the added quantity. The other method is to revise only the quantity column for an existing line item. The first method is recommended because it sets in motion a whole new production schedule. The new quantity will have a different time frame for the order of materials, manufacturing, assembly, testing, and delivery.

Material identification marking and geographic area color coding. Material marking is normally an industry standard. However, there may be a client who wants something different. You need to determine if there are any special marking requirements and take appropriate action. The geographic area color code is normally imposed by construction and used for only very large projects. The sheer size of a project may require having multiple receiving and warehouse facilities. Each of these receiving or warehouse facilities would be identified with a color code tied to an area

within the work breakdown structure (WBS). Instructions included in or with the purchase order would advise the supplier to color code each shipment. Job site receiving and material control is greatly simplified by the color code area identification.

Procedures external to piping should be reviewed for possible application. Normally, all of these procedures or activities will be performed by people in other groups. The trigger or the initiation of any special requirement will need to be noted in the piping-appropriate specifications or technical notes.

PMI (positive material identification) procedures. PMI is a very complex, extensive, and expensive process. PMI is not required on all projects. If required at all on a project, it may not be required for all materials or all systems. Because of the costly nature of PMI, it should only be used where absolutely necessary.

Testing. Is there a requirement for any special testing? The vendor, supplier, manufacturer, and project inspector must be advised of this. It is your material: You are preparing the RFQ and purchase order. You must make sure that the special testing requirement is included.

Standard and special inspection. The same applies here as with testing.

Bar coding (purchase order/purchase order item identification). This is an area that is a growing requirement throughout the industry. The important issue is to make sure the end result is achieved. There are dozens of bar code systems on the market today. When the bar coding requirement originates with the client or construction, you need to determine which system to use. You then need to make sure that your piping vendors and suppliers can supply the compatible bar code identification tagging. You also need to include the bar code identification requirement in your piping RFQs and purchase orders.

Packing and shipping (very important when overseas shipping is required). The vendors and suppliers cannot be expected to know what you do not tell them. You need to determine what is actually required for the packing and shipping of all piping materials. The vendors and suppliers then need to be clearly advised on what is required for each order. All orders will not be the same. You may want to work with the other disciplines and develop a single document with multiple types of packing instructions (Type A, B, or C, for example). Nonmetallic materials could

require Type A packing; carbon steel material could require Type B packing; stainless steel material could require Type C packing; and so on.

The execution method used to define the material quantity requirements will be influenced by many factors. There is no such thing as a standard when it comes to material procurement. Each project must be treated as an individual case. The prerequisite quantity-defining data (P&IDs and layouts) must be developed to a much higher degree for all high-risk materials, such as any exotic alloy, large diameter, high cost, or long delivery item. The quantifying effort (sketching, manual, electronic transposition) must be more precise and very closely controlled. The PEL must ensure that the piping design group and the material control group both have the correct procedures in place and that they understand the critical nature of this activity.

Material take-off (MTO) and control form the next step in the procurement of piping material. A number of issues affecting MTO need to be determined during the early stages of a project. These issues may include, but are not limited to, the following:

Number of take-offs. Will there be only one piping material take-off, or will there be more than one? The answer to this, combined with the method, has a big impact on the labor hour estimate, the schedule, and the staffing.

Total project versus WBS breakdown. This is an area where, more than once, there has been a total lack of foresight and communications. The result is added cost and delay to the project. Every project having more than one physical area should always have work done by the individual area and then totaled. If the project has multiple areas and there is no formal published breakdown to use in the material take-off, trouble lies ahead. A breakdown should always be done for bulk materials such as piping.

Method of take-off. The forced timing of a take-off and the type of information available will sometimes influence the take-off method. Projects with compressed schedules (fast track) may require a take-off of all valves very early. If the P&IDs have been prepared in one of the smart P&ID CAD systems, the valve MTO is simple and quick, but only as accurate as the P&ID data. However, if the P&IDs were not done in a smart system, then someone will need to do a manual tabulation and check of the data.

Purpose of each MTO. The purpose of the MTO has a bearing on the method and the accuracy of an MTO. When we are after a definitive cost

for a single system or complete plant, we should act to achieve that end. If we are only trying to get a rough order of magnitude (ROM) estimate with some plus or minus percentage factor then we should not spend excess time dotting *i*s and crossing *t*s. Make sure the end justifies the means.

Timing of each MTO. The timing of any activity for an engineering project will be one of two things. An activity will happen at the optimum time relative to its related upstream and downstream activities, or it will be out of phase with related activities. An MTO could be called for too early and prove a waste of money because the P&IDs and other data were not developed. An MTO could be called for too late to order material and get it to the job site on time. There are a lot of ways to make mistakes in this business. You can do the MTO work too early and not have the right information. You can do the MTO work too late and miss the boat.

Bump philosophy and round-off. This is another area that takes experience, judgment, and very good job knowledge. The term *bump* refers to the contingency that is applied to the raw take-off quantity to ensure the field is not short. Bump is used for all unit items such as valves and for bulk pipe. Round-off is normally used only for bulk pipe. Large diameter alloy valves would not normally have a bump applied to the raw take-off quantity. We would verify the count and then buy the exact quantity. However, small diameter, carbon steel vent and drain-type valves would have a bump applied to the raw take-off quantity prior to purchase. Bump for pipe is sometimes added to allow for cut-offs and scrap or waste produced during fabrication. Round-offs would be applied to the linear footage take-off of bulk pipe. The round-off is to allow for the purchase of the industry-common single or double random pipe lengths.

In addition to the preceding items, there may be the need in a small office to coordinate this project's MTO effort with the MTO effort of other projects and the potential limited staff in the piping material control group. The lead piping material controller must handle this as a normal function of doing business. However, the wise PEL will confirm that the resources are available when needed for his or her project. The piping material control function will also perform some or all of the following activities, depending on the needs of the project.

- Material take-off
- Summarize material by type, size, and material
- Prepare material requisition packages
- Obtain approvals required prior to issue

Requisition status reporting may need to include the following categories:

- Total requisitions issued
- Requisitions not issued
- Closing date schedule for requisitions
- Requisitions past due, reason, and action
- Bid summary status monitoring
- Engineering approvals, complete/incomplete, why
- Bid summary approvals, complete/incomplete, why
- Supplier selection

Identification of proposed suppliers or bidders for the project is also an important function. There are many ways to determine a bidder's list. The client and project management will normally determine if material and/or equipment will be purchased through full competitive bidding, the client supplier list, or sole/single-source suppliers. The PEL needs to be fully knowledgeable of this aspect of the project procurement plan and make sure that any facets that affect piping are accurately incorporated. Regardless of which bidder's list is used or how it is assembled, piping is responsible for correctly listing the proposed bidders on each RFQ.

It is the responsibility of the PEL (and the piping team) to prepare each RFQ package. A complete RFQ will normally include the full purchase description for each item, quantity, specification(s), technical notes, attachments (if applicable), and the RFQ cover sheet. The RFQ cover sheet should have the recommended bidders identified and have the appropriate approvals completed. The purchasing department will normally add the required terms and conditions that apply for the project. Once the total package is complete and all approvals obtained, purchasing will need to issued it to the bidders.

A purchase order is a contract, a legal document with a potential for extensive financial impact to the project, the supplier, the client, and your company. Suppliers may become aware of a pending material need during the early design stage. The PEL and the other members of the piping team should use care in any discussions with strangers or known supplier personnel. Once a purchase order is issued for quote, the PEL and all of the piping group should be on guard against the possibility of saying or doing anything that could jeopardize the fair bidding process.

Except for technical evaluation, bid qualification and bid summaries are normally handled by the buyer responsible for that commodity. The technical bid evaluation process needs to be routed through and coordinated

with the PEL so that there is an awareness of status and progress. When it has been determined that the bid meets the technical requirements, then the buyer will qualify the bid for price, terms and conditions. At this point, some time has passed since the first MTO was done. Due to design development, it may be prudent to perform an intermediate MTO to update the quantities. Once a selection of one or more suppliers has been made, a purchase order could be generated. A purchase order can be generated if all issues have been resolved regarding:

Technical compliance. This refers to the actual material the vendor or suppliers are offering. Sometimes the bidders will quote on the exact item that was in the RFQ. Sometimes the bidders will offer an item as an "or equal." Any or-equal item needs to be verified for technical compliance.

Quantity. Did the bidder quote on the total quantity of each item? If not, why not? It would be embarrassing to have selected a supplier based on a low bid only to discover later that the supplier had only half the required quantity and were discounting the item to clear their stock.

Supplier qualification. Have you, your company, or the client used this supplier in the past? If so, then they may not need to prove they are qualified. If, however, this supplier is a new company with an unknown performance history, they may need to be qualified.

Subsupplier qualifications. Some materials on some orders may require the prime supplier to use one or more subsuppliers. The use of subsuppliers is not normally a problem. However, there may be a requirement on some projects to identify and obtain approval of all subsuppliers.

Price. This is obvious. The price needs to be stated and clear as to any conditions. A typical condition on a price is the period the price is good.

Delivery schedule. The delivery schedule is always important. A single-quantity item or the total quantity shipment of a large quantity item could have one specific delivery date. Large quantity items with a quoted incremental shipping schedule spread over time will need to be reviewed.

Restocking. Excess material is often found at the end of the construction phase. Sometimes, if it is the right type of material, the client may adsorb it into their operations and maintenance warehouse stock. You and the project must have the bidder define their restocking position on each type of material.

Pending design developments. As a few weeks to a few months may pass between the time of the original MTO that produced the quantities shown in the RFQ package and the current pending purchase order issue. Have there been any design developments that have resulted in any significant quantity changes? You may need to conduct a new or updated MTO.

It is the responsibility of the PEL (and the piping team) to prepare each purchase order package. A complete purchase order will include the applicable item descriptions, updated quantities, specification(s), technical notes, attachments (if applicable), and a purchase order cover sheet. The purchase order cover sheet will have the selected supplier identified and have all the appropriate approvals completed. The PEL (and others) may need to attend an award or bid-conditioning meeting for some orders.

Monitoring the piping purchase order is also an important aspect of overall piping performance. The PEL and the piping team need to be aware of the status of every piping material purchase order. The piping material control function may also perform some or all of the following activities, depending on the needs of the project.

- Purchase order status reporting
- Purchase orders issued
- Purchase order status
- Orders that are complete
- Orders that are behind schedule (why, what action should be taken, who is taking the required action)
- Production schedule
- Suborder placement (if applicable)
- Material on hand
- Procedure submittal:
  - Welding
  - Casting repair
  - Heat treatment
  - NDE
  - Hydrotesting
  - Export packing
- Drawing or document submittals
  - Source traceability
  - Mill certification
  - Certification of compliance
- Inspection and testing requirements complete
- Item and quantities due to ship

- Items and quantities actually shipped
- Compliance to marking and shipping requirements
  - Addressee
  - Project number
  - Purchase order number
  - Purchase order item number
  - Item code number
  - Area color code (if applicable)
  - Export packing (if applicable)
  - Documentation
  - Bar coding

Supplier performance can be a serious soft spot in the overall project. You or others on the project will not be able to deal with them if they are not uncovered and recognized. The PEL should be proactive in the following area relative to any piping material purchase order.

- Initiate visits to suppliers—Make sure someone from the project, the company, or the client visits the supplier. All findings by these visitors should be documented in written reports. The PEL must monitor these reports for hidden problems and hold-ups. The reports must be read as soon as received for indication of any problems.
- Define the problem—Quick and appropriate action should be taken to define the problem. This can be as simple as a phone call to the supplier.
- Determine and evaluate solutions—There may be more than one potential solution. Make sure the real solution is agreeable to all affected parties.
- Initiate action—Make sure action is started on the approved solution.
- Follow-up—After an appropriate period, check on the status of the corrective action.
- Report—During and at the conclusion of the corrective action period, reports should be made to keep the project manager, the client, and others informed.

There are also logistical issues and potential logistics problems related to procurement of piping material for a construction project. These are a major concern to project management, construction, and the client. Piping material orders may fall into one of the following categories.

Direct. The supplier will ship from their own or their subsupplier shop direct to the job site.

Indirect. The prime supplier is directed to ship to a second supplier for some form of in-transit processing (painting or coating).

The problems of logistics will be further complicated if the project job site is overseas and requires:

- Transshipment marshaling yards
- Export packers and export inspection
- Ports of debarkation (single or multiple)
- Ports of embarkation
- Import customs and duties

There are also issues related to piping material purchase orders that affect the job site. Issues that have a positive or negative impact on the job site include:

Awareness of pending shipments. If you want to get on the good side of the construction manager, here is one sure way to do it. Make sure the field always knows when to expect a shipment. It is not good to have six truckloads of pipe show up unannounced, not have people or equipment to unload it, and have no place to put it. If you know a shipment is due, tell the field it is coming.

Prompt notification of delayed shipments. If a shipment is pending but has been delayed, tell the field.

Lost shipments, shortages, overages, damaged in transit, missing, or incomplete documentation are all issues that may need immediate corrective action and feedback. The PEL should understand that the office team must support the field team all the way through to mechanical completion on the EPC or EPCM project.

After the construction effort is complete, some projects require some follow-up efforts. In spite of all the good efforts by the home office team, the supplier, and the construction forces, there will invariably be surplus material and damaged material. Depending on the number of factors (type of the material, quantity, type of damage, job-site location, potential need for spare parts), this material will need to be collected and identified for potential return to the applicable supplier or disposal. In chapter 4 we discussed some of the action that may be required at this point.

8

Pipe Shop Fabrication

The purpose of this chapter is to present a list of issues that may affect pipe shop fabrication coordination on a project. This list is intended to be as complete as possible. The assumption is made at this point that we are still talking about a project that is E&P, full EPC, or EPCM.

Your company has just been assigned to a new project. This new project is a full EPC project. You must include the requirements for the pipe shop fabrication purchase order in the scope and preliminary estimate. Why all the attention? Doesn't purchasing take care of purchase orders? What are the PEL and the piping group responsible for when pipe fabrication is included in the project execution formula? What are the requirements related to the shop fabrication of piping on a project? The answers to these questions are both simple and complex.

SIMPLE

Question #1: Why all the attention? The piping account (piping material, pipe shop fabrication, and piping field installation labor) will represent 20 percent (or more) of the total project cost.

Question #2: Doesn't procurement take care of all purchase orders? Procurement takes care of only the commercial terms and administration of a purchase order. The technical content and technical requirements contained in the purchase order are the responsibility of the discipline.

Chapter 7 covered issues relating to the procurement of bulk materials and the general interface between piping and procurement.

COMPLEX

Question #3: What are the PEL and the piping group responsibilities when pipe fabrication is included in the project? If the project execution formula includes *P*, then piping is responsible for everything.

The PEL must do the planning and must coordinate all the activities that relate to this purchase order. Some of the activities are internal to piping, and some are external to piping. The focus of attention on this purchase order will start in the development of the scope of work for the project (see chapter 10). In the scope, you will list the requirement for one or more piping shop fabrication purchase orders. It is possible to have many shop purchase orders on a single project. Chapter 7 discussed some of the ways the piping purchase orders could be broken down. The determination of the number of shop purchase orders needs to be established early. If you start a project thinking that all fabrication will be done in the field and then decide to change to shop fabrication, time and money will be lost on the project.

A typical shop fabrication purchase order scenario follows:

Requirement for pipe shop fabrication defined. The project is a full EPC job. Early in the project, the decision is made to include pipe shop fabrication in the project. The reason for having the pipe fabricated in a shop is very simple: It is the best way to achieve the lowest cost and the highest quality. This is the way to go whenever possible.

Number of purchase orders quantified. At this early meeting, there would be broad discussion and detailed planning by all parties involved. The procurement responsibility matrix (discussed in chapter 7) should be used. The number and type of pipe fabrication (fab) purchase orders are established. The project WBS (work breakdown structure) should have been established and should be considered in the discussion of the purchase orders. This WBS/purchase order relationship will then be used in the estimate, the schedule, the work planning, and the work execution. All of the documents and all of the related material will be identified in this early planning.

The piping portion of the project scope of services is developed. The procurement plan for the piping execution on the project is defined in the piping scope of work.

Historical data (past jobs) is reviewed for typical hours per shop fab purchase order: Depending on the number and type of shop fab purchase orders,

it would be prudent to review the historical data from past jobs having equal or similar circumstances.

Evaluation made to adjust historical hours (need to increase hours or ability to reduce hours). You may need to increase the hours for some reason, or you may be able to lower the hours. It would be prudent to define the premise of the shop fab purchase order activities under "Assumptions and Clarifications" in the scope of services (see chapter 10).

Prepare home office labor estimate (including hours for shop fab purchase order). Using the number of shop fab purchase orders and the hours per purchase order, along with all the other data, the piping purchase order labor estimate is prepared (see chapter 11).

Receive approved home office budget. At some point, the approved project budget will be issued. There may be a difference between the estimate and the approved budget.

Adjust services and deliverables to be compatible with approved budget. See chapter 11 for a detailed discussion on this subject.

Prepare discipline control level schedule (CLS). All activities and tasks directly and indirectly related to the shop fab purchase order are planned in the terms of the project calendar. The shop fab purchase order portion of the piping CLS must be compatible with the receipt of information from other disciplines, the generation of deliverables, and the needs of construction. Once approved, the shop fab purchase order portion of the CLS will tend to be the main driver of all the piping effort.

Prepare potential bidder list. The bidder list for the shop fab purchase order will be a joint effort between piping, project, procurement, construction, and the client.

Evaluate need to qualify potential bidders. Is the job overseas? Is there some new material on the job? It is foolish to allow a bidder who is unknown, untried, and unproven to submit a bid. An unknown and unqualified bidder could submit a low bid and win, based on that low price. Later, the project will pay through extra charges or rework. The fabricator might even go out of business with the work unfinished.

Qualify bidder(s) as required and adjust bidder list, if appropriate. Some suggestions later in this chapter may help with this.

Prepare all specifications. This is the first activity that is indirectly related to the shop fab purchase order. Various specifications are required for the job whether there is shop fabrication or not. Some specifications are required specifically by the shop, and some have general application. In most cases, it will be clear which specifications are required by the shop. Those required for shop fabrication should be among the first to be prepared.

Prepare definition of fabrication scope (tonnage, material take-off, sketches, or other). Because of the early procurement planning meeting, we knew we were to have a shop fab purchase order. As a part of the estimate process, we establish a count of the lines on the job. We prepare the piping transposition to define the preliminary configuration of each major line. We route this through the piping material control group to establish a preliminary shop fab material quantity.

Prepare fabrication drawing (isometric) issue schedule. Based on the piping CLS and the balance of the project engineering schedule, a drawing issue plan (or schedule) is prepared. This activity will result in a preliminary count of the total isometrics and the estimated quantity per week during the issue cycle.

Prepare schedule for required shop fabrication and delivery. Working with construction and project, a preliminary fabricated pipe RAS (required at site) schedule is prepared.

Prepare draft shop fab purchase order. A company form can save hours and reduce errors here. Most of this should be boilerplate based on your company culture. A small part of the form may be some very project-specific, technical requirements. All the specifications, standards, and details should be listed.

Assemble all documents. Pull everything together into a package. The package should include the (your) originator's routing and sign-off page, the list of proposed bidders, the boilerplate, the specifications, the standards, the reference details, a copy of typical production isometrics, the material take-off, the total and incremental isometric counts, the isometric issue schedule, the required RAS schedule, and any other items that may apply. A package such as this shows organization skills and helps to coordinate tasks.

Obtain required approvals. It may seem that every approval level finds an error in the project documents. You should not let it worry you. You should remember that a project is a team effort. Part of the effort is the making sure we all agree on what is to be done.

Release to purchasing for issue. This is the first time that purchasing will take direct action on this RFQ. Up to this point, they may have been only on the sidelines. They no doubt have been providing a valuable service as an advisor.

Purchasing issues RFQ for shop fab piping. This should be handled by the purchasing department in accordance with the standard company or project procedures.

Bidders prepare bids. When the bidders are preparing their bids, all questions from bidders should only come through the purchasing department.

Bids received by purchasing. On or before the designated bid closing date, purchasing will receive the bids.

Bid summary or bid tabulation is prepared and fabricator(s) selected. There are three aspects to the bid evaluation process. One is commercial; the second is performance; and the third is technical. The commercial aspects deal with all material costs, labor costs, and services. The purchasing department is normally responsible for the commercial evaluation. The performance aspects deal with scheduling. Construction and the project scheduling lead may be responsible for this evaluation. The technical aspects deal with the material and manufacturing procedures. The technical evaluation of a shop fab purchase order is the responsibility of piping. There will always be questions about a specific bid. After all the questions have been asked and all the answers received (and accepted), one or more fabricators will be recommended to the client.

Shop fab purchase order awarded. This may be done in a formal meeting situation, or it may be somewhat informal. The award may also include the kickoff of some purchase-order-related activities. The successful fabricator may be directed to prepare and submit a formal manufacturing plan, welding procedures, NDE procedures, and definitive production schedule. They may also be directed to proceed with the purchase of some portion of the material requirements.

Fabricator preorders material. By direction or by design, the fabricator makes ready to start the fabrication.

The preceding activities occurred over a long period of time. Other design activities have been ongoing. There will also be another long span of time between the award of the shop fabrication purchase order and the client's approval of all or part of the design. During this time, the shop fabricator is in a preparation and hold mode. After the design completes the final approval stage, the next activities happen in a somewhat systematic process. This process will include:

- Fabrication isometrics are created, checked, and approved for issue.
- Fabrication isometrics are released in accordance with the schedule.
- Fabricator receives isometrics and fabricates pipe.
- Fabricated pipe is inspected and released for final prep and shipment.
- Pipe is shipped to the job site.
- Pipe is received and accepted at the job site.

All of the services or deliverables required to accomplish the preceding will require hours. The shop fab purchase order is both a service and a deliverable. As such, it will need to be included or accounted for in the estimate. The preparation and handling of a shop fab purchase order are not free. The number of hours required for a single shop purchase order will depend on many factors. The procurement responsibility matrix (discussed in chapter 7) will give guidance to the depth of involvement. The hours required for the preparation of the shop purchase order can be reduced through the use of a boilerplate.

Question #4: What are the requirements related to the shop fabrication of piping on a project? This chapter is intended to bring attention to these requirements. It is impossible to predict everything that will happen. Each new project or situation may add new problems.

Shop fabrication of piping spool pieces on a full EPC project will normally be covered by a home-office-generated purchase order. On most projects, this purchase order will be the largest and most important purchase order in the piping account. It may also be the earliest one to be initiated by piping. Important requirements that need thought and consideration are as follows:

- Which shop fabricators should be potential bidders
- Fabricator performance history
- Fabricator backlog and commitments

- Fabricator production capability (size or material restriction)
- Fabricator engineering capability
- Fabricator material control capability
- Fabricator quality assurance/quality control capability
- Fabrication schedule/duration
- Fabricator status reporting, documentation, and communication

As stated in chapter 7, the procurement department is the primary contact for all vendors and suppliers. As such, it is normally the responsibility of the procurement group to determine answers to these questions. However, the PEL is accountable for the success of the pipe fab order. The PEL needs to ensure that procurement has a list of the proper questions to ask. Additional requirements may include the following:

Inspection support by piping personnel. This type of assignment is rare, but it does happen.

Designer assignment in fab shop for engineering reviews and shop drawing checking. This type of assignment is highly recommended.

Qualifying a pipe fabrication shop needs to be done very carefully. Errors can easily be made. Any error can cause a major cost and/or schedule impact. Some issues that piping, procurement, and project should consider are as follows:

An on-site shop evaluation. If you were going to buy a $19,000 car, you would check it out very carefully and test drive it. If your project is about to award a $19,000,000 shop fab purchase order you should check out the potential bidder, and do it firsthand. Go to the shop, and spend some time looking around and asking questions.

Current shop load and future commitments. What is the shop's stated production capacity, and does the current facility survey support that statement? Does that meet your project's requirements? What is their projected backlog during the period required for your project? Will they have the capacity to handle your work and other committed work?

Past performance (on other company projects). Get a list of their past customers, and review the performance on those contracts. Were the other customers satisfied? Were there any major problems?

Union contract renewal date and potential for strike during contract. If this is a union shop, a number of questions need to be answered. Has there been a history of management versus union stability or hostility? Will the current contract expire during the project time frame? What is the potential for a strike?

Engineering practices (fab from client isometric or shop orthographic drawing). What are the engineering capabilities of the fabricator? What are their preferred methods of operation and their alternate capabilities? Can they handle electronic transfer of data? Do the fab shop capabilities offer any opportunities for you to change the home office effort and save the client money?

Material source and availability. Where does this fab shop usually purchase their material? Is the material domestic or foreign? Is foreign material acceptable to the client?

Shop standard material stock (type and quantity). What materials are considered normal stock? What materials are considered special by the shop?

Material receiving, storage, and control (alloy, ASME, and other). Does the shop show evidence of having a well-planned and well-executed program for receiving, storage, and control of material?

Quality assurance and quality control methods. Does the shop have an organized program for the control and documentation of quality? Do their normal practices meet the requirements of the code and your project?

Inspection practices. What do they inspect? When do they inspect? How do they inspect?

Records procedures. What records do they normally keep for a typical order? Do these normal practices meet the requirements of your project? Do you need any additional reports? Is the information available for that new report requirement? Will there be an additional charge for the new report?

Production capacity. What is the total production capacity of this facility? What is that based on? Are there any extenuating circumstances that affect the total capacity levels? For the period of your project work, how

much of the total capacity is open? What happens if the shop gets over-committed? Does the shop ever outsource any of the production? If so, to whom? (All of these questions should apply to the outsource shop, also.)

Number of bays and height of bays. If the shop has only one fab bay and the height of the bay is low, they may have limited size and material capabilities. How do the they handle stainless steel?

Crane capacity. Does the project include any large diameter, heavy wall piping? What is the heaviest piece that could be required for the project? Can the shop handle it?

Type of welding available. Does the shop have the technological capabilities to handle the project?

Number of welders. Does the shop have the staffing capabilities to handle the project?

Welder qualification procedures. Does the shop have the procedural capabilities to handle the project? Are the procedures current?

Weld repair methods and procedures. Does the shop have the procedural capabilities to handle the project?

Heat treatment methods and capacities. Can the shop handle the type of post weld heat treat (PWHT) required for the project?

Bar coding capabilities. Does the shop have bar coding capabilities? Which system do they use? If the project uses bar coding, will the shop's system be compatible?

Shipping methods (truck, rail, barge). What options are available? What are the limits?

Documentation, reporting, and communications. How does the shop handle these areas?

Invoice auditing. How does the shop handle invoice verification?

Billable/nonbillable items. What items are billable? What items are nonbillable? How are they identified on the invoices?

You may believe that not all of the preceding items are the responsibility of piping. Regardless of who may perform a specific task, there is a bottom line. The bottom line is that this is a piping shop fabrication order. If it is not piping's responsibility, then whose is it?

When there is a requirement to assign a piper to the fab shop, there are things to think about and plan. The first and most important is who would be the best person for this assignment. Timing of the assignment and availability of experienced candidates will influence the selection. You and the fab shop need to work out details relating to such things as office space and phone availability. There is also the point of freedom of access to project-related work areas.

It is the responsibility of the PEL (and the piping team) to prepare each shop fab RFQ package. A complete RFQ will include the applicable work description, estimated tonnage quantities by material, material specification(s), technical notes, attachments (if applicable), a sample of proposed drawings, and the RFQ cover sheet. The shop fab RFQ will also include a proposed schedule for the release of drawings and the required schedule for delivery of the finished fabricated pipe spools. The RFQ cover sheet should have the recommended bidders identified and have the appropriate approvals completed.

The point of ethics needs to be mentioned here, just as with any other purchase order. A piping shop fabrication purchase order is also a contract. It is a legal document with potential for extensive financial impact to the project, the supplier, the client, and the company. Potential fabricators may become aware of a pending order during the early design stages. The PEL and the other members of the piping team should use care in any discussions with strangers or known supplier personnel. Once a request for quote is issued, the PEL and all of the piping group should be on guard against the possibility of saying or doing anything that could jeopardize the fair bidding process.

After the bids have been received, the next step is the bid evaluation and bidder qualification. Except for technical evaluation, bid qualification and bid summaries are normally handled by the buyer in the purchasing department who is responsible for that commodity. The technical bid evaluation process needs to be routed through and coordinated with the PEL so there is an awareness of status and progress. When it has been determined that the bid meets the technical requirements, then the buyer will qualify the bid for price, terms, and conditions. Over the next week or so, the bid evaluation process will resolve any unanswered questions, and the bid will be presented to the client for approval. For lump sum projects, the approval

of the client may not be required. After the final selection, the award should happen without delay. You may still be 6 months away from the release of the first piping isometric drawing; you should still issue the purchase order and reserve your shop time.

At this stage, time has passed since the first MTO was done. Due to design development, it may be prudent to perform an intermediate MTO to update the quantities. A purchase order can be generated at this point if all issues have been resolved regarding the following:

- Technical compliance
- Quantity
- Supplier qualification
- Subsupplier qualifications
- Price
- Delivery schedule
- Restocking

It is the responsibility of the PEL (and the piping team) to prepare the shop fab purchase order package. A complete purchase order will include the applicable standard drawings, the fabrication drawing release schedule, updated quantities, specification(s), technical notes, attachments (if applicable), and a purchase order cover sheet. The purchase order cover sheet will identify the selected fabricator and have all the appropriate approvals completed. The PEL (and others) may need to attend an award or bid-conditioning meeting for the shop fab order(s).

Once the shop fab order has been awarded, the shop should rapidly move into action. They will start submitting all the required procedures and other paperwork for the mandatory approvals. Their goal will be to ensure that they are not the cause of any perceived holdup. The pressure will be on the piping group as a whole to meet all the pipe fab-related commitments. The RFQ and the purchase order included a definition of the type of material that would be required. Included also was a definition of the number of drawings the shop would receive and the schedule of issue. It is now critical that these commitments be met. People are quick to criticize a vendor or a pipe fabrication shop if they are not on schedule. To be fair, you should be willing and able to meet all the commitments and promises made in the purchase order.

Piping shop fabrication purchase order monitoring is also an important aspect of the overall piping performance. The PEL and the piping team will need to be aware of the status of shop fab purchase order. The piping

material control function may also perform data collection and reporting activities, depending on the needs of the project (also see purchase order status reporting in chapter 7). Piping shop fabrication purchase order monitoring includes the following:

- Purchase order status reporting
- Total shop fab purchase orders issued
- Purchase order status
- Orders that are complete
- Orders that are behind schedule
- Production schedule
- Suborder placement (if applicable)
- Material on hand
- Procedure submittal
  - Welding
  - Heat treatment
  - NDE
  - Hydrotesting
  - Export packing
- Drawing or document submittals
  - Source traceability
  - Mill certification
  - Certification of compliance
- Inspection and testing requirements complete
- Pieces due to ship
- Pieces actually shipped
- Compliance to marking and shipping requirements
  - Addressee
  - Project number
  - Purchase order number
  - Purchase order item number
  - Item code number
  - Area color code (if applicable)
  - Export packing (if applicable)
  - Documentation
- Bar coding

Piping should be proactive in the following areas:

Initiate visits to fabricator's shop. You need to establish good communications and a good working relationship with the shop. This starts with

face-to-face contact where the work will be done. Remind the project manager of the size of the pipe fab orders and the potential cost risk due to fit-up errors. The project manager is sure to see the benefit of your involvement.

Monitor for hidden problems and holdups. Read every report from or about the pipe fab shop and the pipe fab order. If you have made visits to the shop, you will have a mental picture and an awareness of the items referred to in the report. Address all problems as soon as they are detected.

Define the problem Get in touch with your designer in the shop (if assigned) or your designated shop contact. Determine what the problem is and the potential impact. It would be good to remember that not all reports of problems are in fact real problems. Don't overreact.

Determine and evaluate solutions. You and you alone, cannot determine the solution to the fab shop's problem. Discuss the problem and ask for clarification on any point that is unclear. Offer suggestions based on your own experience and knowledge of this specific project.

Initiate action When the shop needs direction from you or the project, then get it. If the shop does not need such outside assistance, then press the shop to proceed.

Follow up. You will keep a record of the problem in the report file relating to this shop fab purchase order. You should also put a reminder of this problem in your log, daily planner, or calendar. The next time you talk to the shop, ask about the problem and the progress toward a solution.

Report. Don't hide or cover up any problem you find with any piping order. Other people, unknown to you, may also be visiting or talking to the fab shop. If there is any problem in the pipe fab shop, the project manager should hear about it from you first.

The logistical issues related to shop-fabricated piping are a major concern to project management, construction, and the client. Logistics for orders will fall into one of the following two categories:

Direct. The fabricator will ship all fabricated pipe spools from the shop direct to the job site.

Indirect. The fabricator will ship to another supplier for some in-transit processing activity, such as painting or coating. The problems of logistics

will be further complicated if the fabrication shop is domestic and the project job site is overseas. When this is the case, some or all of the following may be required:

- Marshaling yards, export packers, and export inspection
- Port of debarkation (single or multiple)
- Ports of embarkation with import customs and duties
- In-country transportation

The same issues that affect the field for bulk material shipments (see chapter 7) also exist for shop-fabricated pipe shipments. The home office piping team cannot be expected to prevent all the problems in these areas. Home office piping will only be able to solve some of these problems. The PEL should understand that the office team must support the field team through to mechanical completion in every way possible.

9

Contracts and Construction Work Packages (CWP)

The purpose of this chapter is to assist the PEL by presenting issues that may affect the development of piping-related construction work packages (CWP) on projects.

The term *contract* is, of course, a common term found in almost all walks of life. When used in relation to our process plant engineering and construction industry, the word *contract* is sometimes mixed up with *project*. Do you remember the old seafarer's rule about how to tell if a vessel is a ship or a boat? The answer was, ships can have (life)boats, but (life)boats do not have ships. In our industry, a contract is like the lifeboat. The term *contract* as used here has an implied "sub" prefix. A subcontract can also be looked at as a "sub" part of the overall project. It may be helpful to remember it this way: Projects can have (sub)contracts, but (sub)contracts do not have projects. This book is about piping (a mechanical-related discipline), so we will be talking about mechanical contracts. A mechanical contract may include only the piping-related work. It may also include other mechanical-related work such as demolition and equipment setting.

Your relationship to contracts will depend on where you are responsibility-wise, in the project. If you are in construction, you may be deeply involved in contracts. If you work for a mechanical contractor who is bidding on the work, you will be involved in contracts. If you are the client and you are acting as your own construction manager, you will be involved in contracts. If you are in engineering, you may be involved in contracts on some types of projects. (See Table 9-1.)

Table 9-1
General Definition of Project Type Versus Contract Requirement

Project Types (Your Company)	Contracts Required
E	No (1)
E&P	Yes (2)
EPCM	Yes (3)
EPC	No (4)

Engineering's involvement in the contract process occurs before the data and drawings become an actual construction contract. Engineering is responsible for the development of the precontract documents known as the construction work package (CWP). From this point, we will be primarily referring to the preparation of the document that will become a contract, not the contract itself. The document that will become a contract is referred to as a *CWP* until it is awarded. After the award, the term contract applies; however, throughout the balance of this chapter, we will need to use both terms.

The term *CWP* is intended to mean the technical and commercial definition of a work segment to be offered for subcontract bids. Contract packages are not a major requirement if the project is to be EPC. The EPC project implies that the field construction is by direct hire/self-perform through the construction wing of the same company that is doing the engineering. This method is sometimes referred to as *self-perform* or *design-build*. Construction work packages of some sort will exist on all projects that include construction management (CM).

Construction work packages, in one form or another, will be required if your company has an E-only project. They will be required for an E&P-only project and for the EPCM project. On these projects, someone will be selected as the construction manager, and the work will be executed by subcontractors through the contract process.

(1) With an E-only project, the contract package preparation will more than likely be by the client or a third-party construction manager firm. These contract packages may include the requirement to purchase all equipment and materials.
(2) With an E&P project, the preparation of the contract package may be by the engineering company, the client, or a third-party construction manager firm.

(3) With an EPCM project, the preparation of the contract package will normally be by the engineering company.
(4) Self-perform and design-build projects often require third-party services as a part of the construction effort. These are normally handled as field purchase orders.

During the early project planning stages, a decision should be made on the number and type of contracts that will be required. As the PEL, you need to be involved in that decision process. The PEL needs to have an early awareness of the contracts plan because it will impact and drive the total piping effort. Issues that influence piping include the number of contracts, the work definition for each contract, the type of contract, and the discipline focus for the contract.

The number of contracts is influenced by the actual physical and logistical personality of the project. The contracts plan will normally go through a number of iterations before the list is finalized. Piping should be involved in the contracts planning process. The PEL needs to study the overall project, the project execution plan, and the proposed deliverables and be ready to offer input to the plan. The question of which is better, too many or too few, will arise. It does not really matter a great deal one way or another; I would err on the side of too many and cut back, if applicable. The main thing is to try to get the contracts plan settled before the project gets into the detailed-design phase. You and the rest of the project need to know the CWP schedule so that you can plan your work accordingly. Most of the time, the PEL will not be the one who decides the number or makeup of the contracts. Hopefully, whoever is doing the contracts planning will think to ask the discipline leads for input. If so, then here are some recommendations.

There is no correct or incorrect way to determine the number or content of CWPs. The quantity of (mechanical) CWPs on a project may be determined as follows:

- One CWP for the total project (normally applicable for small projects only)
- Multiple CWPs by physical area (normally applicable on large projects)
- Multiple large areas within a project (avoids the “all your eggs in one basket” syndrome)
- Multiple areas separated by long distances
- Multiple areas with major difference in engineering timing
- Multiple areas with major difference in work definition (some areas are grass roots and others are revamps)

- Multiple CWPs by work definition (by total or area)
- A CWP for the pre-shutdown work only (may be limited to piping tie-ins or non-tie-in work in clear areas of operating units)
- A CWP for the shutdown work only (required when work is required on normally operating systems.) This will normally include some pre-shutdown preparation effort to minimize the shutdown period.
- A CWP for the post-shutdown work only (may include activities such as tracing for winterization, painting and insulation, where safe to do so)
- One CWP that covers the total work period (may be done when the total area can be shut down or area is grass roots)

There are many different types of contracts. Here, the reference to type of contract relates to the pricing format for the work. The type of contract can and will have a serious impact on the piping effort throughout the project.

Lump sum. This type of contract is preferred by most in the client community. This type will require checked and preferably corrected drawings showing all work.

Unit price. This type will require a more definitive narrative description of the work with a pricing structure at the task/activity level to match. Order of magnitude quantities would also be required.

T&M. This type will require a somewhat definitive description of the work. The pricing structure would be developed by others on a time and material (T&M) basis.

Multiple pricing. This may be a lump sum contract that has the potential for additions on a unit price basis. As such, this contract would have the firm documentation of the lump sum contract, plus the detailed-task/activity pricing basis of the unit price contract.

Which is the best? Which is the preferred type of contract? There is no correct answer to this question. On one hand, if you have the information and the time, the lump sum may be the best/preferred way to go. However, if there is a time constraint and the definition of the work scope is not fixed, then the unit price or T&M must be considered. In some cases, a contract is awarded based on a unit price and rolled into a lump sum agreement later, when the scope is more defined.

Another aspect of contracts planning is the discipline focus, or depth, of the CWPs. Some specialized construction activities are candidates for stand-alone contracts (pile driving). These stand-alone activities are normally not

required on all projects. When they are required, they are handled by a contractor who specializes in that field. Other construction activities can be bundled and handled by a single subcontractor. This leads to the depth of the contract, or the way the CWP is bundled. Some examples of CWP bundling include the following:

- CWP(s) include all disciplines (omnibus contract that would include all engineering discipline work)
- CWP(s) include multiple disciplines (examples: structural, mechanical equipment, piping
- CWP (s) include single discipline (example: civil)

Contracts or construction work packages take time. Time means home office hours, and hours affect the estimate and budget. In order for an estimate to be developed, the PEL will need to know the number and content of each of the contracts on the project. The estimate needs to consider the extent of involvement by piping staff in each of the three stages. The piping labor hour estimate preparation needs to be documented in detail so that there is no double-dipping in the preparation of the contracts. The process for contracts will have three basic stages:

- Stage One—Detailed engineering and design development
- Stage Two—Bid and award
- Stage Three—Post-award and construction execution

The development of the CWP on the project is an integral part of the overall CM project. The CWP program is dependent on all other engineering and design activities to create the documentation and determine what is to be built. The engineering and design program is dependent on the CWP program to be the bridge or the link to the CM program. An EPCM project will not achieve success without an integrated and compatible schedule that recognizes the realities of both the engineering side and the construction side. The CWP dates are important to the PEL and the overall piping effort.

Review the master project schedule and the contract plan for timing of the following:

- Work scope draft completion for project, construction management, client, or other reviews
- Final engineering and design preparation of the CWP (drawings and data)

- CWP release to TDC with all supporting documents
- RFP (request for proposal) kickoff meeting
- Formal RFP release issued for bid (IFB)
- Pre-bid meeting/job walk
- Bid development by the contractor
- Bid closing and contractor selection
- Contract pre-award meeting and bid conditioning
- Contract award and contractor mobilization

These events and activities for lump sum contracts need to fall later in the overall project schedule. The detail drawings required for a lump sum quote are not normally available until late in the job. If the project will require early mobilization of subcontractors, then the push would be toward a unit price contract based on a detailed narrative scope and estimated quantities. The following dates are also important to the PEL:

RAS (required at site) dates for material supplied by the engineer. Coordinate the design effort with the purchase of material and the contract execution.

Contractor mechanical completion. Coordinate field support and resolution of any surplus engineer-supplied material.

The PEL will need to understand the requirements of the piping-oriented CWP and the locations of resources and inputs. It would be shortsighted to assume that the other disciplines know what you need and when you need it; they cannot be expected to remember. You need to define your needs, determine the origin of those needs, document those needs, and communicate those needs. This is done through proper coordination with the other discipline groups. Coordination with groups outside of piping will be required for a CWP.

Process. Ensure that a revision cycle is timed for the P&IDs so that a clean version of the latest update can be included in the CWP. Are there any secrecy issues with including P&IDs in the CWP?

Civil. Is there any imbedded piping that is required for a civil CWP or civil work that needs to be completed for a piping CWP?

Structural. Are there any structures in a structural CWP that impact a piping CWP? Are there any structures in the piping CWP?

Architectural. If piping is to be installed in or connected to buildings, are the schedules compatible?

Mechanical equipment. What equipment needs to be set before the piping can be installed, and when will it get to the field?

HVAC. Is there any potential for space or installation timing conflicts?

Electrical. Are there any space, routing, or timing conflicts?

Control systems. Where is the split in jurisdiction for instrument piping?

Technical document control. When and in what form are documents required?

Contracts administration. When and in what form are the contract documents required?

Coordination with groups in piping may be required for CWP-related activities.

Piping design. Ensure that specifications, drawings, and scope of work definition will be available consistent with the schedule and type of contract.

Piping material engineering. Ensure that piping material specifications are the correct revision and will be available consistent with the schedule. Ensure that insulation and coating specifications and data will be available consistent with the schedule.

Piping material controls. Ensure that piping material take-off quantities will be available.

Pipe stress engineering. Ensure that pipe stress specifications and data will be available consistent with the schedule. Coordinate the delivery of engineer-purchased items (spring hangers, expansion joints, and so forth).

Management-level reporting is required for CWP activities. Projects will normally require status reporting on a regular basis. Standard reporting may include the development phase, pre-issue for bid (IFB), and the post-IFB status. The pre-IFB status is normally the responsibility of the assigned discipline. The post-IFB status will normally be the responsibility of the project procurement manager (or contracts manager) and the construction

manager. However, the PEL will usually be involved during the bidding stage for clarification. The reporting will be required on an individual basis for each CWP. The CWPs have different milestone dates in the overall project time frame. If there are 10 CWPs that piping is involved in and each CWP has 10 reporting milestones, there are 100 items to track and report.

A typical contract will usually have a number of standard sections with standard articles. For the purpose of this book, we will assume the following. A CWP "shell" containing multiple sections already exists in your company. Wherever possible, this standard shell should be used as the starting point. This shell should be modified only where required to fit the needs of the project. Part I will require input by the piping discipline(s) to these first four articles:

Article 1.0	Description of Work—General (minor input)
Article 2.0	Specification, Drawings, Attachments, and Exhibits (major input)
Article 3.0	Description of Work—Specific (major input)
Article 4.0	Materials, Equipment, or Services Furnished by Others (minor input)

Part II will require input to these articles by others:

Article 5.0	Temporary Construction Facilities and Utilities
Article 6.0	Performance Schedule and Sequence of Work
Article 7.0	Reporting Requirements and Coordination Meetings
Article 8.0	Data Requirements (test records)
Article 9.0	Communications
Article 10.0	Cleanup, Safety, Work Rules, and Regulations
Article 11.0	Quality Control Procedure for Contracted Work
Article 12.0	Construction

As early as possible, the PEL should initiate work on any CWP that includes piping or is piping specific. On large projects, it is also recommended that the PEL assign someone to act as the CWP coordinator. This person would develop all piping input and be the focal point for interdiscipline coordination and status reporting as it relates to CWP action.

Providing an accurate description of the work is very important and will require different preparation efforts depending on the type of contract. The lump sum contract will (or should) have all of the applicable drawings included, so the work description would be, in simple terms, "do everything

that is shown on these drawings." The preparation effort involved here requires the resources, prerequisite data, and the timing to produce checked, bid-quality drawings. This implies that the schedule date for the issue for the bids is such that the design effort can be completed first. In some cases, lump sum contracts have been issued for bid based on unchecked drawings. There is risk in doing this, along with extra effort and cost. The risk is that the contractor may only guarantee the bid price to the drawing included with the request for bid. Extra effort and cost are involved, because all changes made to the bid documents may need to be identified and controlled the same as a revision to a normal approved for construction (AFC) drawing. The lump sum contract will also need to include a schedule for unit pricing that will be used for pricing additions and deletions.

The scope of work for a unit price contract will not normally require all the drawings. It may require samples of representative types of drawings. The preparation effort here is to write an accurate narrative description of all the work. The work descriptions should be grouped by discipline and be prepared by that discipline. The descriptions of the work should be very detailed, should be in keeping with the project area work breakdown structure, and should be in construction sequence order. A logical construction sequence supported by the project field cost codes will normally start with demolition and proceed through the final activities, such as insulation. A category that is *not* required on a specific contract should not be removed: The note "not applicable" should be added to the section title.

The pricing basis for a lump sum (only) contract will require input from piping. The bid price will be for everything shown on the drawings. However, Part II will require the disciplines to identify major items in the price breakdown (of the lump sum proposal) and develop a schedule for price changes. These schedules will be used to price additions or deletions to any lump sum, cost-plus, or time and material contract.

A unit price contract and the unit price for adders—the addition of a work activity—on a lump sum contract will require definition. The format for the unit pricing structure will need to be reviewed and approved by project, construction management, and procurement. The format can be broken down into individual material and labor task items or may be bundled into a grouping of tasks that represent a completed activity.

Example: Task Format (each pipe size/rating)

- Receiving pipe
- Unloading pipe
- Cut pipe

- Bevel pipe
- Erect pipe
- Weld pipe
- Weld NDE
- Paint pipe
- Consumables

Example: Bundles Format (each pipe size/rating)
Handling and erecting pipe. Labor for receiving, unloading, and storing material in yard; labor for count, control, and dispersal of studs, nuts, washers, and gaskets; labor for unloading and hauling to erection site; labor for bolting up flanged connection; and consumables.

Determining a complete list of labor tasks—work activities by every pipe size, schedule, and rating—is time-consuming, but necessary. This task is also simplified somewhat by boilerplate from the contracts manager and past projects.

The process for preparing and issuing a contract is long and complicated. The PEL needs to determine the project requirements for the review and approval stage of a CWP. Someone other than piping may be responsible if the CWP is multidiscipline. For a discipline-focused CWP, however, the assigned discipline may be responsible. The PEL (or the piping CWP coordinator) may be required to attend various meetings related to the IFB/RFP phase. Typically, there will be a bid-conditioning meeting (attended by all bidders and others) where the discipline is required to review the scope in detail and answer all questions. No direct communication between a bidder and the discipline is allowed before or after this meeting.

As previously stated, a construction work package is part of a contract, a legal document with potential for extensive financial impact to the project, the contractor, the client, and (most importantly) the company. Contractors may become aware of a pending CWP during the preparation stage. The PEL and other members of the piping team should not have any discussions with strangers or known contractor personnel. When a contract is issued for bid, the PEL and all of the piping group should guard against the possibility of saying or doing anything that could jeopardize the fair bidding process. Any questions or communications that are received should be directed to the contracts manager.

The next step is the bid qualification process. Except for technical evaluation, the process of bid qualification and contractor selection is normally handled by contracts administration, CM, and project. At this stage,

it is normally the low bidder and the contractor who appears best able to work with the construction management team. The PEL would not normally be involved unless there was an exception to one of the technical requirements.

For the actual contract award, there may be a formal meeting. The PEL (and others) may be required to attend a bid-conditioning or post-award meeting for the contract. Participation at the meeting may be as little as being introduced, or it may involve a detailed review reading of the total contract. Questions and clarifications should be documented.

When required, post-award contract monitoring by the PEL is also an important aspect of the overall project performance. Proactive approaches should occur in the following areas:

Job-site visits. Initiate visits to the job site but make sure that the first and last point of contact is the CM.

Communication. Maintain open lines of communication between the office and the CM.

Problems. Monitor for hidden problems and holdups, such as late delivery of critical items.

Responsive to field requests. Be ready, willing, and able.

Use a professional approach. Clarify what the contractor used as a basis for the bid; define the problem; determine and evaluate solutions; recommend action; follow up; and report.

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Part IV

Project Execution

10

Project Definition—Scope of Work

This chapter discusses the importance of defining the "target." The target is the finished plant, and it needs to be fully described in a scope of work.

> "If you do not know where you are going, then you will never know if you ever get there."
>
> (Unknown)

I have no doubt that there are many philosophies regarding this subject. There will be many opinions as to whether there should even be a scope of work or what could or should be included in a typical scope of work. There will also be a wide variety of opinions as to who can and should participate in the development of a document defining the project. At one end of the spectrum, some believe that there should only be the project manager's description of the project. I strongly advise against this philosophy. This method relies on the project manager to be omniscient. It excludes any input from the individual engineering disciplines that will do the work and eliminates the benefit of any input from experienced and knowledgeable leads. This method is based on a false premise that places the project at great risk. The risk includes the omission of costly elements critical to the success of the project and the final plant performance.

The true scope of work (SOW) document for a major process plant project should not be so simplistic that it could be written by one individual in isolation. The SOW is a very complex, multifaceted document that should

have each section written by the specialist responsible for that area or group of activities. In turn, the review of these sections should also be done by individuals on both the company and the client side who have that specific area of knowledge and responsibility. For the purpose of this chapter and the rest of this book, we are going to assume that there will be a document called a scope of work. We will also assume that all the discipline leads will participate in both the development and review of that scope.

Your company has been awarded a project, and you have been assigned to be the PEL. Where do you start? What is the first thing that needs to be done? Everyone involved in the project will have a different answer to what needs to be done first. Each person will have a different set of priorities and a different time schedule. How do you start a normal project? Anyone who has been in this business for more than two jobs will know that there is no such thing as a normal project. Each project has its own personality. Projects are affected by everything, including the client, the feed, the final product, the technology, the plant location, the engineering company location, the engineering company people, the vendors and suppliers, the weather, and on and on. There are also five tenets of project evaluation: safety, constructability, operability, maintainability, and cost.

All of this is true; however, there are still the basics. Some sort of basic, company-specific standard operating procedures (SOP) will need to be accomplished on every project. Every discipline lead, including the PEL, should meet with their department manager and the project manager to determine the minimum sequence of activities or events that should occur on a normal project.

The first major document you should prepare on any project is a description of the project from a piping standpoint. You need to prepare a definition of the piping scope of work as you see it. There are a number of reasons for this. Your company may not call it a piping scope of work definition, but someone will want to make sure that you know what you are supposed to be doing. On many process plant projects, the total home office labor hour budget includes project management, engineering, procurement, construction planning, and nontechnical administrative support services. The piping labor budget is often 24 to 28 percent of the total home office labor hour budget. Piping may constitute as much as 30 to 33 percent of home engineering. The piping material costs and field labor required to install that piping are also a very large percentage of the overall project costs. Even if no one proposes the preparation of a scope of work at the initial project kickoff meeting, you need to start one anyway. A few reasons follow:

The first and most important reason is the client. The client has a big investment on the line. These projects involve huge initial investments and future

market commitments in the millions and even billions of dollars. Clients want assurances that the people most responsible for the success of their project will know their job. Being able to write an accurate scope of work that defines the project will go a long way in giving the client that sense of confidence.

A second reason has to do with the project manager and you. The project manager is responsible for defining the project to the client and the company. Smart project managers do not try to write all of that definition themselves. They will collect the works of all the discipline leads. This also affords the opportunity to cross-check one against the others for continuity. The project manager (PM) may not know you, and he surely cannot see inside your head. The PM deserves to have a person as the piping engineering lead who knows both their job and the project.

A third reason for a written scope of work has to do with maintaining objectivity in dealing with change. There is nothing you, the project manager, or the client can do to prevent changes. Scope change and scope management are a fact of life in this profession. The best way of dealing with change is to have a firm basis to evaluate additions, deletions, or recycle. You must know what constitutes the "base case." The scope of work document forms that base case. A project scope of work is a complete narrative of the project, including the piping portion. Your piping portion is the basis for both the initial piping estimate and change management. Later, when questions arise, it will be easier to identify what was or was not included in the base case and what is now an addition.

A fourth reason for a written scope of work has to do with you and your department manager. At some point in the very near future, you will be submitting your labor estimate to your manager. You will be requesting an approval of your estimate along with a staffing plan for the project. If you have no written scope of work, it will be difficult to press for the proper skill levels that you know will be needed. If, on the other hand, you have a well-defined scope of work to support your estimate, you are more likely to receive the full support you need.

The fifth reason focuses on you as the PEL. One of the traits we touched on in chapter 1 had to do with leadership and being organized. If you are an organized person, you will have a compelling desire to know exactly what the job is about and what is going to be required. You will want to see far ahead so that there are no surprises. You cannot do that if you do not know the scope of the job.

The sixth reason also has its focus on you. At various times, you will have new people assigned to the job. You will need these people to become knowledgeable about the job as soon as possible. You will also want that

knowledge to be accurate and consistent. A written document of scope information is easier to control for accuracy and more likely to be interpreted in a consistent manner. It is also a very good time-saving tool for the PEL.

Look at it this way. It is early Monday morning. Six new people who were due on the job today are in your office. You just got through the introductions. The phone rings, calling you into what will be a 2-hour meeting. With no written scope of work, you have six people sitting around wasting time until you get back to tell them about the job. This is not the picture of a well-organized leader. This wastes the client's money and plants a negative impression on the six new employees. On the other hand, with a written scope of work (and other well-planned, well-organized documents), the new employees can be productive during the time you are in the meeting. They can be reading a detailed and descriptive definition of the project. When you come back, you can get them together for questions.

A seventh and very important reason for a written scope of work (and other written documents) is backup. No one is immortal, invincible, irreplaceable, or immune. You should also remember that none of us has a right to be irresponsible, either. Unfortunately, people get injured in accidents. Even a simple accident may keep them away from the job for a few days. A major accident may take them away for a long period of time or even for the balance of the project. People have serious illnesses that take them away from the job, or they change jobs for any number of reasons. People also die. Do you think that your loss could not impact the job?

Let's assume that you are the PEL, you are halfway through a job, and you are involved in an automobile accident that leaves you in a coma. Someone must step in and replace you. Put yourself in the shoes of your department manager and that person who will be your replacement. There is nothing in writing: You have it all in your head. Right now, your head is turned off and is not responding to any prompts. The new PEL has a tremendous obstacle to overcome. That person must try to discover what the job is all about and, at the same time, carry on normal day-to-day operations. The people assigned to the job will not be much help, either, because they did only what they were told, when they were told by you.

Let's assume, though, that there is a well-defined scope of work. It was written in the approved and standardized department format with which your replacement is totally familiar. This, in addition to the other documents, could be read by the new PEL outside of the framework of normal day-to-day operations. The new PEL can also rely on the help of the other people assigned to the job, because you kept them informed. You shared the information about the job with them.

The final reason for a written scope-of-work is job history. Now is a good time to bring up the subject of project closeout. We are just starting this project; we have just had our first kickoff meeting. Why should we bring up project closeout now? The reason is very simple. If you are going to be required to produce specific records at the end of a journey, it is best to know that at the beginning and start collecting early. In chapter 17, we will discuss project closeout in detail. For now, it is only important to recognize that the piping scope of work is a document that should be retained as a part of the departmental project closeout report. The project closeout reports, retained consistently from all jobs, will form a valuable base for preparing future proposals.

How do you start a scope of work? The first thing to do is determine the format to be used for the document. The scope of work document should be a company standard format, a structured "shell" format. The shell may be an outline or essay format. During talks with your department manager, determine the preferred format. This format should be consistent for all disciplines and from one job to another. A PEL should take the shell and tailor it only as required to define the individual requirements for the specific job. Several projects may be in-house at any given time. If each scope of work document is in a different format, it will be difficult for the managers to find and relate to specific key points.

What should be included in a scope of work? The scope of work for the project should provide all the answers related to four basic questions. These questions include what is to be built, what does it take to build it, what are the deliverables, and what are the assumptions and clarifications that need to be made.

The question "What is to be built?" relates to the actual plant: It is a description of the physical facility. This part is referred to as the *scope of facilities*. The question, "What does it take to build it?" relates to the services, activities, and systems it takes to engineer and design the facility. This part is referred to as the *scope of services*. The question, "What are the deliverables?" relates to the number and type of documents to be delivered to define the project. The generic term *document* as used here will include the possible electronic transfer of design data. The final part is a section that is used to clarify unusual or unknown issues relating to the facilities, services, and deliverables.

The typical scope of work might include the following:

- Part I—Scope of Facilities
- Part II—Scope of Services

- Part III—Design Development and Deliverables
- Part IV—Assumptions and Clarifications

Part I—Scope of Facilities

General Description

In this section, you should identify the client, the project name, the project location, and the type of plant. Beyond this simple identification data, you need to paint a very clear picture of all of the work areas. Start with an overall view, then break it down into each of the individual geographic areas. Describe the uniqueness of each.

Detailed Area/Unit Description

In this section, you should describe each process unit, each utility unit, each tankage area, and any interconnecting pipe racks and infrastructure. Where applicable, you should highlight any unique equipment that requires piping. Some key points that should be covered are as follows:

- Type and quantity of equipment
- Physical personality of the plant (horizontal, vertical, or combination)
- Type and complexity of equipment
- Size, type, and congestion of piping
- Number of pipelines
- Grass roots or revamp

Piping System Description

This section should include an accurate as possible listing of the basic systems, including the line class ratings and the material for each. For example:

Service	Flange Rating	Material
Hydrocarbon	150# RF	Carbon steel
Hydrocarbon	300# RF	Carbon steel
Hydrocarbon	600# RF	Carbon steel
Hydrocarbon	600# RF	9 chrome—½ moly
Medium-pressure steam	300# RF	Carbon steel
Steam condensate	150# RF	Carbon steel

Facility Design Basis

This section should list only the applicable codes and standards intended for this specific project. The ASME piping codes to be used should be listed, along with specific company specifications that are to apply. The nature of the project or a request by the client may dictate that only a specific section of a code will be applicable or not applicable. It would be prudent, in these cases, to cite the specific sections of that specific code. The revision or version of the document should be indicated, also. For example:

- ASME B31.3 (add revision in affect and date) all
- ASME B31.3 (add revision in affect and date) Section X, paragraph xxx only
- ASME B31.3 (add revision in affect and date) all except, Section Y, paragraph zzz, shall be modified to add . . .

PART II—SCOPE OF SERVICES

General Description

Investigation and communication are required before this section can be written. This section will describe your piping team's approach to the project execution. Your execution plan must be coordinated with all the other engineering disciplines. You must have a clear understanding of how the project is to be run. Will the project be an all-electronic project (3D-PDS, 3D-AUTOCAD, 2D-Intergraph, 2D-AUTOCAD), will it be all manual, or will it be some combination of these? As the PEL, you will need to find out what the other disciplines are planning to use. You need to know what their expectations are. You can cost your company and the project a lot of money if your team uses systems that are not compatible across the job. You also need to select an execution plan and an execution system that will produce documents in the format the client wants as deliverables.

Piping Services

This section will include a detailed description of the responsibilities of each of the piping subgroups as they relate to this project. For example:

- Piping material engineering is responsible for . . .
- Piping design is responsible for . . .

- Piping material control is responsible for . . .
- Piping stress engineering is responsible for . . .
- Piping engineering lead is responsible for . . .

Be as descriptive as possible in defining the activities and responsibilities of each person assigned to the project. It may help to go back and read chapter 1 to remind yourself of the duties and responsibilities for each piping subgroup. It would also help to meet with each of your group supervisors to get their input. Having them participate will ensure a buy-in on their part to the work activities.

Services Design Basis

This section will include a description of any specific design basis affecting the services. The units of measure for the project will be imperial (feet and inches). For example, for an E-only project: "Detail dimensioning and dimensional checking of equipment connection locations or piping to specific equipment connection points is not included."

PART III—DESIGN DEVELOPMENT AND DELIVERABLES

General Description

This section will describe all the piping documents—the types, their purpose, and the timing of preparation and delivery.

Design Development Documents (not for issue)

Some documents prepared on a project are considered internal developmental documents. These are drawings that are not normally included as formal issue documents. These documents are considered necessary to the development of the project, but they will not normally be issued for construction or for any other purpose. Nonetheless, they still need to be defined. Every company has them and calls them by various names. The point is, these documents do exist. They will be developed on the project for a specific purpose. They will be developed on project time and paid for by the client. These documents will be used in technical reviews that will also involve the client. The client will see them. You may not plan to issue these documents; however, the client does have a right to these documents. After reviewing the scope of services, the client may decide they want some

specific document to be a deliverable. These developmental documents should be listed. For example:

Document Type	Estimate Quantity	Remarks
Piping transpositions	6	
Vessel orientation layouts	12	
Equipment studies	5	
Equipment location control plan	3	Also called *General arrangements*

Project Deliverables

This section should include a listing (as accurate as possible) of the type and quantity of piping documents to be prepared for the project. For example:

Document Type	Estimate Quantity	Remarks
Specifications	12	New
Standards	5	New
Details	5	New
Plot plan(s)	6	2–new, 4–existing
Piping plans	30	New plans of new area
Piping plans	60	Existing plans, revised
Fabrication isometrics	2,520	New
Purchase orders	8	1 shop fab, 7 material
CWP	5	

Appendix A contains an extensive list of the potential piping deliverables for a project. Some may read this list and say it is not complete. You will, of course, be right from the perspective of your experience. Some will say it is too long and unrealistic, that there are too many documents. They will also be right, from the perspective of their own experience. This list is a consolidation of documents that have been required on projects I have experienced. The point here is that there is no absolute list of deliverables that fits every company and every project. Your company may already produce some of these documents but call them by another name. Use the list to tickle your thought processes or however it best suits your situation. The bottom line on deliverables is this: Produce all the deliverables necessary to purchase, fabricate, and install all the piping for the project. It is possi-

ble to produce too much paper. Too much paper may tend to confuse the piping fabricators and installation contractors. This confusion could lead to delays and back-charges and add cost to the job. Make sure you produce only the deliverables necessary to get the job done.

Part IV—ASSUMPTIONS AND CLARIFICATIONS

This section should include a description of any assumptions or clarifications made as a basis for the project.

An example of assumptions is "Piping assumes that space currently open and unused in existing racks will be available to the project for running the new lines."

An example of clarifications is a document or service not produced by piping such as "Piping will not product heat-tracing drawings for this project" or "Piping will not perform material takeoff services on this project."

You may ask, "How much do I include in a scope?" That question is difficult to answer. A person who has not been a PEL or has not been involved in writing a scope will not easily understand the idea of fit for purpose. It may be easier to ask the reverse question: "How much can I leave out of my scope?" How much could I leave out of my scope of work and still give my department manager, the project manager, or the client that warm fuzzy feeling about my capabilities? How much can remain undefined and still provide a basis for an accurate piping labor estimate? How much can remain undefined and still provide a basis for an accurate piping control level schedule? How much information can be left out and still provide a basis for managing changes in the future?

Do you remember reason number four for writing a scope of work? Your next major activity is preparing your labor estimate. After your estimate has been prepared and approved, you will prepare your discipline's detailed control level schedule. You will want to make sure your scope is detailed enough to support the hours you include in your estimate. If your estimate shows hours for a specific activity, your scope should include that activity in the Scope of Services section. Your control level schedule should include all of the activities and tasks stated or implied in the scope. The schedule should be consistent with the estimate. The key to this process is having compatibility with all the project planning documents (scope, estimate, and schedule).

11

Estimating

The purpose of this chapter is to provide a discussion about the function of estimating labor and other project costs. You should do all of your estimates in a manner consistent with your company procedures. You should use only the approved company forms and programs. You should not introduce any bootleg techniques on your own without full department knowledge and approval.

(Author's note: At various places throughout this chapter on estimating, I have used a specific number of hours for a deliverable or an activity. These hours are hypothetical and are intended for example only. It is not my purpose to tell you how many hours your company should take to do the work.)

> "I don't need to do an estimate—it's just piping."
>
> "I have never done an estimate before. My budget was always given to me, and I just got the work done."

Everyone has heard these statements or others like them at some time. They are, in fact, inaccurate or untrue, or both. Every company in every line of business has a level of management where estimates are made and budgets are established. A person new to the company or new to the role of supervision may not have had any real exposure to the estimating and budget process. Every project is started by one person or group saying, "We should do this." However, the very next question from the boss, the company management, the backers, or the stockholders will be, "What will it cost?"

Why do we do estimates? We do estimates because we are asked how much a project will cost, and we need to establish a target. We do estimates because, if we do not, we will have no basis to control the costs on the project. We do estimates because there is no such thing as "one price fits all." Every project is different. The differences include everything from the client to the product, the geopolitical location, or the distance above sea level.

Lets look at Table 11-1 for a very simplistic comparison between two hypothetical projects.

For these projects, the differences are manifest in every aspect. They may be the same type of plant and have the same capacity. The plants have different clients in different countries. The process package development for the front-end package is different. The Project A job site is 690 feet above sea level versus 50 feet above sea level for Project B. For Project B, there is no fresh water available for cooling, so there will be an extensive use of Fin-Fan air coolers. Project B is a total grassroots project. Project A

Table 11-1
Typical Project Differences

Item	Project A	Project B
Plant type	Same	Same
Capacity	Same	Same
Feedstock and products	Same	Same
Client	Single entity	Multinational consortium
Job site	Tulsa, Oklahoma, USA	Middle East
Location	690 feet above sea level	50 feet above sea level
Process development	Client and engineering contractor	Licensor Y
Cooling water available	Yes	No
Utilities and tankage	Expand existing	Install new
Infrastructure (admin, maint, etc.)	In place	Install new
Shipping facilities	Modify existing	Install new
Project profile	E—(partial) P—CM	EPC Turnkey, self-perform construction w/ ex pat labor
Execution strategy	New work = 3D-PDS Revamp = modify exist 2D-CAD and some manual as required	3D-PDS w/maximum electronic document transfer

has some infrastructure in place but will require major revamp. Project A requires subcontracting and the development of construction work packages. Project A will require a site team to define the as-is condition of the existing areas and update the 2D-CAD files. Every project is different. Even projects for the same client in the same facility will have differences. It would be an invitation to disaster to start a project without a proper estimate. This means an estimate to do the actual work that will be required and that matches the project modifiers.

Many things can modify an estimate. An estimate will be impacted depending on the presence or absence of a modifier item and by the extent of that modifier. There may also be synergistic relationships in the modifier list that will tend to compound an effect. Here are a few items that should be considered.

Project size. You may have a very small project, a small project, a medium-sized project, a large project, or a megaproject. The size of the project in relationship to the dollar value of the project is a matter for interpretation by each company. The $50 million project classified as a small project for one company may be a megaproject for another. The new project that fits the size of the company's average project will normally not tax the capabilities of the current staff. The large projects and megaprojects will require a much longer project execution time frame and a different organizational structure.

Project type. Is this project a total grassroots project, a total revamp project, or a combination project? These possibilities make a difference to the planning process, the estimate, and the actual execution of the project.

Client involvement. Client involvement relates to the number of client people who will be directly involved in the piping, the extent they will be involved, the identification of a decision maker, and the availability and strength of the decision maker. There will be delays and added costs for a project that requires full (client) approval of all major aspects but does not provide a full-time (client piping) representative in your office. There will also be added cost to the project if a number of people provide conflicting input to no single decision maker.

Client specifications and standards. Using client specifications has a built-in delay and risk. Our client community is normally made up of operating companies. An operating company is in the business of producing

products at the lowest possible cost, not developing and maintaining specifications and standards. It is sometimes 10 or 20 years between major projects for a client. In that same time period the codes may have changed many, many times. When a client wants the project to use (only) their specifications and standards, there will be added costs to the project. Almost all of the major engineering firms have specifications and standards that are in compliance with industry codes and conventions. The engineering company is in the business of providing knowledge and service. For the company to stay in business, it must ensure that these specifications are in compliance with the current issue of the applicable codes. With the company specifications and standards, people on staff know where to find design data. The work can start earlier, the work will go faster, and there will be fewer mistakes.

Special materials, processes, or services The projects of today involve far more complex technology than in the past. Materials are reaching farther into the extremes of pressure, temperature, and corrosion. Processes are becoming more sophisticated and require special considerations for operation and maintenance. Projects that are lump sum, design-build may require services that were not previously part of the piping scope. Additional time may be needed to provide for research and training.

Licensor agreements. A licensor agreement is normally a contract between the client and the process licensor. The client has purchased the rights to a patented process from the process licensor company. A licensor agreement may have little or no impact on your work, or it can be a serious deterrent to productivity. Some licensor agreements have no effect of any kind on your day-to-day operation. Other licensor agreements could cause restrictions on your company. Your company may be required to institute procedures for printing and disseminating P&IDs. All licensor-related documents may require numbered copies with a restricted and controlled distribution. Changes to the P&IDs, even the correction of line sizes or spelling, will need approval of the licensor. You also need to recognize that this is a one-way street: You can't make changes, but the licensor can and will.

Government regulations. This is an area where making an assumption can be a serious mistake. All governments have agencies and departments, and all of these agencies and departments have regulations. The regulations of one agency (or department) may conflict with the regulations of another

agency (or department). Clients and company management tend to think that as long as they stay inside the property line, they will not have a problem with government regulations. This is simply not so. Even a public road or a rail line that traverses the project property will fall under Department of Transportation (DOT) regulations.

Units of measurement (imperial versus metric). This book will not argue for or against metrication. In the United States, we predominantly use the imperial unit (feet and inches) for measurements. A project that requires metric measurement units will require adjustments and procedures to catch mistakes caused by faulty interpolation.

Joint venture project. A joint venture project will normally be one of the very large or megaprojects. *Joint venture* means that two or more companies are involved in the engineering, procurement, and/or construction. One company is the prime contractor; the other companies are subcontractors. If you are a subcontractor, then you will normally be obligated to the prime contractor for some key elements and decisions. If you are the prime contractor, you will need to provide for communications and coordination with all subcontractors. You may also be required to assign a piping representative in the subcontractor's office.

Foreign purchase. This may affect only the bulk material (pipe, valves, and fittings) or some or all of the tagged equipment items and bulks. This could be a U.S. project with mostly domestic purchase and limited foreign purchase, or it could be a foreign project with both U.S. and foreign purchase. It could be a foreign project with all foreign purchase. These procurement plans will cause changes to your execution and, thus, your estimate.

Procurement participation. Procurement participation means the extent or depth that piping people will be required. This will vary from none to extensive. There may be a requirement to visit manufacturing plants or pipe fabrication shops to qualify them as potential bidders. There may be a requirement to assign a piper to a shop or module yard full-time to answer questions and report progress.

Material availability. Spending by the industry for new projects or revamp projects goes through peaks and valleys. When we are in a peak period, it has a positive and negative effect on engineering. The positive

effect, of course, is that we are not facing a layoff in the immediate future. The negative effect is the limited capacity of fab shops and mills. The availability of shop space and mill quantities causes a ripple effect into the engineering office. These factors may cause some activities to be done earlier and out of sequence.

Constructability plan (stick build versus module). The constructability plan can be all stick build, all module, or a combination of the two. The approach that must be taken to a module project is different from that for a stick build.

Personnel experience versus training. This is a very touchy subject, but it is one that cannot be ignored. If you take the preceding list of project modifiers and select the least extreme of each, you will have one picture. Consider the people who will likely be assigned to the project. They may well have all the skills required for the project. There may not need to be any consideration in the budget (or schedule) for training new skills. Now take the preceding list of project modifiers and select the most extreme condition of each. In this scenario, the project looks vastly different. Again, consider the people who will likely be assigned to the project. Do the people have the skills required to do this more complex project, or is there a need in the estimate (and schedule) for some training?

What is the difference between an estimate and a budget? Many people confuse the two terms. The dictionary definitions for these words are as follows:

Estimate: A judgment of size, number, quantity, value, etc., especially of something that needs calculation or assessment. An estimate can vary, according to context, from a rough guess to close determination.

Budget: A written statement of money: where it is drawn from, its amount, how it is spent, (also) to plan expenditure with a given amount of money.[1]

Here is one way to look at these two semirelated terms. First, both terms are guesses. They both relate to hypothetical numbers (hours or costs). The term *estimate* is "doer" oriented. The party (the doer) that is to do the work makes an estimate of how many hours they think it will take, how much material they think it will take, and what they think it will probably cost. Notice that these are all "they think" statements: They have not done this

[1]*The New Lexicon Webster's Dictionary of the English Language,* Deluxe Encyclopedic Edition, Copyright 1990.

actual work yet, so they are guessing. This (doer) estimating process will use applicable historical data collected over the years. It will also include knowledgeable input from experienced people have prudent contingencies to cover the potential unknowns that occur on every project. In the end, it is still just a guess. It is not the real cost.

The term *budget* is "payer" oriented. The party (the payer) who has ordered the work determines how much they are willing to pay for the project. They will do their own estimating to determine what each phase of the project should cost, including the engineering phase. They will do some price checking to determine what the major equipment and materials may cost and what the direct and indirect field costs may be. They will include such things as preliminary amounts for permitting fees, licensor fees, heavy equipment rentals, and third-party testing. Being prudent in their thought processes, they will include factors for what they think they should include for escalation and contingency. They will have determined what they think they should have to pay for the work. This is their budget. This is also just a guess. It is also not the real final cost.

The real cost of any process plant project is not known until the plant is finished and is successfully running in a full production mode. Billings, charges, and back-charges will continue for months after start-up, all of which change the final price. In some cases, the engineering company will never know the true cost of the project. The client just does not want that information to be public knowledge. Some project cost information is required for permitting fees and taxation exemptions. For these purposes, the client establishes and allows the release of a plant cost that is based on the guesses made in the estimate and budget process.

Awareness that the estimate and the budget are only educated guesses does not reduce the moral obligation of all members of the project team to do everything possible to hold down and control costs.

Remember,

no cost control—no projects (for your company),
no projects—no company,
no company—no job (for you),
no job—no salary,
no salary—no mortgage payment.

Every individual should be motivated at all times to look for ways to avoid adding extra cost, along with ways to improve the quality.

Lump sum versus cost-plus are the two basic and most often-used terms for the way clients contract engineering work. There are lump sum con-

tracts and cost-plus contracts. For the lump sum contract, the client has entered into a contract between themselves and your company on the basis of "When you do X work, we will pay you Y dollars." The contract will normally be payment for project, based on a negotiated compromise reached between the company estimate and the client budget.

For the cost-plus contract, the client has entered into a contract between themselves and your company on the basis of "We have agreed to what we think it will cost, but if it runs over then we will also pay the additional costs." This contract will normally be payment for work, and it is also based on a negotiated compromise reached between the company estimate and the client budget. The contract to execute the project was made between the client and your company. You and your people should recognize these realities about this contract:

- The contract was not made between the client and you.
- Regardless of the type of contract between the client and your company, there is a cost limit somewhere.

You and your people should strive to execute every project as if it were a lump sum project. You should function with this thought in mind: If you do not do everything you can to save money, it may affect you personally.

In chapter 10, we discussed the process of defining the scope of work. The process of estimating the labor to do that work is the next step. This step cannot be done properly without a scope of work definition. Estimating can be described as taking everything listed in the scope of facilities and scope of services and attaching a labor hour or material cost to it. This may be easier said than done. We have not yet done the job, so we do not know who will be assigned to the team. We do not have the P&IDs, and we do not have the actual equipment outlines or any actual buildings or structures. We do not have an exact count of the lines. We only have the guess we identified in the scope. In short, we do not have much. We may or may not have a historical base or records of past jobs. We may only have experience.

Take everything listed in the scope of facilities and scope of services and attach a labor hour or material cost to it. If you are new to this company or you have been in the background on previous jobs, you will not have a feel for how long it takes to do something. You will need to rely on the company data for estimating factors. If the company has not collected consistent data from past jobs, you will have a tough time doing an estimate. This possibility is very remote in this day and age. It would be extremely rare

to find a company that does not collect some kind of data on past jobs. These records are a starting point.

What kinds of records are kept? It is not possible for me to know what records are actually kept by every company. I can only suggest those records that could be collected to help in the preparation of the piping estimate. There is a risk to the business if your company does not collect data on every job in a consistent manner. The records of past jobs will talk to you as the PEL and to management. These records will show trends in the execution of the different projects for different clients. These records of past jobs should be collected and stored in a database system. The system must protect client-specific proprietary information but must allow searches and examination.

There are two levels of data collection. The first is the general project data; the second is the discipline-specific detail data. This detail data will be associated with piping-specific deliverables and activities.

The general project categories of information follow, along with how each might impact your next estimate.

Year of the project. It is important to know when each project was done. You can sort the projects by year. You can take data from numerous projects (of the same type) and look for trends, or you can take project data from specific years and look for relationships with other facts.

Project number. The project number will be an easy way to reference data in other files if the need arises.

Client name. This will allow for a sort of all past projects for this client. The client's name will need to be entered in a consistent manner every time, or there needs to be a "sounds like" search capability.

Project name. This will help when looking up a specific job from the past. Some people will remember the project name but will not remember the client. The project name is not to be confused with the project description. Many clients (and engineering companies) will give projects a code name for confidentiality. This code name may be a Greek letter or an animal name. It will not be in any way descriptive of the plant itself.

Project description. The project description should be a real description that relates to the actual plant. Names such as ammonia plant, crude unit, hydrocracker, polyethylene plant, VCM plant, and waste treatment plant

are descriptions that should be here. These also need to be consistent or there will be problems doing sorts.

Project type. The project types are grass roots, revamp, or combination. This may need to be a multientry field so that percentages of each category can be recorded (for example grass roots = 80 percent; revamp = 20 percent).

Project range. The project range will record the data relating to E, E&P, EPC, or EPCM. This will have a big impact on the hours in the current estimate.

Project scope. I do not suggest entering all this data from the full project scope here. That is just not reasonable. Scope data should include counts of key project factors. These factors would then be used to determine discipline-specific factors for deliverables. (Examples: Total P&ID count, total equipment count, total line count, total isometric count, total (piping) material cost, and total (piping) tunnage.)

Project TIC. The Total Installed Cost (TIC) of past projects is a factor worth knowing when doing an estimate of a new project. The data recorded may not be the actual final cost, but hopefully it is reasonably close. In some cases, this will be the only thing you will have as a starting point. The Client will say they are going to build a $200 million dollar grassroots plant. They want to be able to plan for the total installed cost.

Total equipment cost. The total equipment cost (and the equipment count) can be used to determine the average cost per piece of equipment. This same data can be used to help develop the TIC of a new project.

Total home office hours. The total home office hours include the home office engineering hours. They also include hours for nonengineering groups. It is important to know these two numbers, along with the project type and project range. The new project may not be the same type, or it may not have the same range of services.

Total engineering hours. The total home office engineering hours are important to collect. These hours can be used to do all types of comparisons, such as total engineering hours versus TIC or engineering hours versus total equipment count.

Total piping hours. The collection of accurate data from past projects on total piping hours is very important for the PEL. To have the total piping hours and the ability to do correlation with the other project data will allow you to do estimate comparisons. It will also give you the ability to defend your estimate in relationship to past projects.

Piping subgroup hours. Having actual piping subgroup hours from past projects will allow you to determine statistical averages for all jobs or for all jobs of a certain type. This is important to know when determining services to be included in the project range.

Line number count. The prime unit of measure of work and, therefore, hours will differ for each engineering discipline. For the equipment engineering group, it is mainly the equipment count. For the instrument (control systems) engineering group, it may be the instrument count or loops. For the piping engineering group, it is the line count. Some may say, "My company does not use line numbers." I recommend that you change the way you do things and start using line numbers now. Keep in mind that most of the current database-oriented design systems such as PDS or PDMS require some sort of identification method for pipe lines and extracted isometrics.

The preceding categories are not proprietary to any one company. It is not the secret list of the company I happen to work with at any given time. This is all generic data available within the company. This is a description of my own personal data collection list, which I have collected for many years. I do not use a sophisticated program to store or sort the data. I just use a simple spreadsheet file. It is very portable, and I can maintain it on my home computer. This file has been enhanced to add certain data columns and automatically extrapolate percentages that relate to piping deliverables. I would strongly suggest that you check with your department manager to determine what records are kept for your company's past projects. You may also check with the estimating department to see what they have on file. It would be extremely rare for a company not to collect and record general project statistical data.

The second level, the piping-specific detail data, is a bit harder to find. When we get to this level of data, we run into the proverbial "rock and a hard place." Upper management will resist the systematic collection of the data that is needed to answer the question they demand that we answer. Questions like "How many hours are required to do this?" are asked every day. When we try to set up a program to find out, management says it costs

too much. The information required (piping-specific detail data) is available every week throughout the life of a project. The concept of collecting discipline detail data is not my own, and it is not new. There have also been two very good papers published on this subject.

- Kerridge, A. E., "Collect useful engineering performance data," *Hydrocarbon Processing*, June 1996.
- Uppal, K. B., "Cost estimating made simple," *Hydrocarbon Processing*, September 1997.

The detailed piping-specific data that should be collected is the same as what will be estimated. It is the data that will indicate labor hours and costs for the activities and deliverables included in the scope of facilities and scope of services. After the data is collected, it should be identified to the piping subgroup activity or deliverable. The data should match your company estimate format and scheduling format. Every company should be able to collect actual labor data. The labor and cost data should match the deliverables normally developed for a project. Over a period of time, the database of information will grow. Through the process of averaging the hours by document category, the basic labor cost will be determined.

The collected data will indicate that a specific activity or type of deliverable took a given number of hours on a specific project. These numbers need to be divided by the number of that deliverable to find the units per hour for that project. Like data from all projects and projects of specific type should be merged. The data to merge is the quantity of each deliverable, along with the expended hours for each category. After the data is merged, you should know the statistical averages for each.

All of these deliverables and activities will not be required by every company or on every project. Some jobs will only require piping material engineering, piping design, and pipe stress. Therefore, there will be no material take-off or purchasing required. Just the same, your company should have the foresight to set up an all-encompassing data collection that will fit any project. After the data collection program has been set up and there have been a number of projects completed, the data should be made available for use.

Having all the general project and piping-specific statistical averages is not enough. You should never just use the raw numbers from the past. We have already made the point that no two jobs are the same. After you learn as much as you can about your new project, and you look at the past, you determine the number of hours you think this project will require for each

activity and deliverable. You may feel that the company statistical average is appropriate for this project, for a given deliverable. However, you should not blindly use only the statistical averages in all cases. Some activities will be much more simple, and some will be much more difficult. The statistical average is used as the default estimate value. Sometimes, it is wise to use another labor hour value for a specific deliverable. This number is called an *override.* An override can be any value greater or lesser than the default value. All estimating forms or electronic estimating programs should be capable of a fixed default value (based on the company statistical averages) for each line item, plus the ability to insert an override.

When do you use the default and when do you use an override? This is when you need to use experience and judgment. The experience can be your own, or it can come from other people. You will need to review what you know about the project, the project type, the project range, the scope, the execution plan, and the client. These factors may suggest to you that the project will be easy or will be more difficult. You will also need to make a judgment call about every aspect of your estimate. Don't be afraid to discuss your feelings with your department manager and the project manager. Don't forget to ask a peer (another PEL) to review your estimate. A peer will be looking at the project through eyes that are not emotionally involved. They may see things that you do not want to see or identify activities or deliverables that you have left out of your estimate. They may also be able to suggest new techniques that could reduce the hours. When developing an estimate, the following should be considered:

Piping Material Engineering

Specifications (standard). A standard specification is one that would be used on most projects. These specifications would have a prewritten shell that would require only minimal editing to make each client/project specific. The estimate for these specifications will require only minimal hours for the initial editing and minor maintenance throughout the life of the project.

Specifications (special). A special specification is unique and would not be used on the average project. These specifications would not have a prewritten shell. These will require total research and development. These specifications will require detailed reviews and editing to make each client/project specific. The estimate for these specifications will require a

much larger number of hours for the full development, editing, and maintenance throughout the life of the project.

Piping line list (originate and maintain). A piping line list may be generated in one of two basic methods. These two methods are both viable and could be required on the same project.

- The smart P&ID method. The line list is a deliverable as an output from a smart P&ID program. For this method to be done correctly and to be truly effective, the line list data development must be done at a much earlier stage. Line list data does not happen by itself. A smart P&ID is only an electronic drawing (collection of symbols) with the capabilities for storing certain data for specific symbols. If you do not populate all the data fields for the symbol, you will not receive the answer when you ask the question. If you do not input all the line list data at the time the P&ID is developed, you will not get a line list when you program the output. If this new project will be the first in your company to use smart P&IDs, then you would be wise to include some time for training and for recycle.
- The traditional method. The traditional method for developing a line list is as a stand-alone (manual or PC-related) document in parallel with the P&ID development. This method has been used for years by companies until the recent development of the smart P&ID systems. This method may still be used for a revamp project on older units where smart P&ID development would not be judged cost-effective. This method allows for later staffing and actual execution of the line list data development.

Project lists such as the line list, the equipment list, and the instrument list all have a synergistic relationship with the P&IDs. When the P&IDs are informally distributed or formally issued, the lists should be distributed/issued at the same time. These documents can and should be made to have the same revision for continuity. The estimate for the line list will require a large number of hours for the development, editing, and maintenance throughout the life of the project.

Piping specialty (SP) item list (originate and maintain). The piping SP list is a listing of the odd items that occur on every job. They are items that are not standard enough to be written into the individual line class specifications. A piping SP list may also be generated in one of the two methods described earlier. These two methods are both viable and could also be required on the same project. The estimate for the SP item list will require a

number of hours for the development, editing, and maintenance throughout the life of the project.

Specialty item data sheet. The process of properly defining a special piping component is multidiscipline related. An item is marked on a P&ID by the process engineer. At that time, they will not stop and fill out any specific paperwork. They are usually too busy with the main goal. Later, the piping material engineer (PME) will become aware of the presence of the need. The PME will initiate a request for the SP item data. This data can be in the form of a formal data sheet, or it can be the input of the required data to the appropriate fields of the smart P&ID. Whatever the methods, the result will be a document that can inform the design group, get them on the design, and initiate a RFQ for the SP item. The estimate for each SP item data sheet will require hours for the development and maintenance of each throughout the life of the project.

Specialty item (vendor catalog or certified drawings). Every SP item or nonstandard item to be purchased and used on the project will normally require documentation. The documentation will include the technical and dimensional data. This data should be reviewed (squad checked) by the PME, the design group, and the process engineer, when appropriate. The estimate for vendor drawing squad check will require appropriate hours for each. These hours are spread throughout the life of the project.

Piping commodity catalog (originate and maintain). The piping commodity catalog is a project-specific listing of the full purchase descriptions for all piping materials that will possibly be used. All computer systems are code number oriented. Code numbers convey complete identity with a minimum of digits. This is also true of piping material. Computer-oriented piping material requirements planning programs use item code numbers to reduce data storage and increase processing speed. Behind the code number is a full description of the item sufficient to allow for proper purchase. The piping commodity catalog is a printout of the project file. It will need to be checked like any other project document to ensure accuracy. The estimate for the commodity catalog will require hours for the development and maintenance throughout the life of the project.

Calculations. Calculations by the PME are normally required on all projects. They are required for pipe wall thickness, flange ratings, and for branch reinforcements. The ratio of required calculation to the TIC of the project is as good a way as any for estimating the quantity.

Reference database (3D geometry for electronic modeling). "All you need to do is sit down at the computer and go to work." That's what the slick sales pitch of the computer company wants you to believe, but it's not true. If you are going to execute your project in the 3D environment, then you must first populate the project piping database file. The database must be loaded with all the piping material by line class and by item code number with physical (dimensional) geometry. The estimate for reference database hours is for the development and maintenance throughout the life of the project. This activity may by included in the computer department budget at some companies.

Supervision. Every subgroup function will have supervision-related duties and responsibilities. These will include subgroup-specific tasks such as estimating, scheduling, planning, reporting, and coordinating meetings. A reasonable rule of thumb here would be 10 percent of the subgroup technical hours.

Piping Design

Some activities and deliverables in piping design may need to be expanded to the specific deliverables.

Specifications (standard). A standard specification is one that would be used on most projects. These specifications would have a prewritten shell that would require only minimal editing to make it client/project specific. The estimate for these specifications will require only hours for the initial editing and minor maintenance throughout the life of the project.

Specifications (special). A special specification is unique and would not be used on the average project. These specifications would not have a prewritten shell. These will require total research and development. These specifications will require detailed reviews and editing to make each client/project specific. The estimate for these specifications will require a much larger number of hours for the full development, editing, and maintenance throughout the life of the project.

Piping standards. A piping standard is one that would be used on most projects. These standards would be predrawn and would require only minimal editing to make them client/project specific. The estimate for standards should require only minimal hours for the initial composing, editing, and minor maintenance throughout the life of the project.

Plot plan(s). Plot plans themselves will come in at least three varieties. The scratch plot plan is developed for the grassroots project. The revamp project adds equipment to an existing facility. The standard plant plot plan is a proprietary process that includes a fixed layout. All of these may occur on the same project. The hours required in the estimate for plot plans is a function of the initial development, the various review/approval cycles, and the maintenance throughout the life of the project. The standard plant plot plan should take fewer hours, normally requiring only the title block additions to make it project and client specific. The revamp plot plan would need a slightly higher number of hours. The allowance here includes the hours required to confirm that the new equipment will actually fit, hours to update the graphics of the existing document, and time to manage the review and approval cycles. New unit plot plans require more work, more steps, and, therefore, the most hours. The process technology, the complexity of the site, and the number of approval levels, among other factors, will all add hours to the plot plan for a new unit.

Piping transposition or piping one lines. A piping transposition is a document or tool primarily used by piping to prove the plot plan. Transpositions can be developed manually, in 2D-CAD, or by an electronic pipe router program. The transposition also has a number of side benefits that will aid the piping effort and bring value to the overall project. These benefits include the following:

- Identifies the routing of the most critical lines
- Identifies the heaviest concentration of lines
- Aids in the sizing of the pipeway widths
- Identifies the location of key control points
- Provides the basis for an early preliminary material take-off
- Provides the basis for the major equipment piping layout studies and vessel orientation

Transpositions will not be required on all projects. The standard plant developed by some companies would not require one. The revamp project that is adding only a few pieces of equipment in client-defined locations also would not require one. The choice of the utilization of a transposition is on a project-by-project basis. The hours required in the estimate for piping transposition is a function of the initial development, the various review/approval cycles, and the maintenance throughout the life of the project.

Major equipment piping layout studies. *Major equipment* is another relative term. What may be considered major equipment by one company may be minor to another. For our purpose, *major* relates to those one or two pieces of equipment that are unique to the project or the company. We do not have major equipment on every project, and if we make a mistake, it could be the deal breaker for the project. The hours required in the estimate for the major equipment piping layout studies is a function of the number, type, complexity of the equipment, the initial layout development, and any review/approval cycles.

Vessel orientations. The vessel orientations are another critical item to the project. We are not talking here about the simple pots-and-pans-type vessel. We are talking about the large and very large vertical and horizontal process plant vessels. These are the complex reactors, the multitray fractionation columns, and the critical feed surge or accumulator drums found in refineries and chemical plants. These vessels require the expertise of a knowledgeable senior piping designer to determine the orientation of the internals, the placement of the nozzles, the routing and supporting of the external piping, and the arrangement and placement of the platforms and access ladders. The hours required in the estimate for the vessel orientation activities is a function of the number, type, complexity of the vessels, the initial orientation development, and any review/approval cycles.

Plant equipment location control plan (equipment general arrangement plan). Some people refer to this document as the LCP (location control plan), and some refer to this as the GA (general arrangement). Regardless of what it is called, this document should be considered the most important and most critical of all the project documents. It is the primary location-defining document for the early part of the project. This document has a limited useful life and will go out of business as other documents are produced and issued. One of these documents will be required for each process unit, utility area, tank farm area, and off-site area. The hours required in the estimate for the LCP/GA activity is a function of the number of plant areas in the project. The hours required will consider the number of actual documents, the content of each, the initial development, the required review/approval cycles, and the ongoing maintenance throughout the life of each document.

Indexes, design model index (3D plant design), piping drawing index. Index drawings are sometimes considered unimportant, unnecessary,

and a waste of hours/cost. The people who normally promote this idea are not the people who really need them. Index drawings are made for the people in the field. Indexes are intended as a road map for the use of the construction manager and the contractors. Index drawings are a low-cost item and simple to develop. The hours in the estimate should reflect a minimal effort for the initial development, the required review/approval cycles, and the ongoing maintenance throughout the life of each document.

Design development. The hours required in an estimate for design development will vary depending on the project execution method. The project may be executed totally in one of the current 3D-PDS formats, totally in a current 2D-CAD format, all manual design, or some combination of these. The procedure used to estimate labor hours for 3D-PDS work is different than for 2D-CAD and manual work.

Estimating the hours for design development for a 3D-PDS project is based on a labor hour factor for model creation by object type and category.

Example:

- Equipment creation, simple = 5 hours/item
- Equipment creation, moderate = 8 hours/item
- Equipment creation, complex = 12 hours/item
- Equipment creation, very complex = 20 to 60 hours/item
- Piping creation = 8 to 10 hours/line
- Interference detection check (3D-PDS only) = 8 hours/report

The hours shown for the equipment creation include a number of tasks making up the whole activity. These include the review and check of the supplies drawing (also known as vendor drawing squad check), the task of actual input, and the audit or verification of the input.

At the time you do your estimate, you and the rest of the project will not know which equipment type will be specified or which vendor will be the successful bidder for that type of equipment. With this in mind, you must structure your estimate on the conservative side. What I mean by this is figure the full number of hours for each piece of equipment. Later, project hours may be able to be reduced, if equipment vendors supply electronic models of their equipment in a format that is compatible with your project's operating system. The project can also save hours if the company has an electronic library of equipment models that can be used over again. There is a risk involved here. You may not need to create the complete model, but you will need to check all imported models for dimensional accuracy.

Estimating design development labor hours for both the 2D-CAD method and the manual method of execution is about the same. The most common method is the hours per square foot of finished drawing area. The actual figure you should use needs to be based on the company's historical averages for similar work. The hours per square foot for drawings is influenced by both the complexity of the equipment and the relative congestion of the piping (See Table 11-2).

The hours per square foot of drawing space are for a multi-task activity. The hours include the following tasks: equipment drawing squad check, inter-discipline drawing squad check (structural, etc.), design drawing creation, drawing checking, and drawing correction.

Piping plan drawings. The hours to be included in an estimate for piping plan drawings will vary depending on the method project execution method. Piping drawings may not be a deliverable from a 3D-PDS project. The field and the client may have a PDS terminal and be able to view the model. However, if drawings are required (from a 3D project), each drawing could require as much as 8 hours to download the drawing, proof it, and apply required annotations and titles.

The 2D-CAD project drawings will also need to be extracted from the design model and plotted on the project title block. These drawings need to be checked for accuracy and continuity before issue.

In today's environment, the making of manual piping drawings would be rare. It would normally be limited to the isolated revamp project where a client wants the existing record drawings brought up to date. The hours estimated for each drawing will need to include all the tasks required for the activity. The estimated hours will depend on the condition of the original drawings, the type of equipment being added, the complexity of the new piping, and the real world conditions at the site.

Table 11-2
Hours Per Square Foot of Drawing Area

	Piping Congestion		
Equipment complexity	**Simple**	**Moderate**	**Complex**
Simple	20	26	32
Moderate	28	34	40
Complex	36	44	52
Very complex	48	56	64

(Number = hours per square foot of drawing area)

Piping isometric drawings. The hours included in an estimate for piping isometric drawings will also vary depending on the project execution method. Piping isometrics from a 3D-PDS project will be based on the expected number of finished line numbers times a factor for sheets per line number. Then an estimated number of hours (anywhere from 1 to 3 hours) to extract, review, annotate, and handle each isometric.

The 2D-CAD piping isometric and the manual piping isometric require about the same number of activity labor hours. The piping designer does the same tasks for each isometric; he or she just uses a different type of drafting machine. First the isometric is drawn, and then the isometric is checked and corrected (sometimes called back fixed). Some isometrics, due to the material or other factors, will need second checks as a form of quality control. This adds more hours. Hours also need to be added to handle, process, and control all the isometrics. The end result could be a labor hour estimate factor of anywhere from 8 hours (for simple piping isometrics) up to 15 hours or more (for complex configurations, large diameter, or high cost alloy piping isometrics). Again you should try to determine the company statistical averages from actual past projects.

Piping isometric log (originate and maintain). The piping isometric log or isometric production tracking log or isotrak is nothing more than a spreadsheet (or other) program to list and track the development of each isometric. If the project deliverables do not include isometrics, then this item in not required. If the project deliverables do include isometrics, then this should not be an optional item or a negotiable issue. This is the most important control tool for the piping design lead on an isometric project. The hours required for this will depend primarily on the project execution method. Manual and 2D-CAD isometrics will require a longer tracking life, so the estimated hours may be as much as 1 hour per isometric. Isometrics generated from 3D-PDS projects will have a shorter tracking life, so the estimated hours may be as little as ½ hour per isometric.

Revamp documentation. This is a tough area to address. Not many companies keep good records for their revamp project documentation. A revamp project is not glamorous and is not normally the core business for the engineering and construction firm. Here are some guidelines based on my experience.

- Demolition drawings. Count the actual drawings and use a factor of 8 hours per drawing. These hours will include the walkdown to verify the lines

in the field, the markup of the old tracing, and some normal handling of the odd revision or two.

- Tie-in list (originate and maintain, including hanging tags in the field). The estimated hours for tie-ins is a function of the number of tie-ins, the client's procedure for tie-point location and approval, the actual making and hanging of the tie-in tags, plus developing and maintaining the tie-in list, itself. It is not unusual to spend upwards of 8 hours per tie-in.
- Tie-in location index (drawing). This is an item that would not be required on every project. This item has value on a project that has tie-ins that are spread over the total plant. To generate a tie-in location index, one should use the simplest method available (plot plan overlay of xref). The number of hours may be as few as 10 hours per drawing. The real payout to the client is in the savings in the field.
- Tie-in isometrics. Tie-in isometrics may or may not be required on your project. They may be required because tie-ins are "hot tap" connections to lines in service or because two construction work package time windows (one for the shutdown with tie-ins only and a second for all other piping) create multiple subcontractor responsibility. If neither of these conditions apply, then don't feel that you need to create tie-in isometrics. Because you do have tie-ins is not justification for making tie-in isometrics. The hours required in the estimate for true tie-in isometrics will be the same if not greater than a standard isometric.

Heat tracing is a complex subject. There is a number of reasons why heat tracing is required for a process plant project. There is tracing for process system integrity or for winterization. There are also a number of commodities that are used for the heat medium (such as steam, hot oil, hot water, glycol, and chilled water). There is also a number of mechanical methods used to apply the heat tracing. There are at least three ways the tracing design effort can be done (by the engineering company responsible for the overall project, a third party specialty heat tracing design company, or by the construction sub-contractor). There is a right time to do the tracing design work. Finally, there is the Heat Tracing Documentation.

- Heat tracing details: Use standard details (less labor-intensive)
- Manifold index: Prepare a spreadsheet index of all supply-and-return manifolds. These will assist the designers with system design, the field contractor with installation, and the client with operator training.
- Heat tracing isometrics: On isometric projects, use only approved and issued piping isometrics for this purpose.

- Heat tracing plans: On non-isometric projects use only approved and issued piping plans and sections.

Piping Design Stress Documentation

Piping design stress log. Each area or unit supervisor on the project should develop and maintain a design stress log. Unless this is done and done properly, there is no way to know if all the required lines actually were analyzed by the stress group. The factor to use would be .25 hours times the number of lines that actually will be stress analyzed. Not all lines on this project or any other will actually require stress analysis.

Calculations (deadweight loads for structures). This is not an extra item. The hours for this are (or should be) included in the design development or layout hours.

Stress sketches. Hours for the stress sketch activity should be based on the estimated number of actual lines that will require stress analysis times a factor for preparation and handling.

Piping Material Sketches

It is important to estimate the number of sketches required. Sketches will normally be required for all large diameter lines (24 inches and larger), all alloy lines, and all special construction lines. Use a factor of 1.5 hours (minimum) for each material sketch, estimating one hour to draw the sketch and one-half hour to track and maintain each sketch.

Final Electronic Database Transfer

This is not a problem isolated to only the piping discipline on the project. There is also no consistency in the requirement or method for doing this activity or for estimating the labor hours required. The best approach is to make sure the project manager has this issue as a line item in the overall project estimate.

Supervision. This is the time required for the piping design lead supervisor. It may also include some hours to be prorated to the area or unit supervisors for nontechnical duties. A good rule of thumb for this is to add 10 percent of the piping design technical hours as supervision.

Piping Material Control

Specifications (standard). The piping material control function may or may not develop any specifications at your company. However, if they do, a standard specification shell should be used on most projects. These specifications would require only minimal editing to make it client/project specific. The estimate for these specifications will require only hours for the initial editing and minor maintenance throughout the life of the project.

- Commodity purchase specifications (pipe, fittings, flanges, and so forth). The information in these specifications may also be prepared and issued as purchase order technical notes.
- Field receiving geographic color code

The bulk of the hours for piping material control will be limited to one or more of these three main work functions. The extent of these work functions will depend on the scope of services required or agreed on for the project. The three main work functions include the take-off of the piping material, piping material requisition and procurement, and field material status and control.

Piping material take-off may include three passes throughout the life of the project (preliminary, intermediate, and final). Depending on the technology and the methods used there may be 1 to 3 hours for each line number on the project. Piping material requisition and procurement activities will be based on the number of requisitions and purchase orders. It would not be unusual to allow 20 hours for each requisition and purchase order. Field material status and control is normally a reporting activity and can be handled as a part of the supervisor's duties. Some projects may, however, require more extensive support for field material control. This could include job site assignments for someone to handle material receiving reporting, material allocation control along with material shortage, overage, and damage reports. The estimate for this last item would be a simple duration factor (number of weeks required times the planned hours per workday).

Pipe Stress Engineering

Specifications (standard). A standard stress specification is one that would be used on most projects. These specifications would have a prewritten shell that would require only minimal editing to make each

client/project specific. The estimate for these specifications will require only minimal hours for the initial editing and minor maintenance throughout the life of the project.

Specifications (special). A special stress specification is unique and would not be used on the average project. These specifications would not have a prewritten shell. These will require total research and development. These specifications will requires detailed reviews and editing to make each client/project specific. The estimate for these specifications will require a much larger number of hours for the full development, editing, and maintenance throughout the life of the project.

Data Sheet(s)

Engineered spring supports and engineered expansion joints. Most of the hours leading up to defining the need for one of these items will be accounted for in the pipeline analysis category. You and the stress engineer need to make a reasonable prediction of quantity and then use a reasonable or historical basis for the hours per item. The hours will need to account for all of the handling requirements, also. Data sheet handling requirements may include the following:

- Initiate the data sheet and complete all technical information.
- Create a dimensional drawing of item or select dimensioned cut sheet from vendor catalog.
- Route data sheet and drawing to piping design (and others) for squad check.
- Modify data sheet and drawing for comments, as required.
- Prepare RFQ package complete with all applicable specifications and attachments.
- Complete procurement interface activities.

Drawings, preengineered pipe support elements. Pipe support elements (anchors, base supports, field supports, guides, rod hangers) that have been preengineered and packaged allow a company to be more cost-effective in executing that part of a project. It will also raise the quality of the design while improving the level of safety for the finished plant. Every company should have its own "canned" set or package of these devices. These canned sets also have the required calculations to back them up, proving they are fit for purpose. With the right canned package, a project should need only 10 to 15 hours to prepare a complete standard project is-

sue. However, if the client requests something different from the company canned package, the hours will go up dramatically. Each type of new device and size permutation of that device is required to have a set of calculations to back it up.

Piping flexibility analysis log. This is a minor item as far as labor hour requirements are concerned. It is, however, an item that is a project retention file item and, therefore, should not be overlooked. Every line on the project designated for analysis (informal or formal) by the pipe stress engineer will be controlled. The stress logs used by any two companies will differ, but they should cover the same basic control categories. The hours to create, maintain, and archive the stress log may be as little as .25 hours per entry.

Piping flexibility analysis. There are two methods for estimating hours for this category. One (Method A) works well and is suitable for proposal estimates and very early project estimates. The second (Method B) is more accurate and should be used whenever possible.

- Method A. Make an estimate of the total number of lines on the project. Multiply the total line count by a factor (total stress hours divided by total line count) based on data from past projects.
- Method B. Make a count of the actual lines on the project that fit the requirements for stress analysis. Multiply the actual stress line count by actual stress hour (required per line) based on data from past projects.

Supervision. These will include subgroup-specific tasks such as estimating, scheduling, planning, reporting, and coordinating meetings. A reasonable rule of thumb here would be 10 percent of the subgroup technical hours.

Piping Engineering Lead

There are at least three ways to compile an estimate for the PEL hours. One way (the easy way) is to determine the duration of the project in weeks and then simply multiply by the hours in the normal workweek. If the project is anticipated to be a 52-week project and there are 40 hours in the standard workweek, then there will be 2,080 hours for the PEL. With this method, all the estimated hours might be put under the catchall "PEL Supervision and Administrative Duties." This first method assumes that the PEL will be assigned full-time to only this project. This method might also be used when doing a rough order of magnitude (ROM) estimate for a new proposal.

The second method is required when the PEL will not be assigned full-time to only one specific project. The PEL estimate for this scenario requires the determination of the actual level of activity commitment to the specific project. The specific list of PEL duties and responsibilities for each project will need to be considered individually. The list of responsibility items and the hours for each will need to be defined. This method is more difficult but may be necessary for small projects or where there are limited PEL resources. In this method, the hours for all projects should not add up to more than 40 hours in one workweek. When the total hours of all projects add up to more than 40 hours in one workweek, then other options will need to be evaluated. The options to consider include the following:

- Reshuffle some of the activities to level the hours
- Delegate some of the actual work to others
- Use an extended workweek (overtime)
- Combination of all of the preceding

The third method is a combination of the previous two. First, look at the project from the duration standpoint (the first method). This is will determine a first rough cut at the number of hours. Then divide the hours among the actual duties and responsibilities for the project.

- Example: 6-month duration (26 weeks × 40 hours per week = 1,040 hours)
- Activity hours add up to 1,200 hours.

If you run out of labor hours (based on the calendar) before you have filled all the labor activity hour boxes, then you will need to determine the reason. The reason may be any one of the following:

- The project is a short duration project with full services. Revisit your scope of services. You may have included services that were not required for this project.
- You may have allocated too many hours for some or all of the activities. Consider execution methods as a way of trimming activity hours to a more realistic number.
- The project is a full-services project that does not seem to match the initial schedule. Push the project scheduling team for a more realistic schedule.
- More work is required for this project than one person can do within the scheduled project time. You will need to delegate some of the actual PEL work to others. Some duties you simply cannot delegate to

others. These must be done by you (for example, performance reviews). There are, however, some activities that could be assigned to someone else (for example, subcontract package development). Delegating work to others has a positive side. The PEL who delegates some technical work will free up their own time. They will also aid the development of a subordinate.

PEL activities may include but are not limited to the following:

Project Interface Coordination

Client Meetings. Depending on the company, the client, and the project manager, this requirement can be minimal or extensive. In general, the PEL may need to plan on at least one formal client meeting per month. Client meetings will have any and all subjects on the agenda. If the meeting is in-house, then you should plan on one full day. This would include any special preparation time before the meeting, the actual meeting time, and then follow-up time to answer questions and initiate changes. If the meeting is at the job site or at the client's offices (not in-house), then the required travel time needs to be added to the time estimated.

Project manager meetings. Ask the project manager what the meeting schedule will be for the project. Project manager meetings will tend to cover the nontechnical issues relating to cost, schedule, procurement status, and overall engineering progress status. Don't forget the pre-meeting preparation time and the post-meeting follow through.

Engineering coordination (interdiscipline) meetings. You need to take a hard look at the type of project and talk to the engineering manager. It would not be unusual to have engineering coordination meetings once a week. Due to the subject matter of these meetings and their frequency, there is normally less pre-meeting prep time and post-meeting follow-up requirements.

Engineering and design reviews. These meetings are ad hoc meetings that will occur for specific purposes at specific times in the project lifetime. A list of these meetings should have been in your scope of services and approved by the project manager. Typical meetings and hours are suggested here:

Scope of work review	= One or more all-day sessions
Project labor estimate review	= One or more all-day sessions per iteration
Project schedule review	= One or more all-day sessions per iteration
Unit P&ID review	= One week per unit
Overall plot plan review	= Half day (+/−)
Unit or area plot plan review	= Half day (+/−)
Critical equipment design review	= Half day to full day (+/−)
Periodic unit progress design reviews	= Number required/All day/ per unit

Discipline Control Activities

Front-end planning. This will include the time and the activities required to collect and read everything there is to know about the job, discuss the job execution philosophy with your department manager, arrange interim space, move, develop a preliminary organization chart, and set up job files.

The following items are not onetime activity events. These are ongoing activities that require attention throughout the life of the project. The number of hours for each should reflect the initial development and the ongoing maintenance.

- Scope development and maintenance. Two-thirds of the hours here are used to develop the initial scope document; the final one-third is for maintenance.
- Estimate development and maintenance. One-half of the hours here are used to develop the initial estimate document; the other half is for maintenance.
- Schedule development and maintenance. One-third of the hours here are used to develop the initial schedule document; the final two-thirds is for maintenance.
- Progress measurement and reporting. Be careful about double-dipping here. If you have already put hours in the project manager meetings for reporting, do not add that time again here. The time to be included here is the time it takes to collect data from your group leads and update the project's periodic status report. The hours here should not be more than 1 hour (average) per week for each week of the project.
- Change management. This is where knowing your client and the type of project will be important. Some clients and some projects will have a low probability of change, and others will have a very high rate of change. The

average change request or change notice can take as much as 2 hours of your time to handle. Let's say that there are 25 P&IDs on the job. During the life of the project, there are 10 proposed changes per each P&ID. This means that 250 changes will need to be managed. These 250 changes could result in 500 extra hours of PEL time. This does not include the hours to actually make the changes by the piping technical subgroups.

Subcontractor bid package development. You should have a count of the planned construction work packages listed in the scope of services. Even with the number, you will need to discuss the actual approach with the project manager. The hours in the estimate for this item will be a function of the number required and the following:

- Does the company or the project have a bid package document shell that can be used as a starter?
- Will the contract(s) be lump sum or unit price?
- What is the extent of company involvement? Is the company (and you) responsible for the initial draft only? Is the company (and you) responsible for full subcontract administration for the life of the contract?

Procurement support activities. You should also have a count of the planned purchase order packages listed in the scope of services. The PEL hours will be minimal to cover coordination internally among the various piping groups and externally with project, the client, and procurement. This is another place where people tend to underrate the true requirement. Review the requirements in chapter 7 to generate and manage a purchase order.

Client coordination trips. Do not confuse this item with the client management meetings listed for project status. This item (client coordination trips) includes hours for meetings at the job site or central office. The hours here should include travel time, actual meeting time, and follow-up time.

Vendor coordination trips. You (or some of your people) may need to visit the pipe fabrication shop or one of the actual piping material vendors. The hours here should include travel time, actual meeting time, and follow-up time.

Job-site data collection trips. If the project is a total grassroots job, then this may not be an important issue. If the project a revamp or a grassroots addition, you need to visit the job site to have a firsthand visual picture of

the facility. Your people may also need to visit the job site to accomplish specific job-related tasks. An example may be to verify the as-built status of existing drawings. The hours here should include travel time, actual meeting time, and follow-up time.

Construction coordination and support. Construction coordination and support (by engineering) time is sometimes included in the engineering side of the project estimate and sometimes in the construction side. The placement of the labor and cost will normally depend on who is doing the construction management. You need to obtain direction from the project manager.

Quality control activities (ISO 9001). More and more companies are moving to be ISO 9001 certified. If your company is ISO 9001 certified, then you will be required to prepare the proper documentation to meet the ISO criteria. If your company is ISO 9001 certified, your project may also be subject to one or more audits during the course of the project. The hours here will need to include the documentation development and maintenance time, plus the time for one or more audits.

Discipline safety training. You and the rest of project will need to get the specific requirements from the client and the job site for this item. Project-specific safety training may include some or all of the following:

- Drug testing
- Client's general safety orientation
- Job-site-specific safety video/badging
- Special H2S training
- Respirator training (which normally requires medical release from personal doctor)

These items can easily use 8 hours per person. If the project extends beyond 1 calendar year, you may need to renew all training and testing items. Travel time to and from the specific training center location may also be required.

Discipline technical aide. With the large, very large, or megaproject, I strongly recommend that you include a technical aide (TA) on your staff. A skilled and experienced TA can do all the filing of correspondence and technical data; all the tracking of deliverables during the production phase; and all the routine duties required to determine periodic status. The TA may

not be required full-time and may be shared with another project during the off times.

PEL supervision and administrative duties. This is a mandatory part of your job. This is the time required for MBWA (management by walk-around), the time you are really doing supervision. This is also the time for performance appraisals and any potential problem resolution.

Department management prorate. This is the time allocated for your department manager for visits to the project. This is an important project; the client, the project manager, and you deserve and should expect some level of attention from the piping department manager. The estimate and the final budget should recognize this and include hours for it.

Your next step will be to take your company estimating forms and do a preliminary estimate. You are not expected to get it right the first time. Review the project scope of services for the required activities and deliverables. Enter the quantity of each required deliverable in the appropriate box on the form. If you are using a smart electronic form, the program will use the default values for each deliverable, and you will have a preliminary estimate. As you review this first pass at an estimate, you may identify some deliverables that could require more or fewer hours. For these deliverables, enter an appropriate number of hours in an override column. The review process should continue through each of the activities and deliverables until you feel you have a realistic estimate.

What about labor grades? Every company has different labor grades in every department. If they did not, then everyone would be making the same salary. We all know this is not true. We have some people who are newcomers, and we have some people who are considered "old-timers." The entry-level newcomer and the old-timer do not make the same money. Labor grades are blocs of salary ranges. Each labor grade will relate to a salary range that has a bottom end, a mid-range point, and a top end.

Why do we need to estimate labor grades? There are a number of reasons depending on the company staffing profile. A small company doing a project with a fixed staff, all having the same salary level, may not need to do it. A large company doing a project with a fluid staff having various salary levels would need to consider it. The term *fluid staff* means that people with different skill levels and salary levels will move on and off the project, as needed. If this is the case, you and the project manager need to know how long each level will be chargeable. To determine how long each level will be on the job, you need to know what each function is; when that

function is required; and what the classifications are. The piping department manager will need to be involved in this phase of the estimate. Do you need to know everyone's salary to do a labor grade estimate? No, you are estimating the labor grades, only.

Let's say that the piping department at your company has 10 labor grades. They are designated as *T* (for technical); levels 1 through 10 (10 being the highest); *N* (for nonexempt); and *E* (for exempt). The nonexempt and exempt categories relate to the time-and-a-half versus straight time for overtime. Labor grades T-1 through T-7 are *N* classifications, with T-8, T-9, and T-10 being *E* classifications. For our purpose, we will assume that you are a T-10E labor grade.

The piping work effort will be made up of various combinations of people with different labor grades during the different project phases. Some of the project activities require the input of the top technical talent—therefore, the top labor grade. Most of the project activities can be done with mid-range or lower labor grades. With this in mind, project management could do one of the following:

- Price the piping labor estimate based on the assumption that all of the people assigned will be T-1N. If this is done, the company will be losing money, because some of the hours will be used by people of much higher labor grades.
- Price the piping labor estimate based on the assumption that all of the people assigned will be T-10E. If this is done, the company may end up losing the bid, because some of the hours will be used by people of much lower labor grades.
- Price the piping labor estimate based on a realistic projection of the number of hours to be used in each project phase by the logical labor grades for that activity. If this is done, the company will be less likely to lose money or the bid, because the estimate is based on factual labor grades.

Labor hours in an estimate are priced by including the direct salary, the salary burdens (federal and state mandates), overhead, services, fees, and profit. The actual pricing of the estimate is the responsibility of the project and company management. It is not your responsibility as the PEL. You do need to give them your best evaluation of who (labor grade) and how (what number and when) you intend to use the hours by project phase and by group. This is important to both the company and the client, because it contributes to the projected project cash flow.

12

Scheduling

This chapter will discuss the importance of scheduling and make some suggestions on how to develop a piping discipline detail schedule.

Experience has taught us that, if a schedule is not made for complex projects, then something very costly is going to be missed, and the recovery will have a cost factor increase of two or three times normal. That should be reason enough to justify schedules. A second and equally important reason for preparing schedules is communication. You need to communicate as you perform your activities and produce your deliverables. You must also understand that the client and your company management also have a deliverable: the project. The project is made up of the many deliverables from many disciplines. Both the client and the company management want to be confident that you know what you're doing and that the many deliverables you are responsible for will fit the needs of the other disciplines and the overall project effort. Properly prepared schedules, defining the proper level of detail, will provide that communication and confidence.

Various types of schedules may be prepared for a process plant project depending on the scope of work. A schedule will have been developed by the client months or years ahead during their own project justification phase. The client's project justification schedule is potentially a very important document. This schedule may be significant because it includes milestone dates for the contracted delivery of the plant's products. Clients risk hundreds of millions of dollars on a new plant project. They do not take this risk without a plan, and a milestone schedule is a part of the overall plan. Key parts of this schedule would be shared with the potential bidders

through the invitation to bid and the proposal criteria. Each of the bidders would normally include a schedule in their proposal response.

After the project is awarded, there will be a number of project-specific schedules. Why are there so many different schedules? That's simple: There is actually only one schedule with levels of detail and reports for different users. There is a specific level of detail and type of report for each specific level of users. Each schedule level has an owner/user and a purpose. Each schedule level must roll up to the next higher level, and each schedule level must be compatible laterally with other disciplines. The lower down the schedule/report scale you go, the more the detail you will see. A single line item bar on a higher level schedule may 50 line items on the next level down.

Schedules, the owner(s), and their purpose may include the following:

Project justification schedule (clients). This schedule would have been made by the client at the conceptual stage of the project. This schedule may have included only a few lines to indicate a cost justification analysis period, the contractor selection period, the detailed engineering period, the procurement period, the construction period, and the start-up period.

Master project schedule (company project management and client). This schedule will be very close to the client's project justification schedule. It will be updated as required to make it current with the signing of the contract. It may also be updated for any agreed-to realities impacting the project. Typical master project schedule may be displayed on a single 8½″ × 11″ printout. This schedule may only have three or four major activity bars and only five to ten critical milestones.

Project management schedule (project manager). This schedule will take the master project schedule and break it down into project phases with 40 or 50 activity bars of more definitive detail. This schedule will include key roll-up bars for engineering, procurement, and construction. This schedule will have one bar each for the engineering disciplines.

Project engineering schedule (project manager and engineering manager). This schedule will take each of the engineering disciplines and break their work into each major activity level. The engineering manager and the discipline leads will adjust this schedule so that all the feeder/supplier activities are compatible.

Discipline detail schedules (DDS), (engineering manager and discipline leads). This schedule will be used by the discipline leads to break down the discipline work activities to the task level. This task level is where the actual work is done. This is where the production of the deliverables will be visible and where the required staffing resources are identified. This is the primary scheduling tool for the PEL.

Project procurement schedule (project manager and procurement manager). This schedule will be used by the procurement manager to plan all the activities required to obtain equipment and materials and get them to the job site. This schedule will normally show RFQ, bid closing, purchase order, vendor drawing submittal, manufacturing/fabrication, inspection, testing, shipping, and receipt at job site. Disciplines have a key role in the development of this schedule.

Project master construction schedule (project manager and construction manager). This schedule will be used by the construction manager for overall planning of the field effort. This schedule will start with the issue of construction work packages by engineering. This schedule will include many work activities and many subcontracts. In addition to actual construction activities, this schedule will identify important issues such as permitting and unit shutdown periods.

Contractor's construction schedule (construction manager and subcontractor). These schedules will be prepared by the subcontractors to plan their work activities. The construction manager will use these schedules to ensure that the contractor stays on schedule and to coordinate work in the same areas.

From this brief description, I hope to instill the importance of schedules without scaring anyone off. Schedules are very important. They are a part of the planning process and the control process, and they are a living document (or electronic program) that will help everyone, including the PEL. The schedule must be prepared accurately and be used properly, and it must be maintained. What is included in the process of scheduling?

The piping discipline detail schedule (DDS) needs to include all the major work activities for each of the piping subgroups. It needs include the hours for each category of deliverables. (See Appendix A for a listing of typical piping deliverables that may be required on a project.) All of the activities of each piping subgroup must be compatible with each other, and they must also support the activities of disciplines outside of piping.

One of the most important aspects of an engineering project is the import/export concept. The import/export concept means that you sometimes will import information from outside your group, and sometimes your group will export information to others. These imports and exports are in the form of project developmental documents or formal project deliverables. Your piping group will import P&IDs from the process group. Your piping design group will export conceptual layouts to the structural group. The timing of these import/exports must be known and scheduled. What is required to start the scheduling process? There are six key elements to building a discipline schedule.

- First, have the right scheduling tool or system.
- Second, have a scope of work with a definitive scope of facilities and scope of services.
- Third, have an approved labor hour budget.
- Fourth, have the time frame of the overall project with as many of the key milestones as possible.
- Fifth, have a good understanding of the import/export concept.
- Sixth, get the piping subgroup leads involved in the development process.

The scheduling tool. The choice of the tool or system to use for scheduling is broad. Many scheduling programs are on the market. Each will have good points and bad points. However, as the piping lead, you should not buy one of these programs on your own. The scheduling tool you use must be compatible with the rest of the project and company. The segment of the scheduling tool directly used by piping needs to be formatted to fit the piping discipline. The scheduling tool needs to be calendar-date oriented to match the rest of the project and needs built-in formulas and roll-ups to automate the use. Whatever tool or system is used, keep it simple. Schedules change, and they need to be maintained. If the scheduling tool is too complex, then you are faced with a maintenance nightmare. You will stop maintaining it because it takes too much time.

Schedule scope. The schedule must reflect all the work by area, activity, and task. This is required to satisfy what is defined in the scope of work. Typically, this includes the breaking down of the project to geographic areas or units. It will include a definition of the type of work required, such as field as-built work or tie-in definition on a revamp project to the production and issue of fabrication isometrics.

Have an approved budget. The ideal time to develop the DDS is after the labor hour budget has been approved. It is possible to develop a schedule based on the discipline estimate. This should only be done with direction from the project manager. Project staffing and space planning could drive an impending need for discipline-level schedules before the budgets are approved. When schedules are developed prematurely using unapproved labor estimates, there is an automatic need to spend time to revise the schedule.

Project calendar and milestones. The piping DDS must fit in with the rest of the project schedule. To do this, piping needs to know the answers to some very important questions. The answers to these questions will normally show up on the various project schedules. The master project schedule and project management schedule will normally indicate the major dates that are needed. The PEL will need to know key milestone dates, including the following:

- Process release of P&IDs
- Plot plan approval
- Periodic design progress reviews
- Release of vessel fabrication RFQ
- Receipt of vendor equipment certified drawings
- Release of pipe valves and bulks RFQ
- Release of structural steel fabrication RFQ
- Release of pipe shop fabrication RFQ
- Release of all construction work packages
- RAS (required at site) dates for all fabricated piping
- RAS (required at site) dates for all assembly piping material

Import/export requirements. Determining the import/export requirements on the project is not always the same. Projects are not always the same, and the people are not always the same. There are many places and ways that differences occur. Process data is just one of the many items with differences that could impact your planning. Let's look at one example of what the differences might be. Piping needs process data (an import) to properly assign the line class to the lines and develop the line list (an export).

- On project A, the exporter of the required data is the process engineering group within your current company. The process lead on project A is experienced, has worked with you in the past, and understands your needs.

- On project B, the exporter of the required data is also the process engineering group within your current company. The process lead on project B is new to the company, has never worked with you, and does not understand your needs.
- On project C, the exporter of the required data is the client's process engineering group. The client process lead on project C has never worked with your company and does not understand piping's needs.
- On project D, the exporter of the required data is the licensor process engineering group under contract to the client. The licensor's contract may not include the data you need.

Variations of the preceding import examples will occur on every project. They will occur with different types of data requirements from all the different groups. The same complexities will be true for the data your piping groups will export. The projects will be different. The deliverables will be different. The needs of the other engineering groups, the people, and the timing may be different. Determining the import/export requirements is a tedious process, but one that is necessary for the scheduling effort. Determining imports and exports is where communication and coordination are mandatory. You must be able to define your needs in understandable and realistic terms. You must also listen to the other groups and be responsive to their needs. When you are building your schedule, your work will be impacted by when you receive the imports. Your schedule will also be impacted by when you need to deliver an export to the client or some other discipline. Your success will depend on getting all of your team, your piping subgroups, to perform in accordance with the schedule. To do this, they should have an involvement and ownership in the schedule.

Getting the piping subgroup leads involved in the scheduling process is mandatory and the right thing to do; however, it may not always be possible. The people may not be available to the project yet. When it is possible to have the piping subgroup leads present, then the PEL needs to ensure that they are prepared. They need to review the project scope to be fully knowledgeable about their job and their deliverables. They need to know their labor hour budgets. They will need two or more meetings to draft and finalize the piping DDS. Subgroup leads, if possible, should actually do the scheduling of their own work. People are more willing to exert themselves later when they feel they had a part in developing the plan. This is what we call taking ownership.

The job of developing the piping discipline detail schedule (DDS) should not be difficult. Some people think it is difficult and try make it

difficult. Scheduling is, in fact, a task that can be made simple. Let's assume we have a company-wide scheduling system (a tool) that everyone is trained to use. The scheduling system used by the company may be an in-house program, but it more than likely will be a program developed by one of the industry leaders in programs of this type. With the assistance of the program development company, your company has added some industry- and company-specific enhancements. These enhancements would typically be generic activity/task modules that reflect how each of the major engineering disciplines does its work at your company. The discipline-specific modules should be structured to reflect the work activities and tasks that cover 95 percent of the company projects. The idea here is to list every normal function, activity, and task performed by a discipline. It's more productive and safer to use a schedule with a prepared list of items than to try to build a list from scratch on every project. The piping module in this system would have been created to reflect the way piping is done at your company. This piping module and all the others should not be considered rigid or inflexible. The piping module should be generic so that we can use it on a wide variety of projects.

The next thing we have is a project scope. The scope was used to document what we understand the client wants. The client reviewed it and approved it. The scope was then used to develop the labor hours (estimate/budget). If we have the right tool, the scope, and the labor hour budget, then the scheduling process will be very easy.

Building the DDS is now a simple matter of matching the work activities, tasks, and deliverables with their respective estimated hours and the right time frame for the project. Let's look at it this way:

Total piping discipline hour totals are broken down to . . .
 Piping discipline subgroup hours are broken down to . . .
  Area/unit hours are broken down to . . .
   Activity and task hours are broken down to . . .
    The weeks of the schedule planned for that effort.

Don't try to make the perfect schedule on the first try. You will make a first-pass attempt that will require review for compatibility with the other disciplines. This review will force some modifications. Your schedule will also force modifications in some of the other discipline schedules.

To develop a schedule, you need to understand that each line item on your schedule will define the production of a deliverable (specifications)

or an activity (locate and tag tie-in points). Each line item will have multiple scheduling elements. These elements include the following:

- A start date. The start date may be when you can start an activity. All activities have one or more prerequisites for action. A start date may be based on the receipt of some import data. This would be a front-end-driven start date. A start date may be driven by the end date or some successor activity. This is when you must start an activity to be able to deliver a required export to another group.
- The end date. The end date may be when you will finish an activity based on the start date and the hours required. The end date may be when you must be complete with an activity based on the requirement to deliver an export.
- An activity period. The activity period is number of actual calendar weeks between the start date and the end date. The activity period of the project or of a task will have an impact on planning. For example, some activity periods will include holidays. Vacations will also impact planning. In some countries, there is a national holiday when everyone goes on vacation at the same time. Cultural differences may sometimes determine what constitutes the workweek. These will all impact the planning process.
- The activity hours. The activity hours are the budgeted (or estimated) hours for that effort. You may develop the first pass of the schedule based on your estimated hours. You may then be required to modify the schedule based on the approved project budget hours. You must also remember that you will be modifying and updating the schedule for all changes that affect the work effort.
- The productivity factor. One of the important aspects of planning is the productivity factor. The productivity factor will have an impact on the activity hours in relationship to the activity period. When you prepared the estimate, the hours for an activity were assumed to be 100 percent productive. You had a 100-hour task, and you included 100 hours in the estimate for that task. This will work fine for machines. When you build a schedule, you are planning those hours for workers who are human beings. Humans are subject to sickness, personal needs (doctor appointments), transportation failures (auto breakdowns or bus company strikes), and the weather. Sometimes they cannot get to work on time or cannot get to work that day, at all. The productivity factor used for planning a project can be 100 percent. When 100 percent is used, then you are saying that everyone will be here on time, every day, and work the

full 40-hour standard workweek, every week. We know that this is not true. We must recognize that additional people or additional time will be required to make up for lost time. Another method is to build in the lost time with a productivity factor that is less than 100 percent. Your department manager (or human resources) should be able to furnish statistics on lost time from the payroll records. Your company may experience a productivity rate of 95 percent. If this is so, then you would plan your burn rate at 38 hours per week, per person, for nonholiday weeks. For a holiday week, you deduct the holiday and then use a 95 percent factor of the remaining hours.

- The staff count. The staff count is the total weekly hours divided by the factor used for the productive hours.

Let's look at an example of the scheduling process for a typical activity with these six elements.

Start date = August 6, 2001
End date = September 28, 2001
Activity period = 8 weeks. One week is a 1-day holiday week. There are 7 weeks at 40 hours and 1 week at 32 hours.
Activity hours = 960 (960 activity hours ÷ 40 = an even 24 labor weeks.)
Productivity factor = 95 percent (960 activity hours ÷ 38 = 25.26 labor weeks.)
Staff count = (See Table 12-1.)

Table 12-1
Typical Staffing Analysis

Week No.	Hours Available	Hours Scheduled	Staff Count @ 40 Hours	Staff Count @ 38 Hours
1	40	120	3.0	3.13
2	40	120	3.0	3.13
3	40	120	3.0	3.13
4 (1)	40	144	3.6	3.80
5 (2)	32	96	2.4	2.53
6	40	120	3.0	3.13
7	40	120	3.0	3.13
8	40	120	3.0	3.13

(1) = Week 4, work 8 hours overtime per person.
(2) = Week 5 is a holiday week.

This example shows that the holiday and lost time factor equates to the need for an extra 1.11 people for this line item (25.11 − 24 = 1.11). Questions will arise. Do I schedule one person full-time for the duration of the line item? No, you should not do that, because it would cause an overrun. How do I staff only a part of a person? You obviously cannot. You will need to make a judgment based on the schedule, the type of work, the current staff, and the availability of additional people. When the project is schedule driven, then add one person. Four people will allow the possibility of finishing ahead of schedule. The work may go more smoothly and, therefore, faster than scheduled. If this is true, then three people will do fine. There is also additional overtime that could be used to make up the difference.

You should also keep this in mind: We have looked at only one line item. The project is actually made up of many line items. Some of these line items will occur at the same time. Some will have beginnings and endings that overlap. One activity may end at a time that allows for the use of a person for a short period before their next assignment.

All of the required project line items for all of the piping subgroups will need to be defined. The actual or approximate start date and end date are established. The scheduling process is then used to determine the labor hour breakdown and the staffing for each line item. Don't feel discouraged if you can't get it right the first time. You will not have it right the second or even the tenth time. The schedule is a living document that will need to be updated as things change throughout the life of the project.

What about scheduling intragroup activities? Intragroup means the groups within piping. Why do we need to coordinate intragroup activities? Piping material engineering, piping design, piping material control, and pipe stress engineering are the people who do the piping work. In order for them to do the work in an efficient and timely manner, they need to know what is required and when it is needed. You may say that they should know what is required and when it is required. There is some validity to this if the company is small or is a specialized company that delivers only one type of project.

Projects done by most engineering companies will vary greatly in size, complexity, and duration. The number of deliverables will be different, and the content will be different. The procedures for review and approval will be different. The specific need for a piping subgroup's participation is not continuous throughout the life of the project. We also need to understand that at times a group may be an importer of information and at times that group will be an exporter of information.

Proper scheduling of all the activities of all the groups will ensure that the import and export relationships are coordinated. If the right informa-

tion is available to the right people at the right time, you can save time and reduce cost on the project. The PEL needs to start within the piping subgroups and make sure that all the internal activity interfaces are coordinated. The PEL also needs to exert the proper effort to ensure that the piping schedule is coordinated with the other engineering disciplines.

What about coordinating the interdiscipline activities? Interdiscipline means the engineering groups outside of piping. The need to coordinate the piping work with the other engineering disciplines should be obvious. Piping (including all of the piping subgroups) is an importer and an exporter of data. The other engineering disciplines are at the other end of that import/export relationship. The PEL will need to review (with the piping subgroup leads) all the piping activities. Every piping activity will have a prerequisite for starting. This may be some data that is imported from another discipline. Is that data going to be generated? When will it be generated? When will it be released? What will the status be when it is released? In what form will it be when released? All these are valid questions that need to be answered.

Do we need to have consistency in our schedules? The answer to this is the same as we have discussed in past chapters for other subjects. If everyone uses the same tool and understands the tool, they will be more productive and more accurate. We also need to make sure that all groups are "playing the same tune." No one plans on or wants to switch leads in the middle of a project, but it is sometimes required. If everyone is trained to use the same tool, it makes the transition of that new lead easier and faster. I would bet that everyone in the company uses the same time card program, expense report accounting program, and even performance review program. Why not have everyone use the same scheduling program? The scheduling program should be consistent across all projects for a single discipline and be compatibile across all disciplines within the single project.

There are other questions of compatibility. Each piping activity will normally end with a result expressed in a deliverable. This may be in the form of data that is exported to another discipline or to the client or construction contractor. What data is going to be generated? When will it be generated? When will it be released? What will the status be when it is released? In what form will it be when released? This is also true of the other discipline work. You need to make sure your work effort is compatible with the needs of the other disciplines. You also need to ensure that their work effort is compatible with yours. A properly developed and maintained discipline detail schedule will do this.

13

Planning and Organizing

This chapter will offer a few suggestions on how to run a more efficient operation. P10 = Proper prior planning prevents pitiful poor project piping production performance.

Why do you need to plan? There is an old adage that goes something like this: "If you fail to plan, then you plan to fail." That is all the answer you should need to the question of why you plan. Planning is an absolute necessity in any endeavor, no matter how large or how small. There are many examples throughout history where bad planning resulted in disaster. With the disasters, the critics, pundits, and Monday-morning quarterbacks come out of the woodwork and rip apart everyone who is remotely connected to the problem. On the other hand, there are many cases where the endeavor was a total success. These successes were not due to luck; these successes were the result of good planning. You will find that the successful endeavor will go unnoticed most of the time. It is likewise true that the planning process itself can go unnoticed.

If you do your job correctly, people will not see the planning at all. They will not see that you have thought of every possible risk and left nothing to chance. They may not see that you finished on schedule and within the budget. They will only see that the project has been completed. They may just be inclined to say, "Great job, thanks." You should not let the insensitivity of others or their diminished powers of observation bother you. Their inability to see your effort is unfortunate, but you should not invest yourself in a project to impress others.

What is planning? Planning is thinking—thinking about what activities and tasks are to be done; thinking about how every task is to be done; thinking about who will do it; and thinking about when and how it will be done. Planning is also documenting. The thinking done for the project will result in plans. These plans will be important to your success on the project.

Planning is a logical thought process relating to an event that has not yet happened. Plans are the documentation of the thought process. The thinking and the documentation should occur well in advance of the real event. People routinely plan family meals, vacations, kid's college, investments, and retirement. They do all of these types of planning without much thought. When you ask them to plan their part of a project, they seem to go blank. Remember, planning is just a thought process. You just need to stimulate your thoughts and be logical. Being logical means that you may need to take the project apart and handle it one piece at a time. Being logical may also mean that, if this is your first time as PEL, you should not try to do the planning alone. Being logical also means that this is probably not the first project done like this by this company and there may be some planning tools already in existence.

Sometimes a new activity or problem will occur on the project, and you will hit a blank wall in the thought process. One trick I learned a long time ago is the "back-to-front" method. Today the computer and a simple word processing program makes this easy. Start at the top of the page but pretend it is the bottom of the list. Prenumber each line. The number will be in inverse order of the actual occurrence. List the last thing that will be done. Then, moving down the page, ask yourself, "Before I do that, what must happen?" Then, move down to the next step. When you have completed your listing, do your own self-check. You may also want someone else to review it and make suggestions. After you are comfortable with the first pass of the list, use the sort routine in the software program to sort the list in inverse order.

When does the planning process start? Do not be misled by the fact that planning does not show up until chapter 13 in this book. That placement does not mean that you do not start planning until after there is a scope, estimate, and schedule. For anyone with experience, the planning process will start when they hear about the project—the first time they learn that they will be the assigned PEL. The experienced PEL will listen to every word in that first project meeting and start forming a mental picture of the overall scope of the project. At first, the PEL is not looking for every point of detail that may effect his or her work. Rather, they are standing back and trying to see the big picture. They are looking for the important key facts

about the project. These key factors will become subject modules to be address later in the planning process.

Factors that trigger the planning thought processes are as follows:

- Job-site location (foreign or domestic)
- Project execution plan (E only, E&P, EPC, EPCM)
- Project profile (grass roots, revamp, or combination)
- Project magnitude (single unit, multiple units, or total complex including utilities and infrastructure)

A first-time PEL may not recognize the implications of all of these factors or how each may impact the planning process. It would be helpful for the inexperienced first-time PEL to have some support and guidance from a more senior PEL.

What needs to be planned? Everything! Everything associated with the project needs to be included in the planning process. Everything on your part of the project needs to be planned. These plans must be compatible with the rest of the project disciplines. Those plans will also be coordinated with, and in some cases approved by, your piping department manager. The planning process needs to address many things, some of which may appear to be someone else's problem. Here are some of the important items, listed alphabetically:

Appliance needs. There are all sorts of appliance needs on a project. Appliances include copy machines, fax machines, coffee machines, a refrigerator, and water coolers. In most cases, the engineering manager will be responsible for all the appliance needs for the total project. However, you will need to look at the requirements of your group and advise the engineering manager accordingly. Your group may be split between the home office and the job site. At the job site, you may need a copy machine, a fax machine, a coffee machine, refrigerator, and water cooler.

Communications (written). What communications do you need? What communications do you want? What should the distribution channels be? You need to keep your staff informed, but you do not want to lose control of changes.

Data files (electronic). What data files will be required on the project? Who will be responsible for setting up the directories for the electronic files? What is the project file structure? Who has access?

Data files (hard copy). What files will be required on the project? How big will the files become? How much space will be required?

Deliverables. What are the required deliverables? What will be the form or format of the deliverables?

Electronic data backup. What is the frequency of the backup? Who is responsible for doing the backup? What if you have computers at the job site that are not linked to the office?

Furniture. How many people will you have at your peak? What will their function be? What kind of furniture setup do these people need? Is all work to be performed on computers? Will some or all work be executed in the field? Will the fieldwork be executed manually or on computers?

Hardware (computers). How many computers do we need in the office? In the field? What kind of computers do we need? What kind of printers and plotters do we need? Where will they be located? Who will maintain the hardware?

Logistics. Will all of your people be grouped in the same building and floor? Will some be located at another floor, building, or complex? Will some of your group be located at the job site? How much interface is required between the office and the group that is remote? What is the cost of commuting when expressed in terms of labor hours and schedule?

Software. What software programs will be required or requested by the client? Are these discipline specific? What version is required? Are these the programs currently in use by the company or are they new? Will program-specific training be required?

Space. How much space does your group need at peak? When is that peak? Are other group space plans compatible with yours?

Staff. What kind of staff do you need for this project? Are different levels of experience and technical capabilities required at different times? When are these times? What are the experience and technical capability requirements for each?

Supervisory backup. Who is in charge if you are not available? Who is the second in command for each of your group leads?

Supplies. We may be well into the computer age, but we still need paper clips and tape, along with the printer paper. We need lots of supplies that people seem to forget. What do we need, where do we need it, and when do we need it? Who is responsible for ordering and delivering the supplies?

Systems (electronic). What systems are needed? Do we need computer network systems, phone systems, teleconferencing, e-mail, the Internet, or electronic time sheets?

Training. Are all of the potential staff trained and current in the systems planned for the project? Are there any new systems or applications planned for the project? Is there any safety training required for the assigned field staff? For field visits?

Travel. Is the job site located out of the immediate daily commuting radius? How much travel will be required? How much travel time will be required each way for each person for each trip? Are there any unusual travel restrictions or conditions that need to be considered? Who will be responsible for approving all travel? Who is responsible for travel arrangements? What is the travel package?

Vacations. What is the time window of the project? What are the traditional vacation habits of your group and office? What are your vacation plans? When should you start a vacation calendar for your staff?

Some companies may be large enough to place all piping groups on projects on a task force basis. Most companies or smaller offices may operate with some groups in the cental core group concept. Regardless of how the company is structured, the work needs to get done. Communications, coordination, and data transfer logistics need to be planned.

There are some important issues that need to be considered when setting up the piping groups for the project.

- Do we full-time task force all the groups?
- Do we task force the groups at all?
- Do we task force only the piping design group full-time?
- Do we task force groups only as needed?

These are important staff planning issues that the PEL needs to address. The PEL needs to work with and under the approval of both the project engineering manager and the piping department manager. The staff planning

issues that are important include who will be needed on the job and which piping subgroups will be needed, in what quantity, and with what level of supervision. You may also need different levels of experience for various group-specific tasks.

Piping material engineering. If the project is not very large or not very complex, all the piping material engineering activities may be handled by just one working supervisor assigned on a part-time basis. Medium-sized to large projects may require full-time attention of the material engineering supervisor, supplemented by other material engineers. Large projects and megaprojects will require a full-time staff, headed by a senior piping materials lead.

Piping design. The piping design group will normally require a full-time supervisor. On a very small project, the piping design supervisor can be a working supervisor. On a medium-sized project, the design supervisor may need to be supported by one or more area or unit design leads. On the large projects and megaprojects, there may be a need to consider additional levels of supervision. One guideline to use is the "rule of ten." If the lead or supervisor has more than ten people reporting to them, then they may be overextended and not able to do a proper job. The piping design group should be a mix of experience levels that reflects the makeup of the overall department. You should avoid stacking the project with all senior people. This can cause an overrun of the labor dollar cost. This also does not offer a chance to develop the next generation of designers. You do not want to overstaff with the inexperienced designers either. This practice will, of course, hold down the labor dollar cost, but this could have a serious effect on the quality of the work and on the schedule.

Piping material control. Electronic project execution capabilities will have a great influence on the staffing needs of this group. This group will be smaller if the project is to be executed using a database-oriented computerized design system (that allows automatic bills of materials and material downloads). If the project will be executed manually or in a nondatabase 2D-CAD environment, the group will be larger, and the timing will be different.

Pipe stress engineering. Pipe stress engineering staffing will be driven more by the location of the job and the nature of the piping systems. If the project is located in a high seismic zone, there will be an increased requirement for stress engineer involvement. Piping that is outdoors and has

a high wind or high snow load potential will require increased stress engineer involvement. Plant piping systems that are predominantly hot and high pressure will require increased stress engineer involvement. On the other hand, if the plant is in a low seismic zone, with a moderate to low wind load, low snow load potential, and the piping systems are all low temperature, low pressure, there should be a reduced requirement for stress engineer involvement.

What do each of these groups need in order to function? This addresses the space, furniture, computer, and other needs of the groups.

Piping material engineering. If the project is small and the piping material engineer (PME) is to remain in the core group area, then there are no particular space or furniture needs. If the project is large and the PME needs to be located in the project task force area, then space, furniture, and computer systems need to be provided.

Piping design. The piping designer workstation needs will be based on many factors relating to the execution of the project. Will there be all home office execution? All job site execution? Mixed execution location? All computer execution? All manual execution? Mixed execution method?

Piping material control. If the material controller is to remain in the core group area, then there are no particular space or furniture needs.

Pipe stress engineering. If the stress engineer is to remain in the core group area, then there are no particular space or furniture needs.

When will these groups be required on the project? The answer to this question is in the DDS (discipline detail schedule) discussed in chapter 12. The work by all of the piping subgroups will not start on the first day of the project. The work by these groups will tend to be parallel but not continuous for all groups over the life of the project. Therefore, the planning for their involvement will require a great deal of logical thinking.

Piping material engineering. The piping material engineer activities commence very early in the front end of the project. This early involvement is driven by the development of the P&IDs, the materials of construction selection design criteria, and the piping material specifications. The piping line list is also an early development need. Later, depending on project scope, the PME will be involved in the technical review of bid submittals for piping materials.

Piping design. The plant layout activities (if applicable) of piping design will commence shortly after project kickoff. It is normally advisable to hold off staffing this group too early. Detailed piping design should not start until the process engineering group has obtained the client's approval of the project P&IDs. Until the P&IDs have been approved by the client, they should not be released for detailed design. Piping design work done using unapproved P&IDs could be subject to recycle.

Piping material control. Unless there are long delivery piping items, this activity should not be required until the project is well along.

Pipe stress engineering. Proper stress analysis of a pipeline or system requires that the pipeline or system be designed. This logically implies that the design effort is well along. Except for occasional questions that may relate to the early plot plan development, the stress work will normally be concentrated to the detailed design stage.

All of these functional group issues need to be considered. Those that are applicable to the specific project will need to be addressed when doing staff planning. The key elements of this planning should be the subject of discussions with the management on the project and with the department management. Not keeping the piping department manager informed would be shortsighted, indeed.

Data and information import/export requirements are another important aspect of project planning. Information is critical to the piping and the overall project effort. Information is imported and exported by piping. Information is a primary resource used to do work and produce the required project deliverables. A truly experienced engineering lead will (or should) know what information is required, when it is required, and where it will come from. The problem is that not everyone has the same high level of experience.

The process of defining imports and exports is not long or complex. The company should already have a listing of deliverables normally produced by each discipline. They should have a listing of typical documents received from clients, vendors, and suppliers. There should also be a listing of the various forms of communication produced by or received by the project. The leads for the total project should edit these lists to delete items that will not apply to the project. They should also add any new item that will be produced on the project. These project-specific lists should then be reviewed by the PEL to determine which ones will be required by the piping groups. It is a good idea to sit with the lead for each discipline when

reviewing their list. This review should include a brief discussion of content, format, timing of issue, and frequency of issue.

The piping discipline job files also require good planning and organization that will make a difference. We are not talking about the project manager's files, the electronic drawings, or CAD files. What we are talking about is the discipline-specific correspondence and technical data files required to do the job. We are talking about files that are considered a part of your project responsibilities by your company—files that are required for the day-to-day operation of your group. The existence or absence of these files may also have ISO 9001 quality or mandatory legal implications.

If this is your first time setting up job files on a project, you will need to seek help. You need to check with a number of people and ask a lot of questions. The first place to start is in your own department. Your department manager should be able to give you the correct minimum criteria. Every job being different may mean adding some specific file categories, but there should be a published company-recommended file index. You may also want to check with another PEL who is more experienced in project execution. In chapter 10, we suggested that you have a peer review of your scope of work. You may want to ask this same person for suggestions about setting up your files.

Having and using a filing system illustrates the philosophy of having a place for everything and having everything in its place. This concept is smart planning. Having a place for everything is only one part of the process. To do this, know the size and scope of the coming paper blizzard. You need to review the list of imports and exports. Some may be purely informational and not need to be retained. Most will be project-specific technical input that needs to be retained and managed. Files are created out of necessity. Even if it was possible to do a totally "paperless" project, we would still need to give some thought to file organization. We would also still have some hard-copy documents to store. The files are necessary because of the nature of our business. We need space and an organized method to store and retrieve project-related documents. (Appendix D contains a suggested piping project file index.)

The file categories include the following:

Project retention files. This file category will include any document that your company legal department deems subject to archive retention for use against potential litigation. Examples include signature copies of client approval of project-specific deliverables, and calculations. This file category will also include the master copy of any project criteria documents that de-

fines the piping-specific effort. Examples include piping scope of facilities, scope of services, piping estimate, piping control level schedule, and procedures. This file category will include any document that relates to the way the piping work activities will be executed. If your company is an ISO 9001 certified company, then this file and your work can be subject to an audit.

Piping deliverables (files). This file category will include the master (original) copy of any piping document created for the project. Examples include specifications, standards, details, line lists, tie-in lists, material summaries, and layouts. Included here (though not in a file cabinet) would also be the master electronic file for any drawings or other document.

Project reference files. This file category will include any document that may discuss changes or issues that will impact the piping effort. Examples include letters, project correspondence, project directives, memos, faxes, and records of conversations.

Project technical resource files. This file category will include any document that is a resource requirement for the piping effort. Examples include vendor and interdiscipline-generated specifications, preliminary drawings (or sketches), standards, details, and drawings.

The first category of files in the piping file index is the most important file group to the close-out process (see chapter 16). These files, or files of a similar nature, are the ones that have been identified as mandatory retention files by your company legal department. You as the PEL will have no say in which files will have the retention designation. So, with this in mind, it makes sense for you to find out at the start of the project which files you are required to retain at the end.

Use the filing system as you have it set up. Don't file things in other places, thinking that you will move them later. We stated that the piping project files equate to "A place for everything, and everything in its place." If you will do that (or can do that), then your project will go more smoothly, and your job closeout will be much more simple.

Let's look at an opposing viewpoint. Let's take Company X down the street (not your company). They also have a large project. There is a PEL assigned to that project, also. Company X does not have a standardized filing system. They do not even promote the concept of a standardized filing system. The PEL does not start the job with the realization that some file retention will a requirement. As the project progresses, documents come into the piping group, are created by the group, are used (or not used), and

then "settle" wherever they fall. Documents of all kinds come into this piping group for the 9 months of the project. Some documents are kept, and some are lost or dumped. It is highly probable that some important incoming documents do not receive proper attention. This happens because they are not recognized as fitting into a critical category. Nonetheless, the project was completed. They now tell that PEL to close out the project. They also inform that PEL that certain specific types of documents will now be collected and archived. There was no prior indication that there would be a retention requirement. There was never a place prepared to store specific documents or an operating philosophy geared to putting everything in its proper place. The documents that are now to be retained cannot be found. The PEL is in deep trouble. You do not want this to happen to you.

The other side of the story is the "pack rat" syndrome. This is where the lead (or others) keeps every piece of paper. The reasons for this may be many and complex. Somewhere, at some time, that individual has probably been asked a question that they could not answer. It did not matter that they were not responsible for having the real answer; they were made to feel guilty because they did not have the answer. They may have even been punished for this unfair situation. Being a pack rat is not recommended.

There are a number of important aspects to remember about project files. Among these is the fact that the storage of project retention files will take a lot of space. This space is defined in cubic feet. The retention will normally be outside the company office at a secure third-party archive storage facility. The cost of this storage will be based on cubic feet of space required. The company will be required to pay for this storage for the required (legal) period of time. Your company already has procedures and guidelines on what to keep and how long to keep it. Last, but not least, the need to access the retention files for a specific project historically has been very low. The client will have all the correspondence and documentation they originated; a copy of all project correspondence from your company; and a copy of all the purchase orders, drawings, specifications, and correspondence from vendors and suppliers. The client also has all the project deliverables, such as specifications, drawings, and contracts.

It would be extremely rare for you to keep something of value that does not already exist. If you get in the habit of retaining material from past projects, you must then find a place to store it. Each time you move your office, you have the ever-increasing job of packing and unpacking. Learn to travel light; don't become a pack rat.

14

Staffing and Directing

This chapter is a discussion concerning who will do the work, when to staff, and how to ensure that the work done will meet the project needs and goals.

How important is the staffing of a project? It is very important. No matter what endeavor you begin, choosing the wrong people will hurt you. Let's say you are the financial backer for a new symphony orchestra. You have the best symphony hall in the world. You have hired a highly respected conductor. You have collected the best instruments ever made. You even have the finest music ever written. The audience is in their seats. Would you take just anybody who says they are a musician? Would you take someone whose only claim to fame is as a part-time street musician? No. You want the right people for your orchestra. You want musicians with the experience and the skill level required for your type of musical production.

Wanting the right people for the job means that you want people with the right experience, the right skill levels, and the right attitude. It does not necessarily mean that you want a specific person. All of us have worked with people whom we like, respect, and trust. It would be nice to have them with you on your next project. It is not always possible to get your choice of people by name when staffing a project. It is also not such a good idea to keep picking the same people for the same position, job after job. You may find that these people (the ones you like so much to work with) do not want to work with you again. They may feel that working under you on yet another job will prevent them from moving ahead. In a small company having a small number of people on the staff, there will of course, be repeat performances. In these cases, the department manager (or office manager)

should consider the assignment, the job scope, and the best interest of the individual. Switching roles and altering job content can enhance the individual's worth to the company.

The process of defining the overall staffing requirements for a job is not really very complex. Let's look at a hypothetical project. We might do this by looking at the table of contents for this book. We know and understand the roles and responsibilities of all the piping groups. We can read about and understand the roles and responsibilities of all the other engineering groups. We know about differences in project complexities from the chapters on project descriptions. We learned about the process of procurement and contracts. We developed our project scope of work with its description of the facilities and the required services. Our next step was the estimate of the labor hours required. We then developed a preliminary schedule of activities and tasks. We now need to determine the proper skill levels needed for the jobs.

When we look at an activity bar in our schedule, we find the number of people required for that activity. An activity that is complex and technically difficult should be staffed with the appropriate skill level. We know that most activities have elements that can be done by people having different skill levels. An activity that is simple and routine should be staffed with a lower skill level. It is simple to define the skill level required for activities that require only one person at at time. The activities that require gang staffing (4, 5, 6, or 8 people) may be more difficult to understand.

The department's overall demographics will be a starting point. The staffing of the project will normally reflect the staffing of the department. This is true for a single activity that requires gang staffing and for the total project. We know that people's skill levels can be defined as heavy, medium, or light. Your company may use different terms, but the concept is the same. The normal piping department is staffed with, and has a recognized blend of, light to heavy skill levels. The staffing for the project should be a blend of these light to heavy skill levels. Of course, if the department is staffed with all heavies, then the staffing may well be all heavy. There are also cases when additional people must be hired from outside the company. The total numbers required for the project may not be available from the current department. There may be multiple projects that also require staffing. It may happen that the required skill/experiance level is not available in-house.

The objectives of proper staffing include getting the task accomplished at the right cost. The labor hour estimate you developed was turned in to the project. That estimate was combined with all other discipline estimates. Project management, office management, sales, and corporate executives

apply the appropriate labor costs. The company is paid in dollars (or coin of the realm), not in hours. All the hours that are required, used, or lost will directly relate to dollars. These labor costs will normally be based on the current office averages plus an escalation factor for the duration of the project. If the project costs were set to match balanced light to heavy office demographics, then if it is staffed with all heavies, the project could lose money. To make the right choices in job staffing, the PEL must have a sense of the project financial goals. The PEL also needs to have a full understanding of what he or she will be held accountable for.

Recognizing that you are responsible and accountable for the proper staffing of the job does not mean that it will always happen just the way you planned. You did your estimate, you laid out your schedule, and you defined your staffing needs. You defined your staffing needs in terms of function, skill level, assignment start, and duration. You then turned these staffing needs in to the department manager. Department management is responsible for filling the needs of your project and all the other projects in the house. Department managers will staff jobs to the best of their ability. The department manager may not have the ability to meet all the needs of all the projects exactly as defined. The department manager's ability is a balance between desirability and capability. You may need to be flexible as to when you get staff and a little innovative as to how you make job assignments. You want the right experience and skill for the right job at the right time.

You may be inclined to ask, What is the difference between experience and skill? A skill is knowing how to ride a bike. Experience is the actual participation in the Tour de France or a motocross race. You may not have a problem on your current or even your next project with experience or skill deficiencies. However, at some point you will be hit with one or both of these problems. Experience deficiency in this business is not uncommon. Your project may include an extensive tank farm or a large marine barge and ship loading and unloading facility. If none of the people have any past experience in these areas, you have an experience deficiency. A skill deficiency is also common and is also not so simple to overcome. Let's say your project includes the requirement for a new CAD system. None of the people assigned to the current team or at the company has this skill. These are both potential problems for you and the project. As the PEL, you need to watch for this and make sure all of your management is aware of the problem.

In staffing the project, should you become interested or concerned about the difference between direct employee and agency when someone is assigned to the job? You may wonder whether to treat an agency employee

differently from the way you treat a direct company employee. This is a valid issue. The answer is complicated and can be both *yes* and *no.*

- Yes. If you were not involved in the interview process, you will not know the skill level and capabilities of the individual. You must take the time to determine what they are capable of doing. You must also determine if there are any work conflicts or restrictions.
- No. You should not treat them any differently when it comes to skill-for-skill job assignments.
- Yes. If this is their first time at this company, you will want to make them feel welcome. You need to make sure they know where the emergency exits are. An agency employee will need to know where the various facilities (restrooms, cafeteria, print room, conference room, or parking) are located.
- No. Compliment or acknowledgment of positive contribution to the job effort should be offered the same for both.
- Yes. You should not assume that the agency employee will know everything about the company, the project, or the job assignment. Take the time to fully explain what you expect and require.
- No. The agency employee should have access to the same technical information as a direct employee.
- No. When it comes to problems such as disruptive or aggressive behavior, do not put up with personality or behavior problems on the job. As soon as problems appear, you should take prompt action and follow company procedures.

Along with staffing the job, we also need to consider how we make job assignments to the people. Do we delegate or do we direct? *Delegate, delegation, direct,* and *direction* are very important terms for the aspiring PEL to learn. We all seem to do what the term describes, but sometimes we confuse the term and the definition with the application.

When it comes to delegation, I am as guilty as the next person. Many of us will delegate (assign) work to someone and then treat it as a direction task. We give the job to a person, and then we do not allow them the freedom to succeed or fail. We do not show trust, and we tend to hover too closely. We smother the individual so they cannot be creative and innovative. If the person is truly qualified for the job, then let them alone and let them do it. When a person is given a task that is familiar to them or is routine, they will feel insulted if they are treated as being incapable. When you delegate a task, it is okay to take the time to determine if the person feels

comfortable with the assignment. They must understand the assignment and accept responsibility for its successful completion.

At other times, we will give an assignment that is far over the capabilities of the individual. Then we treat it as a delegation task and walk away. With this type of assignment, we need to stay in there and truly direct the effort so there is not only success but also learning. When a person is given a task that is over their head, they should be mature enough and feel comfortable about saying so. When you direct, you should take the time to make the person feel comfortable with the assignment. Explain what the two of you are going to do together. Note the word *together.* Define the roles that each of you will have in the effort. Make sure that the person understands the assignment. Make sure they understand that they have a contributory responsibility for the successful completion of the task. We should make sure every person has goal-oriented (budget versus schedule) work assignments.

The definition of a goal-oriented work assignment is very simple. In the engineering and design community, *goal-oriented work assignment* means that we define all the parameters of the assignment. We define what we want done (the activity). We define the process required (the tasks). We define the results (deliverables). We define when we want it done (schedule). We also define the total number of hours (budget) for each task and for the completed activity. The goal has been clearly defined. The parameters involved in the success of the goal have been spelled out. There has also been the opportunity to ask questions and get answers. The designee at this point is on the brink of making a contract with you. Admittedly, it is not a formal, written contract document. This contract is not one that would stand up in court, but it is a commitment to do something, nonetheless. The people (or persons) who will be involved in this assignment have the opportunity to ask questions. They can ask you to clarify any unusual aspects. They also have the opportunity to say that they are not qualified for the job. They may state their concern that the budget or schedule does not seem appropriate. Many people just give work assignments without defining the parameters. They then wonder why things do not turn out right. When a job assignment is delegated to someone it is wise to explain the whole picture. Let's look at the example in Table 14-1.

We make a work assignment. The assignment activity requires five tasks. The budget for the total activity is 320 hours. Task 1 requires 140 hours, multiperson. Task 2 requires 80 hours, single person. Task 3 requires 50 hours, multiperson. Task 4 requires 30 hours, multiperson. Task 5 requires 20 hours, single person. The scheduled completion date is Week 8.

Table 14-1
THE PLANNED WORK EXECUTION

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total task hours
1	40	40	20						140
		20	20						
2		20	40	20					80
3				20	20	10			50
4					15	15			30
5							20		20
Total hours	40	80	80	40	30	20	20.5		320
Equiv. staff count	1	2	2	1	0.75	0.55	0.5		
Actual staff count	1	3	3	2	2	2	1		

We now allow ourselves to get too busy to worry about this activity. It is Week 7 before we check on the status of the activity. We find that only Task 1 has been completed. The actual staffing has been different from what was planned. We also find that all the hours have been used. The scheduled issue date for the deliverables will not be met (see Table 14-2).

How does this happen? People tend to make excuses as to why things don't go just right. We are all familiar with the list of these popular excuses. They include the following:

- That's not my job.
- That's the way we have always done it.
- That's the way I always thought we did it.
- That's the way I always thought we should have done it.
- I just gave the assignments, they are supposed to know how to do their jobs.
- There was not enough time to do it right.
- I did not have all the information (to do it right).

None of these excuses is correct. It happens because we do not supervise/manage our people. It happens because we were taught to be pipers, not to manage pipers. We were taught the technical side of process plant engineering activities, but we were not taught to be good people managers. The successful execution of the piping effort for a complex process plant project of today requires two important points. The PEL must manage both the technical work and the people who will do the work.

Most of this book is intended to help understand and manage the technical side of the work. Managing the technical side, in most cases, is much easier than managing the people side. Learning to manage the people side will be harder for most because it is less predictable. The knowledge and skills required to properly manage people will come from a number of sources. First of all, there is your own past experience. You will have worked for or seen examples of some good supervisors and some bad supervisors. Learn from both of those experiences. Books on behavioral science and industrial psychology are available at the library, the local bookstore, and over the Internet. Anyone who is planning to be in a supervisory position should learn how to treat people. Invest in yourself and take a few courses at your local junior college.

The next best thing to do is get to know your people. If you have never worked with someone, you will not know what they can or cannot do. They will also not know or understand your expectations. Get to know them and learn what they are capable of doing before you make the job assignment.

Table 14-2
THE ACTUAL WORK EXECUTION

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total task hours
	40	40	40	40	40	40	40		
1						20	20		320
2									
3									
4									
5									
Total hours	40	40	40	40	40	60	60		320
Equiv. staff count	1	1	1	1	1	1.5	1.5		
Actual staff count	1	1	1	1	1	2	2		

Make sure the people who report to you do the same for the people who report to them. We are not talking here about the private lives of people. We are talking about their professional lives. What are their skills and experiences? What is their professional job history? What kind of assignments and experiences have they had in the past? If nothing else, ask them for a copy of their resume. Tell them about yourself and about the project. Give them time to ask questions. You may be working together on this project for some period of time. Don't be afraid to develop a good professional relationship.

The next thing you must learn to do is listen. When you listen, you must also hear. When you listen and hear, you will develop insight. Here are some examples of listening, hearing, and insight. I once overheard a conversation between two individuals where one repeatedly used the words "I always" in regard to past assignments. When the time came to give this person a new job assignment, the person was asked, "What have you always done, and what would you like to do on this job?" This insight provided the opportunity to expand the person's experience. It also resulted in a happier employee. On another occasion, an employee stated that they had a fear of heights and suffered from vertigo. They wanted to be excused from climbing the tall columns during trips to the job site. The person's request was respected, and all the climbing tasks were assigned to other people. Later, this same person was overheard gleefully describing their great adventure weekend, which included skydiving and bungee-jumping. The insight from this incident led to the questioning of the various aspects of the person's actual work. This review resulted in the discovery of potential costly errors and the release of that individual from the job.

Another important lesson for the new supervisor to learn is where they stand. They must understand what it means to be in the middle. You are not considered one of the troops, and you are also not considered truly a part of upper management. You are in the middle. The troops will see you as a part of upper management. They see you that way because you are the boss: You go to those meetings where all the "secret stuff" is discussed. The troops do not know what really goes on in those meetings every week. They do not know that you may be behind schedule and over budget. They do not see you defending them. Upper management does not actually see you as one of them, either. They give you orders and direction, and they expect you to execute the order without question. It is not easy to walk this middle line.

At this point, it may be appropriate to clarify some field assignment issues. We all know that everyone assigned to the job in the office will not

go to the field. It is not possible in most cases due to the company location versus the job site location. It is also possible that no engineer or designer will receive a job site assignment. There will be circumstances of job scope that preclude this from being required. It is, on the other hand, highly desirable that individuals with high potential for advancement get field experience. Individuals who aspire to be a piping engineering lead should take advantage of any opportunity for expanding their knowledge base. They should also be on the lookout for an opportunity to aid in the development of a rising star. This includes field assignments.

Two very important things should be remembered when sending people to the field. First: safety. There should be no mystery or question about safety. Safety affects everybody, and safety is everyone's responsibility. Second: the objective. The objective is to get the job done. People assigned to a job site also need to understand what will be expected of them. The person expecting the most from people assigned to the field is the construction manager. The construction manager's expectations include the following:

- Know and follow all safety rules.
- Know why you are there.
- Know who you report to.
- Know and follow all the construction manager's procedures.
- Be on time and able to work every day.
- Be swift and accurate with answers or solutions.
- Leave your ego and your personal problems outside the gate.

Let's take a look at these items in more detail. Know and follow all safety rules. Everyone at a job site should be focused on safety. There are people at most job sites whose only assignment is to teach and preach safety. There are people at all job sites who are assigned to enforce safety. You and the people you assign to the job site are also expected to be safety oriented. You break the rules, and you are out of here! Accidents will happen at job sites no matter what precautions are taken. Some accidents at job sites are types that have nonrecoverable consequences. The person you must count on for your own safety at all times is you.

Know why you are there. The job site can be a very busy place on most projects. Clients and construction managers would not feel kindly toward someone who appears to be lost. They do not have the time or an interest in holding your hand. All field visits and assignments should have a purpose and objective. That purpose should be clearly defined, scripted, documented, and approved by the home office project manager, the field construction

manager (or superintendent), and the client, if applicable. The script should reflect a consistency between the amount of work to be accomplished, the number of people involved, and the hours available on the site. This is the basic scope, budget, schedule triangle.

Know who you report to. When a person is going to a job site, they need to know who is the "responsible party." Do not expect to just show up and be allowed to wander around. Visits to existing facilities, before construction has started, will require checking in with a "responsible" client representative. For job sites in a construction mode, the construction manager is normally the responsible person you must see. Think of it this way: Construction managers are very territorial. He or she will want to know who is in their territory and why you are there. Communicate with the responsible person before you go. Report to the responsible person when you get there. Depending on the duration of the trip or assignment, meet with the responsible person on a periodic basis. Last but not least, check out with that responsible person before you leave.

Know and follow the construction manager's procedures. This primarily applies to a long-term field support assignment but could apply to other situations, also. Again, we have the issue of territory. When you are assigned to a job site to solve problems, don't cause them. Most projects today are executed by subcontractors through the contracting process. The construction manager (CM) and the field contracts administrator (FCA) will have procedures for documenting all questions, answers, and changes. These procedures must be followed, or there could be irreparable cost implications. They will, no doubt, require that there should not be any one-on-one direction between you and a subcontractor. They will also require that the resolution of all problems or questions be documented and routed through the CM and the FCA.

Be on time and able to work every day. Conduct that may be deemed acceptable in the home office is not normally considered acceptable in the field. If you (or the people you send to the field) are in the habit coming in late in the morning, you will need to consider a change. All the construction managers I ever worked with had a 24-hour workday mentality. Because of the vast burden of their responsibilities, they tended to eat, sleep, and drink the job, 24 hours a day. When it is time to work, they want everyone to be where they are supposed to be and be there when they are supposed to be.

Be swift and accurate with answers or solutions. This is a point that cannot be stressed enough. There may be 10 or more workers and some very expensive construction equipment waiting for your answer. While you try

to decide on an answer, they wait. Although you try to justify not making a change because of your ego, they wait. When they wait, they are costing the project (and the client) a lot of money.

Leave your ego and your personal problems outside the gate. It is difficult, but you really need to do it. When you are on a job-site assignment, you need to be a team player in the full sense of the word. You and all the other people need to focus on the job at hand. All your negative ego traits, private problems, and other nonwork-related issues should be put aside.

15

Controlling Change

This chapter is a discussion of the primary types of change and the management of those changes.

There are many facets to a project. The project may include both grass roots and revamp. It could be full EPCM and have multiple units with some third-party licensor involvement. The project may be located in another part of the world, thousands of miles away from your home office. The project may start out as lump sum engineering with cost-plus early construction and conversion to lump sum after final work package issue. When someone says you must control the project, you may tend to become confused by these many and admittedly complex facets.

There is, however, one primary key to the control of any project: You must control the scope. If you and the rest of the project do not control the scope, you will not be able to control any other facet of the project. To control the scope, you must first be able to identify it. If you cannot identify the scope of your project, then you will not be able to control it. (Defining and writing the scope was discussed in chapter 10). The original scope was intended to define the basis for the two primary cornerstones of a project. These two primary cornerstones are the physical facilities and the required project deliverables. Other secondary cornerstones are cost, schedule, quality, and safety. After a project scope is written, it is totally unrealistic to expect it to be perfect, or remain unchanged. All projects will experience additions, deletions, or adjustments to the scope. This is commonly referred to as *scope creep.*

Scope creep will directly affect one or both of the primary cornerstones. Scope creep will also have a trickle-down effect on the secondary cornerstones. Here is a statement that may surprise you: Scope creep is not preventable. Scope creep is only somewhat controllable, and it is only controllable when it is recognized. At this point, it may be pertinent to note other terms that relate to the control of scope. The other terms are *management of change,* or *change management.* These are both good terms, and I will use them periodically in this text, where applicable.

One of the major responsibilities of a discipline lead is the control of scope. It is nearly impossible for the PEL or any other single individual on the project to do this. One person cannot control the scope and the impact felt by the project in cost (budget) or time (schedule). In chapter 1, the duties and responsibilities of the PEL were defined. The definition included prompt recognition and notification of all scope changes or trends that may cause a cost impact to the project. This is something that every person must do. The PEL is not expected to control the scope of the total project. The PEL is, however, expected to control the scope of the piping portion of the total project. The PEL is responsible for knowing the piping scope of work. The PEL is responsible for recognizing changes to the piping scope of work and generating the proper notices of a change.

The PEL is not expected to do this alone. The PEL needs the help of the piping team. This means that the PEL and all of the piping subgroup supervisory staff on the project will need to know the original scope. They must then be motivated and vigilant as work is done. They must be able to control the communications entering and leaving the group. To control communication, as used here, does not mean to prevent communication. They must responsibly question anything that appears to be an addition, deletion, or modification. Changes to the original scope may be in the facility description or in the services description. The changes may be additions, deletions, or modifications to something already in the scope. When the form or content is changed, then there is a potential impact to the budget or the schedule. All of these changes will cause the scope to creep. Change management or the management of change cannot and will not stop changes. Change management is activity on the project that includes a formal process for the documenting, reporting, reviewing, and approval of all changes.

Scope creep is not preventable. The truth of this statement may rest on the individual's position on the project and the perspective gained from experience in the industry. The people who define the projects are normal human beings. They do not walk on water, and they are not omniscient. The people

on the client's team and the people on the company team who put the project together were very smart and did put in a lot of effort. However, no matter how smart we think we are or how hard we try, we always seem to miss something. Changes to a typical process plant engineering project are a fact of life. A piece of equipment will be added (or deleted). Site conditions are found to be different than previously understood. Changes happen.

What kinds of changes will there be? There are only two basic categories of change on a project. The scope of work had two sections: the scope of facilities and the scope of services. Therefore, there will be changes to the facilities, to the services, or to both. You may be required to add, delete, or change things such as areas, units, equipment, or lines. These will be changes to the scope of facilities. On the other hand, you may be required to add, delete, or change things such as specifications, data sheets, drawings, or purchase orders. These are changes to the scope of services. It is just that basic. The complicated part tends to be what these changes are called and how that may apply to your project and you.

In chapter 4, there was a discussion of the type of contract under which your company is doing this project. Most people operate under the misconception that you can do things differently depending on the form of the project's financial contract. We all know there are different levels of responsibility on the project. It is not the responsibility of the discipline leads to determine whether a change is allowed by the contract form. That should be left up to the project manager, the legal department, and the client. I would suggest that the discipline leads should operate the same, regardless of which form of contract the project falls under. Changes (under any kind of contract) will fall into two basic classifications. These classifications will have some generalizations and some specific terms or names. These terms tend to be just a politically correct way to imply origin. These are as follows:

- Change order: A written order to the contractor, signed by the owner and engineer or architect, issued after the execution of the contract, authorizing a change in the work or an adjustment in the contract sum or the contract time. The contract sum and the contract time may be changed only by change order. (Construction Dictionary, *Construction Terms & Tables,* Published by Greater Phoenix Chapter #98, The National Association of Women in Construction, October, 1989.)
- Trend: The general drift, tendency, or bent of a set of statistical data as related to time or another set of statistical data. (*Dictionary of Scientific and Technical Terms,* 4e, McGraw-Hill, 1994.)

If we accept these definitions, then we can readily recognize that change orders are client oriented, and trends are internally (discipline and company) oriented. Both of these types of change will be characterized by certain facts or features. Table 15-1 is intended to highlight these areas.

The engineering company project management will typically be aware of a change order long before anyone else on the project. The client will normally discuss major equipment changes with the PM long before the disciplines become involved. The direction of the notice and the related communication for change orders is normally from the top down. This will only be true, however, if the project is being run properly. We have all seen projects where the client has been given (or has taken) too much liberty and has unlimited access to the design floor. On the other hand, you, as a discipline lead, will typically be the first to identify a trend that affects your scope. It then becomes your responsibility to notify the project manager and your department manager. The direction of the notice and related communication for a trend is normally from the bottom up.

Two problems most leads will have identifying a trend (change) and knowing what to do about it. With a little thought, both of these problems will go away. It is this simple: Know what was in the scope, know what is the current requirement, subtract one from the other, and that is the answer. Every PEL is different and will function differently. It may be best, however, to try to conform to some consistent practices (habits) in doing business. One habit I have found to be successful concerns the periodic scope review. Once a month, normally when the monthly status report is due, I review the complete piping scope of work. Any change to the types or numbers of deliverables between the original scope and the current requirements (minus any previously reported change) is a trend. You ask, "How do you keep track of what has been reported and what has not?" Simple: It is okay to markup your scope. It is also okay to revise it and reissue it to the project and your department manager.

Do trends only show up as an increase or decrease in the number or type of deliverables? The answer to this is *no.* There are three factors that may initiate a trend that is not related to the number of deliverables. You need to make sure management (both project and departmental) is fully aware of any trend that may originate as a result of one or more of these factors. The first of these is productivity. Productivity becomes apparent when there is a negative relationship between the plan and the actual performance of a task. When you did the estimate, you predicted it would take X hours to do a specific task. The performance to date shows that it is taking 25 percent more time to do the same task. This is a trend. This is not a

TABLE 15-1
Typical Change Order vs Trend Differences

Normal Source	Change Order Client	Trend Disciplines
Typical focus	Addition of equipment along with related physical needs and material	Change in deliverables, numbers of drawings or quantity of bulk or other materials. Change in labor hours and/or schedule
Project impact	TIC & schedule	H.O. eng. budget
Scope section	Facilities	Services
Timing of identity	After project scope approval	After engineering budget approval
Number and Cost Impact	Few in number but high in capital cost	Many in number but small in cost
Example	Client added spare exchanger to allow continuous service during bundle cleaning. Requires: space (may require plot plan change and moving of other equipment) foundation costs exchanger cost piping costs construction costs	Line count for original estimate was 658 (line numbers). Four months later after P&ID issue line count is determined to be 925 (increase of 333 or 50%). Requires: more hours to define line routings more hours to process the drawings more material for fabrication and assembly more field costs for installation
Notification paper trail	Client to engineering company project manager at the top, then down to the disciplines and others on the project. This type of change will never start with the disciplines.	Discipline members to the discipline lead at the bottom then up the ladder through the engineering manager and the project controls team to the project manasger. This type of change should never be discussed between the discipline lead and the client without the presence of the project manager.

change to the number of deliverables; it is not an increase or decrease to the number of specifications, drawings, or purchase orders. It is a change to the planned number of hours required to do the task or produce that deliverable. This is a trend that needs to be reported to both the project and the department management.

The second factor is work recycle. Recycle is apparent when you are forced to redo work after it is once completed. This is also a trend. This action is not a change to the number of deliverables; it is not an increase or decrease to the number of specifications, drawings, or purchase orders. This action is also not a change to the planned number of hours required to do the task or produce that specific deliverable on a one-pass basis. This action is a duplication of the effort and a requirement to reinvest hours to rework completed items.

The third factor is schedule disconnect. Schedule disconnect has many causes. It can be originated by the client, a licensor, a vendor, project management, other disciplines, or even internally within the piping group. A radical example of a schedule disconnect trend may be as follows. The licensor was scheduled to release all the process package with the equipment data sheets on a specific date. You and the other groups staff up and are ready on the specific Monday morning in question. On Monday morning, the phone call comes that notifies the project that there will be a 6-week delay in the actual delivery of the package. What does this do to your plan? You had to fight to get the people in the first place. Do you release them? Do you shuffle the work and do other tasks out of sequence to give the people other work and keep them on the job? The final decision from this will be a trend. This action is not a change to the type of deliverables; it is not an increase or decrease to the number of planned deliverables. This action is also not a change to the planned number of hours required to do the task or produce that deliverable. This action is a delay of the effort and require an investment in the hours to redirect work to hold people. This could result in recycle of work later and lower productivity.

There may be people who claim that this is business as usual. They try to say that the hours for inefficiencies, delays, and recycle are already included in the estimate and the budget. They try to call this normal contingency. That is just not true. No right-thinking discipline lead prepares an estimate with unlimited fat in it to cover any and all possibilities. No project manager could really believe this premise and then institute a trend procedure and require the disciplines to manage change. If the budget did, in fact, contain an all-inclusive contingency, then we would not have a change management program. If all contingencies are included, then nothing is excluded; that being the case, there are no changes.

This is a good time to discuss the impact of a change based on the timing of that change. By timing, I mean where we are in the evolution of the project when the change was made—which phase of the project we were in when the change was identified. Chapter 5 contains the definition of the typical activities during the different project phases.

Let's take the following example. The client adds one 10″—600# RF 9 Chrome Gate valve at the outlet nozzle at tray 43, located 70 feet up the side of a vertical tower. We have the same project conditions as defined in the opening paragraph of this chapter. When was the change made, and what is the impact of this change? We will look at three timing scenarios.

Change scenario number one: The change is made prior to the completion of Phase I and the issue (for client approval) of the P&IDs. The impact of the change at this time is minimal. Valves of this size and type are covered in our piping material specifications. The equipment layout and vessel orientation are not started yet, so there is no impact to piping design. This addition is an expensive alloy valve and, as such, is one we would want to include in our valve RFQ package. We just need to add this valve to that inquiry. Because we are still in Phase I, there is also no major impact to other disciplines. This change was made at a good time. The cost is limited to the cost of the valve, the prorated field cost for installation, and the minor home office cost to issue a supplement to the RFQ. The valve is a long lead delivery item, but because we found this out early, we will not cause any delay to the contractor in the field. This type of change made at this point of the project has a very low impact on the job. It also has a very low degree of risk, because it will be absorbed into the natural evolution of the project.

Change scenario number two: The change is made late in Phase II of the project. The cause is a late decision to comply with the hazop review comments. This is very late to be making this type of change. The design work has progressed and is well along. The vessel orientation has been completed, and the fabrication drawings were issued. The vessel fabricator is in the process of final shell assembly but, fortunately, the vessel has not been post-weld heat treated yet. We need to go back and review the vessel orientation layout to determine if there is enough clearance and proper access for the new valve. Do we need to move the nozzle? Do we need to extend or add platforming? Does this valve addition cause a change to the pipe support method or location? We need to take a serious look at the piping layout around this nozzle. We have added more weight to the nozzle, and we changed the geometry of the line. Does the nozzle need to be reinforced? This is the identical change as before, but now the vessel group is impacted. We may also be affecting the vessel fabricator. The valve purchase order was issued long ago. This valve must now be ordered. Finding out about this valve now is pushing the limit of impact on the field. A valve of this size, rating, and material is not available off the shelf. One will need to be manufactured. Hopefully, there will be no problem with the forging

and machining process. Also, we hope the valve passes all the tests. If it does not, we have a problem. This change made at this phase of the project has a higher cost and a higher degree of risk.

Change scenario number three: The change is made late in Phase III. Now we have a problem. In fact, we have a lot of problems. The vessel is fabricated, stress relieved, and at the job site. If we make any welding changes to the vessel, we will also need to do local stress relieving. The piping fabrication drawings have been issued; the pipe has been fabricated and received at the job site. The final construction work package has been issued. The installation contract has been converted to lump sum. The designers and others responsible for the original layout are not on the project anymore. There is no valve ordered. If ordered now, the valve will not be delivered until 6 weeks after planned start-up. We need to push the valve supplier to expedite the manufacture of this valve. We will be charged premium pay for this. We will need to air freight this valve to the job site. This is the same change as in scenario number one, but now this is going to be very expensive.

At this point, we may ask ourselves what is the best way to identify and handle change orders and trends affecting budget or schedule. In chapter 11, we discussed the estimating process. As a part of that discussion, we talked about having a piping discipline-specific, smart electronic estimate form. This form covered all the subgroups of your piping organization. For each subgroup, it covered each category, type of work activity, and deliverable. For each type of deliverable, there was the ability to have a default labor hour "cost." There was also the ability to have an override if the labor hour cost needed to be adjusted. This preformatted discipline-specific estimate form performed two important functions. It gave consistency to the estimate process, and it acted as an aide for the user to consider all the normal discipline services.

We should recognize that we, in piping, cannot and should not control. Every established engineering company in the world has its own methods and procedures. Every project, project manager, and project controls manager will have their own requirements or preferences. This author and this book cannot and will not propose any overall changes to these. I would only hope they would have the flexibility to allow the use of discipline-specific tools, where applicable. The company and project-specific standard forms tend to be very general in nature. They do not cover the level of detail required by the various disciplines on the project. I would propose that the standard form be used for the final discipline roll-up numbers and the discipline smart form be used as backup. It could be an attachment in

a hard-copy environment or, with a compatible numbering system, it could be available for review in the project-specific electronic database.

The concept used for developing and documenting the original estimate should be used to develop and document a trend or a change order. The PEL should consider using the discipline estimate form as a starting point and develop a mini-estimate form specifically for trends and change orders. It would be a mini-estimate form because you are, in fact, doing a mini-estimate for this specific change. The form should reflect all the subgroups of the piping organization. It should cover all the major activities and deliverables, just like the original estimate form. The major difference in this form is the title block area. Here, there needs to be space to add a number to identify the change and a space to include a brief description of the change. If the form is made properly, it will be an automatic checklist reminder to help ensure that nothing is forgotten. If the form is electronic, it can speed the process by saving the lead time in the preparation process and preventing errors in the math.

16

Reporting

This chapter is a short and simple discussion of the reporting required to keep management and the client informed.

Reporting is important to the overall project, and it is something that could cost you a lot of time and effort. You can simplify your time and effort if you do some planning and organizing. You should know what reports will be required, when the reports will be required, and what the reports are supposed to say. You should use good tools to prepare the reports, and you must also have a good filing system (hard copy and electronic) for your reports.

There will be the various types of reporting. You will need to be aware of timing of the reports; the purpose of the reports; the focus of the reports; and the method of reporting. You must also consider the content of the reporting. All of these—the types, timing, purpose, level of focus, method, and contents—are natural elements of the reporting activity. Discipline-specific job knowledge is a mandatory requirement for reporting. Project content, current project status, and current discipline status are also required for proper reporting. The skill and ability necessary for preparing and presenting the report are also important.

Why do you need to make reports? Let's change the wording of the question a little: Why do you *want* to make reports? You want to make reports because you want both the project management and department management to know what's going on. You want them to know where you are, what your problems are, and what kind of help you need. Too, management does not like surprises. You do not want to hide the good things your people

do for the project; you also do not want to hide problems. It is far better to have everything, good and bad, in front of everybody.

By types of reports, we mean standard or special. Standard reports may be the typical weekly or monthly status or progress reports. A special report may be an ad hoc report based on a specific question from the client. Each will have its own timing, level of focus, method, and content. The timing of reporting will more than likely depend on the purpose of the report. There will be weekly reports, monthly reports, project completion reports at the end of the project, and special reports. Status reports and progress reports will be more frequent. Some projects will require a weekly or biweekly engineering status report. Most clients and company management will require a project progress report once a month. The project completion report will, as the name implies, come once at the end of the job.

The purpose of a report will influence a number of its aspects. The difference between the status reports and the progress reports varies with each company. Both of these reports should be written and available in hard copy. Typically, the weekly status report is informal and may be a one-page form. The primary recipients of the weekly status report are the engineering manager and your peer-level discipline leads. The client may or may not be on the distribution list for copies of these weekly status reports. The monthly project progress reports are a more formal document. The client and the company management are the primary recipients of this report. Discipline contributions may be made in any number of formats, but the final version will be the responsibility of the project manager.

The level of focus for most reports will normally be limited to the department management, project management, or, on some rare occasions, the client. Most companies will already have some type of reporting form or format. Every company, every project, and every project manager will be different. You should always use the existing company or project form whenever possible. Each of the focus targets may demand a different level of detail and could force multiple reports. This is unfortunate and will cause extra work in preparing different report formats. Try to avoid multiple reports with different formats. Try to use the same report format for all levels of reporting. Most importantly, when reporting, make sure you answer the questions you know the reader will be asking. Find out the significant "Hot Buttons" for each of your key reporting levels. If your standard company form does not cover all specific hot-button issues, then you need to take some action. You may need to request permission to modify the standard form or add an attachment to the report to cover the missing area.

The method of reporting will also vary depending on the type, purpose, and reporting level. Some will be firsthand verbal reports. Don't be surprised if you are asked to give an impromptu report. This is not unusual and can be a bit unnerving to some. Staying on top of your job at all times is your best protection. In most cases, you will know that you are to give a report and will have time to prepare. Don't procrastinate. As soon as you know about the requirement, start the preparations. Normally, all periodic reports are written. You may also be required to give a verbal presentation and support it with the written copy. You may be required to just submit the written report or even to submit your report in an electronic form. You need to be versatile. You need to be able to stand up in front of different levels of audiences and make a presentation in a professional manner. You need to be able to write different types of reports and be able to use the different electronic word processing and spreadsheet tools required to make reports.

What should be included in reports? The type of report tends to dictate the contents of the report. The onetime only (special purpose, ad hoc) report must address the specific subject or purpose of the report. You can get books at your local library on how to write these types of reports. When you have a special report to prepare, get one of these books or ask for help. On the other hand, the weekly or monthly status report is more structured and more predictable. The weekly status report should be no more than a few paragraphs (one page, at most) and cover a narrow window of time. The weekly status report should cover the accomplishments for you and your group in the preceding week and what you plan to do in the coming week. There may be a simple summary of staffing (plan versus actual). There should also be the ability to define problems that are affecting your group's performance. When you define a problem, you should also define what steps you have taken to lessen the effect. This report may be somewhat informal and is normally seen by only a limited number of people associated with the specific project.

The monthly management-level progress report is a different matter when it comes to content. This report will tend to be more formal and may be seen by more people. The monthly progress report is normally intended to define where you were supposed to be and where you actually are. This report may have a number of sections, but it should include a summary of your estimate factors. This summary should cover such items as deliverables and hours with original numbers versus current forecast. There should also be a section for explanations of any significant deviations. There should never be anything (good or bad) reported in a monthly

progress report that has not been discussed previously with the department and project manager.

Some people may still create reports in longhand. I do not recommend this. You should learn and use your company's current electronic method. Word processing tools will vary from company to company. They may also change from one project to another within the same company. Computer software companies will continue to change the word processing tools we use. You, as a lead, in charge of a large segment of a process plant project should be using the proper tools. Using the proper word processing tools will make your reports compatible with the rest of the project and the company and save you time. The time savings comes in the use of standardized format, the ability to make rapid changes or corrections, and the ability to copy the last report and update for the current report. Use the built-in spelling and grammar checkers to improve the quality of your reports.

You should save a copy of every weekly and monthly report you make during the evolution of the project. These reports will be the basis for your final project close-out report. They form the history of the group's effort. The weekly status reports for each month will help you with the month-end progress report. The month-end progress reports will be the basis for the final project completion report. Save each report and make it work for you.

17

Project Completion

This chapter is intended to cover job closeout: what to do to prevent over-engineering; warnings about becoming a pack rat, and suggestions about making the next job better than the last one.

For some, finishing the project may be the hardest thing there is do. Finishing the project will focus on those activities that occur during the final 3 to 5 percent of the project. During this time period, there will be many different activities. These project completion activities need to be accomplished completely and successfully. They will also need to be accomplished under the pressure of a diminished budget (home office labor hours) and ever-declining schedule (time frame). All will tend to add stress and confusion. There always seem to be late changes from the client, the vendors, or other disciplines. Things within the piping group may also have been missed during the rush at the height of the production engineering stage. This is not new, and it is not unusual.

The truly knowledgeable and experienced lead will sail through this time with grace and enthusiasm. On the other hand, a first-time lead may panic and appear to flounder. The inexperienced first-time lead may have trouble shutting the job down. This is completely understandable if you think about it. The job has been going on for a year. The motivation has been to gear up and go, not shut down and turn off. There is also natural human self-preservation and defense reaction: If I finish this job, I might be laid off. Anything is possible, but you should be a professional and do what needs to be done. Finish the job.

The activities that are traditionally found at the end of the project include the following:

- The final production of any remaining piping deliverables
- The review and approval of remaining piping deliverables
- The review of other discipline final deliverables
- The revision of any piping deliverable affected by a change in another discipline deliverable
- The final update of all of project deliverables (master copy or file) for any known marks
- The final updates of material summaries and issue of purchase order supplements, as required
- The final updates of construction work packages, as required
- The completion of employee performance appraisals prior to destaffing
- The destaffing of people in accordance with the labor budget and schedule
- The completion of any outstanding labor hour deviations (trends or change orders)
- The initiation of the piping project completion report
- The separation of piping files by category (retention versus disposal)
- Notification to the project manager and the department manager that all project work has been completed
- Request approval to archive designated retention files and dispose of all others
- Request approval to release remaining staff from project (including self)

Finishing the project should not be such a hard thing to do. It's not hard if the scope you developed was a good scope, and you were able to stick with it. It's not hard if you were able to do the other elements of your job correctly or if you were organized in the way you set up the job at the start. When you finish a project, you must know and understand the scope: You must know what the project requirements were. You must be able to account for all the deliverables necessary to construct the piping portion of the project. You must know when you have met all of the requirements and commitments for your discipline and when to start the project completion activities.

In chapter 10, we discussed the starting activities and scope of the project. When you start the project, you know that it will come to an end someday. You know when you start the project that it will run for X number of weeks or months. You know this because there was a target completion

date in the proposal documents. This target completion date was also included in the project master schedule. The project master schedule may have had some revisions and some slippage, but an end date is always included. So, from the start of the project, we know that it will end, and we know when it will end. If this is true, then we should be able to think about job closeout at the start of the project.

The final production of any remaining piping deliverable is mandatory. There is one stumbling block that always seems to get in the way of this activity: It is known as over engineering. The people on the job, and I mean all the people on the job, continue to suggest little improvements. These "improvements" cause extra work and leakage from the budget bucket. The PEL, with the help of the piping group leads, must control changes and overengineering from within the piping group. With the help of the engineering manager, the PEL must control changes and overengineering from outside the piping group.

The key to the control of overengineering is a good understanding of the scope of work and the meaning of the term *fit for purpose.* The scope of work included specific sections that defined the facilities, the services to be provided, the deliverables, and the assumptions and clarifications. This scope of work was reviewed and approved by many people, including the project manager and the client. The implication here—if all these things (defined in the scope) are done, done correctly, and are fit for purpose—is that the responsibility of the piping group has been met. If all the changes were properly defined, approved, and controlled, then the project will be on schedule and on budget.

The PEL is responsible for the review and approval of all deliverables of the piping group on the project. This includes the electronic design files, if applicable, along with all construction and record documents. This review and approval activity will occur over a long period of time. The earliest activity will tend to be the first issue of the project plot plan or the early design criteria or material specifications. This aspect of the PEL's responsibilities cannot be delegated or taken lightly.

The review of the final deliverables of the other disciplines is another mandatory activity. The PEL is specifically responsible for the piping portion of the project. However, the PEL is expected have a broad awareness of the total job to the extent that he or she is able to spot potential conflicts between the piping and other discipline work. The PEL cannot be expected to do a detailed review of all the documents produced by all other disciplines. The detailed technical review of deliverables produced by these other disciplines is an activity that must be delegated. The PEL will not

normally have the time to perform all of these types of detailed reviews. The individual engineers and designers assigned to the project must be capable and trusted to do this. The interdiscipline deliverable review is both a high risk and a delegated task. Because of this, it is recommended that it be watched very closely.

The revision of any piping deliverable can effect a change in another discipline deliverable. Prompt action needs to be taken if and when changes or conflicts are found in the deliverables from another discipline that affects a piping deliverable. It may not be clear which group's document is incorrect, but to do nothing is wrong. When a conflict is found, the action taken must be in the best interest of the overall project. This should consider the five key tenets of project evaluation (see chapter 4).

The final update of all of project deliverables (master copy or file) should be reviewed for any known marks. This is an important but sometimes unrecognized close-out activity. The project has been going on for many months; it has been a long time since the end of Phase I and the issue of the client approved for construction plot plan drawing. Many other documents have also been issued. Some feedback from fabrication shops, contractors, and the field may have triggered a prompt revision. Other feedback may reflect in marks being collected and recorded on the master office copy of that document, but there may be no immediate need for a revision. During closeout, the master office copy of all discipline deliverables should be reviewed for marks and revised and reissued as required.

Final updates of material summaries and issue of purchase order supplements should be made, as required. After the final issue of the last piping deliverable, a check of the final materials requirement files must be made. This check is necessary to ensure that every item of piping material required for the project is on order. You cannot start the plant if a key item is not installed. The item is not installed because it is not in the field. It is not in the field because a vendor did not ship it. The vendor did not ship it because it was never on a purchase order. It was never on a purchase order because someone overlooked it in the material requirement program summary. The final update cannot catch an item that is never shown on a drawing. Depending on the type of material requirement program being used, there should be some method to cross check among three benchmarks. These benchmarks are the material required per the drawings/design file; the material ordered per the purchase orders; and the material available based on job-site receiving reports. If an item is required but is not on order, then prompt action will need to be taken. This is the area where you and your staff must work closely with the procurement group

and the construction management group. If this missing item threatens to delay the plant start-up, then the PEL, the material control lead, and the purchasing lead may need to look at a more expensive alternate source. Paying a 10 percent premium on a $500 item (to expedite delivery) may be required to get the item on time. Compare this with the timely startup of the plant at a profit margin of $180,000 per day. There should not be a lot of discussion on this type of issue. Material that is required but not yet on order will require action. Material that is required but is not yet received at the job site may (or may not) require action. Material received at the job site that is no longer required may require some action depending on the type and quantity.

The final updates of construction work packages should be made, as required. This is another area where there may be some cleanup work. This is, however, where you and your team must work closely with the field. All additions, deletions, and changes to a contract or a contract document must be coordinated with and through the field contracts manager and the construction manager.

Employee performance appraisals should be completed prior to destaffing. This is something that I hope is done consistently as a formal program by all employers. Everyone deserves to know how they are doing on the job. The smart PEL will use democratic delegation in this area. The PEL will prepare a performance appraisal for only the four or five leads that report directly to him or her. In turn, these group leads will be responsible for performance appraisals for the people who work under them in that group. A performance appraisal does not need to be long or complicated. The important thing is that they be honest.

Destaffing should occur in accordance with the labor budget and schedule. This is an area where the PEL must be firm, fair, and professional. To be firm means that you cannot allow the individual engineers and designers to dictate when they are released. To be fair means that you may need to release one of your stars early when the department manager has an assignment that is judged to be a growth opportunity for that person. To be professional means that each individual leaves the job on a positive note and with dignity.

Outstanding labor hour deviations (trends or change orders) should be completed. You need to review your actual expended labor hours versus your approved labor hour budget. You will find one of the following three situations. (1) The two numbers are the same or very nearly the same. This would be rare, but it may mean that you are current with all documentation for trends and change orders. It may also mean that you are very good at

estimating work. (2) The two numbers are very far apart, with the approved labor hour budget higher than the actual expended hours. This may mean that the budget was grossly inflated. It may also mean that your piping group was able to execute the required work faster, better, and more cheaply than previously thought. Some serious thought should be given to determine the reason for the difference. Regardless of the reason, a deviation notice needs to be written and submitted to give back the unused hours. Fair is fair. (3) The two numbers are very far apart, with the actual expended budget higher than the approved labor hour budget. This may mean a number of things. Your estimate (if used for the budget) was too low. Your approved budget was too low for the amount of actual work. There were additions, deletions, and changes during the course of the job that resulted in the increased hours, which were not yet documented. Here is what you do not want people to consider: The estimate was right, the budget was right, but the work was not managed and controlled properly. Regardless of the reason, one or more deviation notices needs to be written and submitted to cover the difference in the budgeted hours and the actual expended hours.

The piping project completion report (PPCR) should be initiated. Every project should have a project completion report. I really hope that every company requires a piping project completion report from every PEL on every project. This is the Janus concept. In order to ensure that you do a good job in the future, you need to know what kind of job you did in the past. In order to refine the estimating process and be successful on future proposals, the company needs to have good historical data for correlation. A PPCR does not need to be a burden or be complicated. Almost all of the parts and pieces are already at hand. A typical PPCR might include a copy of the piping scope of work; a copy of the piping labor hour estimate; a copy of the approved labor hour budget; a copy of the actual list of deliverables; a copy of the piping material cost estimate; a copy of the piping material purchase order cost summary; a copy of the plan and actual schedule; and a copy of the staffing. From this data, all kinds of correlations can be made. The key to writing a good project completion report is in the weekly and monthly status reports that you retained during the course of the project. You should go back and read each one; they will remind you of events that you had forgotten.

Piping files should be separated by category for retention or disposal. In chapter 13, we talked about a filing system (see also appendix D). If a structured filing system like this is used, then job closeout will be much easier. All Class A files are prepared for archive. Class B files are reviewed for

late marks. Revisions are made where required. New issues are made where appropriate. The electronic master or paper originals are turned over to the client in accordance with the project procedures. All Class C and D files are prepared for disposal.

Notification should be given to the project manager and the department manager that all project work has been completed. When all items have been handled, then it is time to advise the project manager and the piping department manager that you consider yourself done, pending their concurrence. They may have some additional duties they want you or your staff to accomplish. If so, you will continue at their discretion. If they concur, then you can take the final two steps.

A request should be made for approval to archive designated retention files and dispose of all others. When the full and final release is given, then the files can be dismantled. Class A files are packaged as directed by the archive department supervisor. Class B file originals are turned over to the project for transfer to the client. Class C and D files are destroyed. Do not be a pack rat. Do not try to keep any Class C or D files because you feel that someone, someday may ask some question. It is just not necessary or worthwhile.

The final step is to request approval to release remaining staff (including yourself) from the project. With all of the items completed, it is time to release any remaining staff. This should be done in a manner that causes everyone to understand that they are done. They are off the job, and there are to be no more time charges allowed. The job is done.

Part V

The Future

18

Where Do We Go from Here?

This chapter is intended as a discussion about the future.

There is a saying that goes something like this: "Those who are unwilling to learn from the past are doomed to repeat it." If we want to make sure there will be a future for this profession, and ensure that the future will be better, then we need to review the past for mistakes. Some issues relating to the past should be discussed as part of the future. The issues are legitimacy, technical vigilance, project complexity, project pace, technology, basic knowledge levels, and attrition. These issues impact the four levels of our profession. These four levels are the industry in general, the client, the company, and the individual in the profession.

In chapter 1, we touched upon the absence of legitimate schools of higher education that address the piping engineering and design field specifically. As I write this, I know of only one fully accredited engineering school in the United States that bestows a 4-year degree in the profession we call process plant piping design engineering. Why is this? I feel that process plant piping design engineering is every bit as complex as the other disciplines we work with on projects. There are some that may even be far less complex. The contribution of process plant piping design engineering has a wide reach of involvement. This involvement has played a very important part in the lifestyle we all enjoy today. Process plant piping design engineering application is so wide and so important that it touches almost every aspect of life in the United States and, indeed, the world. Piping, however, is not recognized as a legitimate stand-alone engineering discipline. I hope to see a change in this someday. I would like to see highly

skilled, competent graduates coming out of schools with the knowledge and skills required to do this work.

The way we do business in the process plant engineering industry is somewhat risky. The total cost of the projects we work on is very high. The discipline leads on these projects are responsible for tremendous design and material budgets. The piping portion alone for one of these projects will equal tens of millions to hundreds of millions of dollars. Yet, the person we place in charge of these millions is not required, encouraged, or helped to maintain technical proficiency. There is no periodic rectification process. There appears to be very little movement to establish accountability in our business. The company that does not pay attention to the generation and the regeneration of its resources will gradually lose ground.

Companies spend millions of dollars to upgrade computer systems. They spend hundreds of thousands of dollars to give training for nontechnical computer-related applications. Yet, they do not appear to consider it important to raise or maintain the level of discipline-specific technical competence. Every year at budget time, companies seem to go through the same routine. Management will go through the motions of putting money in the budget for the departmental technical training needs. They asked the department managers to define their department training needs and estimate the costs involved. Then it is deleted, because they cannot justify why money for training was requested or required. They do not to understand the training ROI (return on investment). They question why training is required. It is very difficult to explain why discipline-specific technical training is necessary. Trying to sell training from the positive payback standpoint is very difficult. It may be easier to discuss what happens when you do not train.

Piping, along with all other engineering and design disciplines today, is affected by technical core competency. This core competency is impacted by a number of factors, including the following:

Corporate culture. Mergers between two companies in the industry will bring a new culture to one or both offices. The company that opens a new office will also bring a new culture to the region where the new office is located. These culture differences may include the expectations to do more functions than were expected before or different activities than were expected before. The current staff needs to be trained to meet the expectations of the new culture. This type of knowledge will not be absorbed immediately. If the company wants the employee population to speak the company language and produce a company product, then the company must be willing to invest time and money to train the staff so they will fully understand

the company expectations. The company must be willing to teach all of the people what the company expects.

Project complexity. Projects are getting more and more complex. Every project involves a very long list of complex steps. Some companies may perform only a few of these steps. Other companies may perform most or all of them. The typical projects today will include a long project definition and justification period, the full engineering, procurement, contract management (work package development), and construction period. Some of these projects require technical involvement in the procurement cycle to assist and assure vendor performance. Some clients require us to be involved and make a meaningful contribution to the early project definition stage. There are also projects where the postconstruction activities such as validation and start-up may be required. This can create a cradle-to-grave span of responsibility and accountability that is far more complex than many people have previously experienced.

Project pace. Some projects are referred to as *fast track.* This is an overused and very misunderstood term. In fact, the typical project has gone beyond fast track. The projects of 30 and 40 years ago tended to have a longer span of execution with more recognizable separation between the specific project phases. The typical project of today will have the building size or plot space fixed before the content is defined. Activities that would have a logical sequential relationship in the past now have a more concurrent relationship. The overall execution period for the project has been reduced. This has been done to expedite the start-up status and maximize the client's return on investment. This accelerated pace affects the ability of all engineering leads to review the design as it develops. If you do not find bad design, you cannot make corrections before it goes out the door.

Technology. Computer systems such as 3D-PDS and PDMS are considered the hot technology of today. This area is getting a lot of attention and, thus, most of the typical corporate training budget. These systems are very important to the overall success of a company and our industry. Any company in the heavy process plant engineering and construction business today must be using these systems. These companies need to keep this technology in its proper context. The computer is really nothing more than a very sophisticated drafting machine. It may have a database of information that will help to prevent some types of mistakes. However, placing an individual who does not have the proper technical training and experience on a com-

puter is not prudent. An individual who does not know piping but is given PDS training alone does not become a qualified piper. The untrained and inexperienced person can be a very fast and impressive computer operator. The untrained piper can create shapes and place objects in space. They then rely on the interference checker to find errors or clashes. The interference checker will only find clashes of electronic objects in the selected models. If a required object is not placed in the discipline model, then there will be no interference detected during the electronic check. The PDS system will not prevent a nonpiper or a bad piper from doing bad piping.

Basic skill or knowledge level. It is hard to evaluate the actual level of skill or basic knowledge for the average piper in an engineering company office. Human resources cites government rules and regulations as a basis and does not allow the disciplines to administer any kind of technical test for competency on new employees. We also do not have an objective method to measure the knowledge level of current employees. We are not allowed to give a yearly test to determine competency. We normally find out about skill levels and gaps in experience only after the fact, when it costs the most. Mistakes are normally found when the construction effort is in full swing. During construction, the $10 error committed in the office will cost hundreds, even thousands of dollars in the field. Someday, clients will demand to know that the people who will be assigned to their project are actually qualified. The engineering company will then need to find a way to certify all engineers and designers.

Attrition. From the 1950s through the early 1980s, there was a boom period in our industry. This period resulted in tremendous growth in the piping engineering and design population. This population growth was fueled by small, medium, large, and megaprojects in industry. These included the refinery, chemical, petrochemical, nuclear power, and fossil fuel power projects. All of these projects required the hiring and training of vast numbers of engineers and designers. This vast pool of experienced, knowledgeable, and truly competent pipers is now aging. It has become a rapidly shrinking number. Attrition in any specific demographic work group is caused by such common factors as promotions to higher levels, changes in life pursuits, retirement, or death. All of these factors exist and are reducing the number of available and truly qualified piping designers. Unless a company recognizes this and creates a program to restock the pool, they will soon be out of experienced piping designers. We will be expected to run complex projects with computer operators who do not know the

meaning of the data or graphics they are manipulating. Corporate executives and upper management seem to think that training is a cost that they cannot afford. They need to remember that the cost of *not* training may be the catalyst for going out of business.

The cost impact of an inexperience piper is felt most by our clients. We see the impact of inexperience when we are at an engineering office. You see it by the amount and type of errors detected in the PDS interference check phase. You see it in the amount of rework and recycle required on the job. You see it in just a visual review of the electronic model or the drawings. We see the impact of inexperience on the job site. Mistakes can cause an all-day tie-up of a crane (at $5,000/hour). That tie-up also affected 10 to 12 workers, and it delayed the next phase of the work. The value of training saves the client money. Properly trained pipers will make far fewer mistakes on the deliverables. Fewer mistakes on the deliverables mean fewer changes in the shops. Fewer mistakes and changes mean a smoother and faster installation in the field. A smoother and faster installation in the field means lower costs. People must learn what "right" means, and they need to learn how to do the job right. Some companies seem to think that anyone who walks in the door, looking for a job, already knows everything that the company wants them to know. This new employee is somehow expected to be a wizard who reads minds and has experience in every facet of the field. This is just not true. Everyone at every level who is new to a company needs training. You may not want to call it training. Call it indoctrination, call it employee alignment, call it whatever is comfortable. The fact remains that someone is going to teach, and someone is going to learn.

Training in the engineering and design industry needs to cover seven basic areas.

Workplace culture. Human resource should have classes that cover subjects such as basic supervision, performance appraisal, management of conflict, fair employment practices, sexual harassment prevention, and ethnic and racial fairness in the workplace.

Computer (general capabilities). Every company needs to ensure that every new employee is trained and competent to use the company-specific general operating systems. These include such applications as word processing for text and spreadsheet applications. E-mail, Internet, and Intranet training are required for proper company and project communications.

Computer (function related). Every new employee who will be expected to use a technical system should be trained to use the company-specific ver-

sion of that design or engineering system. These may include AutoCAD, Microstation, 3D-PDS graphics, and complex analysis programs related to a specific discipline.

Technical (basic and advanced skill) knowledge. Every engineering company should have a program to ensure that they have a competent technical staff. They should have some type of piping-specific entry-level, mid-level, and upper-level technical training. Piping-specific technical training is rarely done today because it is so hard to justify. Clients and project managers expect the job to be staffed with knowledgeable and qualified personnel. There is no such thing as instant knowledge or instant experience.

Project-specific technical training. This is not so hard to justify and is done on a regular basis. The client and the project manager understand that the project requires a new capability. They will readily accept the time and cost required to train the people.

Company-specific safety training. This training is sometimes hard to sell to the project manager. They feel that the people automatically come with the company safety training. They forget that some or most of the staff will be hired for their specific project. They also forget that OSHA requires that safety training be current; it must be renewed every 12 months.

Project-specific safety training. This is the only area of training where there does not seem to be any argument. This project-specific safety training is readily accepted and easy to justify.

What kind of training is required? What training method results in the best learning? These are both good questions. The kind of training that is required will include administrative, technical, and safety training. The learning method depends on many factors. The method of training must consider such things as the subject matter to be taught, the permanence of the activity relating to the subject, the complexity of the subject or material, the number of people to be trained, and the time demand for skilled people. The most important of these is the number of people to be trained, when they need to be trained, and when they need to be available. The subject matter and the number of people to be trained will affect the training method to be used.

There are at least three basic methods for training. In the context of a typical engineering office work environment, there are definite positive and negative factors for each.

Method One:

Random Observation Training (may be called *absorption*). The person (or trainee) sees something done a certain way, and they are required to copy what they observe.

The positive aspects of this method may be:

- This method costs only the salary of the trainee for the training period.
- This method does not involve any costs for classroom or class material.

The negative aspects of this method include:

- There is no guarantee that the observed behavior covers all of the desired subject.
- There is no guarantee that the observed behavior was correct.
- This method takes a very long time to observe all the actual things necessary to become proficient in a specific subject.
- This method does not have consistency of results.
- This method does not work for a large group.
- This method does not meet the needs of any fast-track effort.

Method Two:

Mentor-Directed Experience (also called *mentored learning*). Under the guidance of an assigned knowledgeable individual, a trainee is given a task to do. The trainee is tutored on how to do the task and is monitored to ensure the that the desired results are achieved.

The positive aspects of this method include:

- This method does not normally involve any costs for classroom or class material.

The negative aspects of this method include:

- The person doing the training needs to have a trainer mindset.
- You must validate the knowledgeable level of the trainer.
- This method takes time to cover all the things necessary to become proficient in a specific subject.
- This method reduces the productivity of the tutor during the training period.

- This method does not have consistency of results; each tutor will have different ideas and values.
- This method takes an equal number of qualified tutors to the number of trainees.
- This method costs the salary of the trainee for the training period.

Method Three:

Instructor-Directed Training (also called *structured training*). With structured instructor-directed training, the areas of need and the training subject are more easily identified and covered. Training material is developed for that specific subject. A qualified instructor is enlisted. The material is presented in a formal classroom environment All the attendees are able to hear all the questions and all the answers.

The positive aspects of this method include:

- The person doing the training has a trainer mindset.
- You can validate the knowledge level of the trainer.
- This method requires a shorter time to cover what is necessary to become proficient in a specific subject.
- This method gives a more consistent result.
- This method requires only one qualified trainer to 15 or 20 trainees.
- This method gets greater results in the shortest time.

The negative aspects of this method include:

- The salary of the trainer and the trainees for the training period.
- The costs for classroom or class material.
- The loss of productivity of the trainer for other duties.

Some companies have used the structured classroom method to train people in a variety of piping technical subjects for more than 50 years. These structured training programs are well-known throughout the industry. These training programs have made obvious and significant contributions to the major projects of these companies over the years. There is evidence that the training programs by these companies may have contributed to the growth and success of all companies in the industry.

The primary focuses for a structured technical training class need to be in the industry-specific area where there are no equivalent programs or individual subjects offered in the formal academic community. Piping engineering and design is a prime example of this. Currently, I know of only

one formal, structured program in the whole of academia that addresses this field as it relates to our industry today. Prior to the University of Houston program, the company-sponsored, company-oriented, structured technical training program has been the only training that was available in most areas of the country. The company-oriented programs were able to achieve a very high level of technical training in a short period of time.

As we all know, to become knowledgeable and proficient in anything, a person needs to be trained. To enter the piping engineering and design profession, a person needs to be exposed to a proper piping engineering and design training program. The training program needs to include a wide variety of discipline-specific subjects. Some companies still have these programs "in the can," so to speak. They should require very little time or cost to get them ready for presentation. These programs already have a proven record of success. Where these programs exist, the companies should budget funds to do discipline-specific technical training.

Technology awareness is another issue that is important to our profession. There are two sides to the technology issue relating to process plant piping engineering and design. There is the technology of what we do. Then, there is the technology of how we do what we do. The technology is fairly stable, but it does go through some minor developmental advances. There must be a program to ensure that piping engineers responsible for ASME code compliance (knowing, interpreting, and applying) are able to remain current. How we do our work is moving ahead faster every day. In some areas, this movement seems faster than we are able to keep up with. Some years ago, we would learn and use a new technology (system or application) on more than two jobs in a row. Today, we start a project with the latest state-of-the-art technology and, before we finish, there have been two cycles of upgrades. Late in the job, we get the question, "Why aren't you using the latest version?" The technology causes some major problems that are not easy to understand or manage.

The PEL is an intermediate (middle) level supervisor and, as such, normally gets caught in the middle of these problems. They get it from the top, and they also get it from the bottom. The client or the company project management will attend a seminar or a sales promotion meeting 6 to 9 months into a project and see some new technical tool or computer software application. They want to know why it is not being used on their project. They also want to know how much money it will save if it were to be used on their project. They appear to forget the basic problems caused when you switch horses midstream.

On the other end of the spectrum, there are cases where engineers and designers have refused assignments on a specific project because the project is not using the latest CAD technology. Designers have threatened to quit if they were not transferred to a project where they can use and sharpen their CAD skills. They said they were losing ground in their field. In most cases, these designers are the very ones who are less skilled on the "what-we-do" side of the technology picture. These are the ones who will shun any classes relating to what we do in this profession. They are, however, very quick to enroll in a computer class regardless of whether it relates to their actual professional development. Ask them what magazines they subscribe to, trade and otherwise. They will no doubt list three or four computer-related publications, but not one relating to their actual profession.

Computers and the capabilities they give us are unquestionably very important to our industry, our company, the piping engineering and design professional, in general, and ourselves. However, we must remember that this computer is just a tool. The computer is an ever-evolving tool that we use. The CALMA computer system that was so popular from the mid-1980s into the early 1990s is not even used today. Some of the programs that are popular today may not be in use 5 years or even 2 years from now. Like flowers, CAD programs seem to bloom and then fade away in a very short time. The basics of good piping, however, will still be required.

The role of the client community is another link in the chain. The client expects to have the job done right. This means right the first time, within budget and on schedule. This would appear to be a reasonable expectation. It is not unreasonable, but it is not always possible. They expect every person assigned to the project to be properly trained and current on both sides of the technology picture. Clients should be able to have a reasonable level of confidence in the people that are assigned to their project. The client should also be realistic in their expectations. When a project contains standard processes and traditional equipment, the client should expect that the people have the required level of experience. However, when their project contains new processes and/or new types of equipment, their expectations must allow for some level of training. Some clients have also demanded that some new computer system be used in the execution of their project. They seem to think that switching to a new computer system is as simple as changing to a new pair of shoes. It is just not that simple. They must recognize that special training required to meet the demands of their project will take time. They must also understand that the cost of that training should be charged to their project.

The role of the company is important also. The company needs to remember what is said about the person in a rowboat in the middle of the flowing stream. If you do not continue to row, then you are swept downstream. Our industry will continue to experience changes in the various codes, standards, and material technologies. The industry will also continue to be impacted by the advances in the associated computer applications technology. Changes in both of these areas affect the performance capability of the individual and company. The employee population of any engineering disciplines, including the piping discipline, is not fixed. There is a constant ebb and flow of the people that is not predictable and not controllable.

Companies in our industry could take a page from the book of the major sports leagues. These teams start each season with many of the same players from last year. They have acquired some experienced players from other teams during the off-season. They also drafted some new players from the college ranks or the minors. All of these people have been playing the sport for years; they already know the game; they know the rules; and they know their position. Yet, the teams start every year with an extended period of preseason training.

Everybody is expected to learn the playbook, and they must make the team or be cut. It is not unreasonable for the company to consider doing the same thing. The company should ensure that their permanent staff is competent and remains current with prevailing technology. The company should seek to grow the capabilities of their staff so they deliver real value on every assignment. The company needs to recognize that even the experienced employee acquired from another company will need some level of "spring training." The company also should recognize that there must be a constant influx of rookies and that these entry-level employees need to be trained. At the start of every project, we need to ensure that everyone knows the playbook.

The role of the individual is the final link. The individual who chooses to practice this profession has an obligation. The individual piper has the obligation to seek and aquire the knowledge necessary to become and remain competent. The piper needs to be dedicated. The piper should be an ethical person and have some pride in their chosen profession. The piper, like any other person, should like what they do. If a person does not like their job, they will not do a good job, and they should find something else to do. When one piper does not do a good job, it reflects on all other pipers.

The average person, pipers included, seems willing to spend $30 or so on their car for an oil change or a lube job every 3,000 thousand miles. On the other hand, they are unwilling to invest in their own maintenance. Every profession, except maybe bomb disposal, seems to have people who

only go through the motions of their job. They choose to exert only the bare minimum effort. For life in general, we are thankful that these types constitute only a very small percentage of the overall population. The piping profession is no different. We do find the occasional slacker in our midst. I really would prefer that all the slackers in the piping field find something else to do. They cause a lot of frustration, they give the profession a bad name, and the errors they cause increase the cost of the project. This affects the bottom line of both the company and the clients.

On the positive side, the vast majority of the piping community is made up of dedicated and highly competent professionals. These are the individuals who have been involved in all the major power and process plant projects built over the past years. These are the dedicated and skilled individuals, the process plant piping engineering and design professionals who will execute the next projects, who will teach the next generation and continue to build for the future.

When we discuss the future, the question used in the title of this chapter comes up. Where do we go from here? The piping profession could continue, unrecognized and unappreciated, just as it is today. I hope this is not the case, but I am not in a position to determine where the process plant piping design engineering profession will go. I only know what I would like to see. Before anything will happen, we will need to have a change of attitude. The individual piper, the engineering companies, the client community, and the academic community must be motivated to change. This also means that they must come together in a joint effort with specific goals. They must also recognize that we are talking about major change. The change that is required will be a process that will take at least 10 years.

The road to making the future better for the piper is to recognize the basic problem that exists for pipers. Today, when we look for jobs in the paper or on the Internet, we see the qualifications and requirements. Everyone wants an employee with a BSME (or other degree), a PE license, or the ability to get a PE in the specific state. Having a BSME does not mean that the person knows anything about piping. How does the piper get a degree and achieve the proper level of legitimacy?

The first step in solving this problem is to get the academic community involved. There should be a review of the current University of Houston piping program. This program covers a very broad area, but it may not be as complete as it could and should be for the industry in general. Other subject areas to address the pharmaceutical, pulp and paper, and foods industries may need to be developed and available as electives. This program should then be installed in at least four additional engineering

schools around the country. The location of these schools would be determined based on the geographic concentration of both the engineering companies and the client users. Academia will have a number of problems launching this new program for piping. They will have a problem initially in providing properly qualified yet truly experienced instructors. I see this as a major issue. The technical classes in this piping program should only be taught by people who have broad, long-term, and proven industry experience. The academic community will also need to develop the ability to offer these piping classes in night school and over the Internet. The night school piping program would serve the piping person who is close to a piping school, yet already in the workforce. The Internet program would serve the student or those piping people already in the workforce but are not located close to one of the piping schools.

The second part of this concerns the engineering companies and the client community. Both of these entities need to make a change in their thinking. They both claim to want the same thing from the employee. They want a competent, properly trained, and dedicated professional. They want the work done fast, they want it done right, and they want it done at the lowest cost. In the past, there has been a general tendency to treat the employee, including the piper, as a throwaway commodity. They should now think about treating the employee as an investment. The engineering company and the client company both hire piping people in their operations. They should support any new piping engineering training or academic program. Support may be in the form of advisory board participation. They could work to ensure that the piping engineering programs get equal treatment from their scholarships and grants. They could lend additional support through summer internship opportunities for deserving students. They could also support this program by supplying knowledgeable instructors. Finally, they will show their support by hiring the graduates of this program.

The main element of this change to the piping engineering and design profession is the individual piper. There are at least four categories that we must consider as a part of the future. There is the new student who is about to enter his or her first year of the piping engineering academic program at the college or university. There is the young piper who is already in the business, but who has only a few years' experience. There is the mid-level piping professional who has been in the business for maybe 15 to 30 years. There is also the older piping professional, who is in the autumn or early winter of their career. The new student will be in an envious position and should not have any problem with this new program. The young piper with only a few years in the business should think about going back to school.

They could also upgrade their skills and qualifications by enrolling in the proposed night classes or Internet classes. The piper with 20 to 30 years of experience may be the one with the most difficult decision. Could they and should they go back to school? This group must base their actions on their own individual situations and needs. Some may want to go back to school, and some may not. The final group of pipers is the older professionals who are nearing retirement age. Some of these older piping professionals could consider going back to school. These people who have the right technical experience and the depth of knowledge necessary to present the material in the classroom should consider teaching.

The final element in the future piping picture is certification. The piping professional should be subject to an initial certification process. The piping professional should be required to pass a periodic recertification to ensure ongoing competency. The only program currently for this is the National Institute for the Certification of Engineering Technicians (NICET). NICET already has a program for testing and certifying professional process piping designers. This program includes four levels that address the full range from student to supervisor. Unfortunately, this program was not widely known and is currently relegated to a dormant status. A movement needs to be initiated to revive this program. Every piper should be NICET certified.

The goal is that, someday, the process plant engineering and construction industry will have professional, college-educated piping design engineers. They will have them when, and only when, the type of changes outlined here are accomplished. Pipers will then not be thought of as just CAD operators. We will have piping design engineers who are truly accepted as equals by the other engineering disciplines on the project. Piping professionals will deserve a greater measure of respect. They will also have a fair and equal opportunity for growth and advancement.

Appendix A

Typical Piping Deliverables

The following list is intended to be an all-encompassing list. However, the typical piping project will not normally require every document listed here. It will be the piping engineering lead and the actual needs of the project that determine which are actually required.

Note: The term *specification* is used here for certain documents. These do not always need to be specifications. They could be prepared and issued as technical notes or some other format. The important thing is to make sure all parties understand and agree to the order of priority. The order of priority may be as follows:

- Shall do—Specifications are "shall do" documents. A piping fabrication isometric is a shall do document defining specific work to a shop fabricator.
- Should do—Technical notes may be considered a "should do" document. Some codes are written to be should do documents. (If you have this condition, then you should do thus; if you have that condition, then you should . . .)

Piping material engineering
- Specifications
  - Piping line class material
  - Piping specialty item and data sheets
  - Piping pressure testing

- Piping system internal cleaning (standard)
- Piping system internal cleaning (high purity)
- Positive material identification, traceability, and certification
- Piping painting
- Pipe commodity and safety marking
- Galvanizing
- Piping insulation (hot, cold, and acoustical)
- Coatings and wrapping of underground piping
- Welding—general systems
- Welding—hygienic systems
- Piping system NDE (nondestructive examination)
- Nonmetallic lined piping systems

Data sheets
- Specialty item data sheets

Drawings (vendor)
- Specialty item (vendor catalog or certified drawings)

Lists
- Piping line list (originate and maintain)
- Piping specialty item list (originate and maintain)
- Piping commodity catalog (originate and maintain)

Calculations
- Maximum allowable flange ratings
- Pipe wall calculations

Data files
- Relational database (3D geometry for electronic modeling)

Piping design

Specifications
- Plant layout and piping design
- Electronic design model (3D-PDS)
- Field survey/close range photogrammetry
- Piping tie-ins
- Shop fabrication and handling
- Field fabrication and installation
- Heat tracing (piping, equipment, and instruments)

Drawings
- Piping standards
- Plot plan(s)
- Pipeline transposition

Piping layout studies and vessel orientations
Plant equipment location control plan (equipment general arrangement plan)
3D plant design model index
Piping drawing index
Piping plan drawings
Piping isometrics
Revamp demolition drawings
Tie-in location index
Tie-in isometrics
Heat tracing manifold index
Heat tracing plans
Heat tracing details
Heat tracing isometrics
Piping stress sketches
Piping material sketches

Lists
Interference reports
Piping isometric index
Tie-in list

Calculations
Deadweight loads for structures

Data files
Electronic drawings
Final electronic database

Piping material control

Specifications
Commodity purchase specifications (pipe, fittings, flanges, etc.)
Field receiving geographic color code

Drawings
None

Lists
Piping material summary (preliminary, intermediate, and final)
Shortage and overage reports

Calculations
Piping material cost estimations

Data files
Material history (item and source)

- Pipe stress engineering
    - Specifications
        - Piping flexibility design criteria
        - Preengineered and engineered piping support elements
        - Metallic expansion joints
        - Elastomer expansion joints
        - Pipe restraints and shock arrestors
    - Data sheets
        - Engineered spring supports
        - Engineered expansion joints
    - Drawings
        - Preengineered pipe support elements
    - Lists
        - Piping flexibility analysis log
        - Calculation data files
        - Piping flexibility analysis

Appendix B

The Cradle-to-Grave Concept

The following is a simplified description of the term *cradle-to-grave* when used in connection with piping. "Cradle" refers the initiation of any work that includes piping. This may be the award of a total project. Or, it may be a simple change order to add one piece of equipment and a few lines. "Grave" refers to completion of construction activities leading to start-up of the plant or system. All the required steps from beginning to end for the successful completion of the project or change order would be considered part of this concept.

Action	**Who**
P&ID is marked for new exchanger and lines	Process engineer
Define line commodity	Process engineer
Determine line size	Process engineer
Define line design pressure	Process engineer
Define line operating pressure	Process engineer
Define line design temperature	Process engineer
Define line operating temperature	Process engineer
Define any upset condition pressure	Process engineer
Define any upset condition temperature	Process engineer
Define the system life (corrosion allowance criteria)	Process engineer
Define any insulation criteria	Process engineer
Define any heat tracing criteria	Process engineer

Issue P&ID per project procedure	Process engineer
Prepare scope change and estimate hours	Piping engineering lead
Define piping metallurgy	Piping material engineer
Develop new line class (if required)	Piping material engineer
Define piping line class (flange rating)	Piping material engineer
Calculate pipe wall thickness (if required)	Piping material engineer
Assign pipe line identification number	Piping material engineer
Complete required data listing in line list	Piping material engineer
Develop insulation specification	Piping material engineer
Layout new line routing	Piping design
Define location of new nozzle on 10-V-101	Piping design
Forward vessel sketch to vessel group	Piping design supervisor
Other vessel-related work	Vessels engineering and design
Provide for proper flexibility	Piping design
Create stress sketch with all req'd data (*)	Piping design
Forward stress sketch to stress	Piping design supervisor
Review and approve or comment as req'd	Pipe stress engineer
Define method of exchanger support	Piping design
Define method of line support	Piping design
Create support sketches with all req'd data (*)	Piping design
Forward support sketches to Structural	Piping design supervisor
Other structural-related work	Structural engineering and design
Create material sketch with all req'd data (*)	Piping design
Forward material sketch to material control	Piping design supervisor
Define positioner location requirements for CV	Piping design
Forward control valve position data to instr. eng.	Piping design supervisor
Perform preliminary material take-off	Piping material control
Prepare RFQ documents	Piping material control
Prepare shop fabrication RFQ	Piping engineering lead
Issue RFQ	Procurement

(*) When possible, all "sketches" required to document data transfer should be done electronically.

Track status of RFQ	Piping material control
Report RFQ status to PEL	Piping material control
Finalize detail design	Piping design
Include any stress comments	Piping design
Include any structural comments	Piping design
Perform 10-E-152 vendor dwg squad check	Piping design
Perform control valve vendor dwg squad check	Piping design
Perform required checks of design	Piping design
Release drawing to PEL for issue	Piping design supervisor
Perform final material take-off	Piping material control
Identify any differences in material req'mts	Piping material control
Prepare supplement to material RFQ	Piping material control
Issue PO for long lead valve items	Procurement
Issue PO for other assembly material	Procurement
Issue PO for shop-fabricated piping	Procurement
Establish, track, and report status of valves	Expediting
Draft construction work package (CWP)	Piping engineering lead
Review and approve piping documents for CWP	Piping engineering lead
Issue invitation to bid on CWP	Contracts administration
Issue drawings for shop-fabricated piping	Piping engineering lead
Fabricate shop piping	Pipe fabrication vendor
Manufacture long delivery valves	Valve vendor
Manufacture control valves	Control valve vendor
Know and report status of long lead valves	Piping engineering lead
Know and report status of pipe fabrication	Piping engineering lead
Answer CWP technical questions	Piping engineering lead
Award the CWP	Contracts administration
Start construction	Contractor
Modify vessel 10-V-101	Contractor
Form and pour new exchanger foundation	Contractor
Receive and set new exchanger	Contractor
Receive fabricated piping	Contractor
Receive all other piping assembly items	Contractor
Receive long delivery valves	Contractor
Install new prefabricated piping	Contractor
Install new long delivery valves	Contractor
Install all other assembly piping	Contractor
Install all instrument items	Contractor

Resolve questions regarding missing items	Piping engineering lead
Resolve questions regarding any misfits	Piping engineering lead
Provide criteria for testing	Piping engineering lead
Test new piping installation	Contractor
Provide insulation criteria	Piping engineering lead
Insulate new piping installation	Contractor

Appendix C

Glossary

A&E—"Architect and Engineer"—A term used to refer to the type of project and/or the type of company executing a project. (Example: This is an A&E project. This is an A&E firm.) An A&E firm or a firm doing an A&E project does not normally do any procurement or construction.

AFC—"Approved for Construction"—(document status) Normally reserved for formal project deliverables that have been checked, corrected, and approved (in accordance with the project procedures) for release to the construction entity.

AFD—"Approved for Design"—(document status) Normally reserved for formal project design criteria deliverables (such as P&IDs) that have been reviewed, corrected, and approved (in accordance with the project procedures) for release to the disciplines to start the detailed design phase of the project. Sometimes used interchangeably with IFD.

AFE—"Authorization for Expenditure"—(client term) This term is used to define a process and a milestone in the early phase of a project. This phase will be the definitive scope and cost justification that allows for the final go-ahead.

ARO—"After Receipt of Order"—(commercial term) This is a term normally used by the seller to suggest the estimated delivery (12 weeks ARO) of an item on the RFQ.

BFD—"Block Flow Diagram"—(document type) Term used to describe a simplified drawing showing a group of process units that make up the project. Each unit is normally depicted as box or block.

BOM—“Bill of Material”—(document type) Term used in piping and other disciplines to describe the section of a document that lists the material for that document or assembly. May also be used as a term for a standalone document that lists material requirements for another document.

CAD—“Computer-Aided Design”—(computer term) A broadly applied term relating to any use of computers in the performance of design functions.

CAE—“Computer-Aided Engineering”—(computer term) A seldom used but broadly applied term relating to any use of computers in the performance of engineering functions.

CDO—“Certified Dimensional Outline”—(document type) Refers to any document submitted by an outside supplier or vendor. The CDO as initially submitted will be referred to as a “preliminary CDO.” When it has been determined that the drawing meets all the project requirements, it will be referred to as an “approved CDO.”

CLS—“Control Level Schedule”—(scheduling document) A CLS is the discipline supervisor and lead tool used to manage the work on projects.

CM—“Construction Management”—This can refer to the phase of a project (This project is in the construction management phase), the the type of project (This is a construction management project), or it can refer to identity (That is the responsibility of construction management).

CPM—“Critical Path Method”—(scheduling term) Refers to the technique of creating a graphic system network that defines all the required work activities for a project including a time duration for each activity. This method identifies the network path with the longest duration.

CWP—“Construction Work Package”—(commercial term) Refers to the documentation prepared by the responsible discipline(s) on a project to define a segment of work that will be subcontracted.

E—“Engineering”—This term is used to refer to the type of project. A firm doing an E-only project would normally do only engineering and design functions.

ECN—“Engineering Change Notice”—(document type) The ECN is a tool (document) initiated and used by project controls to inform the disciplines of approved changes in the scope of facilities and scope of services that affect the budget. (Also see FDCN and PDN)

E&P—"Engineering and Procurement"—This term is used to refer to the type of project. A firm doing an E&P project would normally do all or most of the procurement.

EPC—"Engineering, Procurement, Construction"—This term is used to refer to the type of project. A firm doing an EPC project would normally do all of the procurement and the construction.

EPCM—"Engineering, Procurement, Construction Management"—This term is used to refer to the type of project. A firm doing an EPCM project would normally do some of the procurement and manage the construction effort done by subcontractors.

ETA—"Estimated Time of Arrival"—(commercial term) The estimated time of arrival is a date-oriented term that commonly relates to a delivery milestone for equipment, materials, supplies, or services. (Also see RAS)

FAS—"Free Alongside Steamer"—(commercial term) Goods and materials delivered to the dock. Loading is by others.

FDCN—"Flow Diagram Change Notice"—(document type) The FDCN is a tool (document) initiated and used by projects to document and approve all changes on P&IDs that may affect the budget. (Also see ECN and PDN)

FEED—"Front-End Engineering Development"—(industry term) This relates to a time period in the life of a project. It also carries the connotation of specific activities and deliverables. The term "Phase I" is sometimes used for this same period and group of activities.

FOB—"Free on Board"—(commercial term) Goods or materials loaded on the vehicle of conveyance.

HO—"Home Office"—(estimating term) A commonly used term used to differentiate engineering office activities and requirements from the jobsite construction-related activities and requirements.

IFA—"Issued for Approval"—(document status) Normally reserved for formal project deliverables that have been checked, corrected, and are now being released to the client for approval.

IFB—"Issued for Bid"—(document status) A term relating to the status of a construction work package. Issued for bid means that this package has been given to the bidders. Deliverables with an IFB stamp will need to have all future changes identified.

IFC—"Issued for Construction"—(document status) Normally reserved for a production engineering deliverable that has been checked, corrected, and does not require client approval prior to release to construction.

IFD—"Issued for Design"—(document status) Normally reserved for formal project design criteria deliverables (such as P&IDs) that have been reviewed, corrected, and approved (in accordance with the project procedures) for release to the disciplines to start the detailed design phase of the project. Sometimes used interchangeably with AFD.

IFR—"Issued for Review" (document status) Normally used for a production engineering deliverable that does not require formal approval. This document may or may not be checked but is released to the client (and/or other disciplines) for comments prior to completion and release to construction.

ISBL—"Inside Battery Limits"—(technical term) Common industry term used to define the boundary of geographical work units. (Also see OSBL)

ISO—"International Standards Organization"—Normally seen as ISO 9001. The ISO 9001 is the standard that is used to qualify a company to do engineering.

LCP—"Location Control Plan"—(document type) The LCP is normally a developmental tool used on a typical project. It is initiated by and maintained by the plant layout group but requires responsible handling by all disciplines. The LCP comes to life after the plot plan is issued "AFC." It is intended that the LCP will show all equipment and nonequipment space requirements complete with actual (Cartesian) coordinates for location. The LCP will go out of existence as the structural foundation location drawing is prepared and released.

MFD—"Mechanical Flow Diagram"—(document type) Industry term used by some for the detail flow schematic of a process system complete with all valving and control logic. (Also see P&ID)

MTO—"Material Take-Off"—(technical term) An omnibus term sometimes used to define a specific activity and sometimes misused to designate the piping material control group, in general.

NDE—"Nondestructive Examination"—(technical term) Common term used in various industries to refer to requirements relating to the testing and certification of materials. Criteria for NDE in piping are normally

found in the project piping material line class specifications or the welding specifications.

OSBL—"Outside Battery Limits"—(technical term) Common industry term used to define the boundary of geographical work units. (Also see ISBL)

PDI—"Piping Design Instructions"—(document type) A typical piping department tool to be used on all projects to provide and control job-specific technical data. This tool, properly managed, insures piping is in compliance with the ISO 9001 guidelines.

PDL—"Piping Design Lead"—(job function) This position/function reports to the LPE on a typical project and is responsible for the detail technical piping design activities.

PDN—"Pending Deviation Notice"—(document type) The PDN is a tool (document) initiated and used by the discipline leads to inform the project manager of all changes in the scope of facilities and scope of services that may affect the budget. (Also see ECN and FDCN)

PDS—"Plant Design System"—(computer term) Refers to the intergraph multidiscipline 3D computer programs.

PEL—"Piping Engineering Lead"—(job function) This position/function reports to the piping department manager and to the engineering manager on a typical project and is responsible and accountable for the total piping effort.

PEP—"Project Execution Plan"—(typical corporate term) A series of documents produced on every project to define specific criteria for the execution of that project.

PFD—"Process Flow Diagram"—(document type) Term used in the industry for a simplified or conceptual schematic of a process unit.

P&ID—"Piping and Instrument Diagram"—(document type) Common industry term for the detail flow schematic of a process system complete with all valving and control logic. (Also see MFD)

PIM—"Project Information Manager"—(job function) The title or position associated with the person who has the assigned responsibility for all electronic applications on a specific project.

PMC—"Piping Material Control"—(job function) This position/function reports to the LPE on a typical project and is responsible for the piping material take-off and procurement interface activities.

PME—"Piping Material Engineer"—(job function) This position/function reports to the LPE on a typical project and is responsible for the piping material engineering activities.

PO—"Purchase Order"—(commercial term) Common term defining the document or documents required to complete the purchase of equipment, materials, or services.

PPM—"Project Procedure Manual"—(typical corporate term) A second-tier book of documents addressing specific procedures for the day-to-day project functions (e.g.: drawing approvals).

Pre-FEED—This term refers to the phase of a project: Pre (before) the FEED (front-end engineering development) work by the client or an engineering contractor.

PSE—"Piping Stress Engineer"—(job function) This position/function reports to the LPE on a typical project and is responsible for the piping stress activities.

PWHT—"Post-Weld Heat Treat"—(technical term) A common term used in various industries to refer to requirements relating to procedures to be followed in the manufacturing or fabrication of materials or assemblies. Criteria for PWHT in piping are found in the project piping material line class specifications.

RAS—"Required at Site"—(commercial term) Required at site is a date-oriented term that commonly relates to a delivery milestone for equipment, materials, supplies, or services. (Also see ETA)

RDB—"Reference Database"—(computer term) The 3D-PDS term for the location of electronic data related with the project.

RFP—"Request for Purchase"—(commercial term) Refers to the step in the procurement after the quotes have been received, the bids have been evaluated, one or more vendors/suppliers have been selected, and the paperwork is prepared for the actual issue of a purchase order.

RFP—"Request for Proposal"—(commercial term) Refers to the step in the contracts process where a CWP is ready for release to the potential bidders. Similar to the RFQ when buying equipment or bulk material.

RFQ—"Request for Quote"—(commercial term) A term relating to the status of a purchase order for equipment or bulk material. A request for quote

means that this package has been given to the vendor/supplier to submit price and delivery data.

SOF—“Scope of Facilities”—(document term) Refers to the first portion of the formal scope of work document used in the definition of a project. The SOF defines what is included as the physical plant, equipment, and systems.

SOS—“Scope of Services”—(document term) Refers to a portion of a formal scope of work document used in the definition of a project. The SOS defines the method of project execution and the planned deliverables.

SOW—“Scope of Work”—(document term) Refers to the two-part formal scope of work document used to define a project. The SOW contains the SOF and the SOS.

TDC—“Technical Document Control”—(job function) The group that is charged with the responsibility for the handling and control of all technical documents on a project. This includes all client reference documents, all vendor/supplier documents, all internal discipline project deliverables, and some selected project developmental documents (e.g.: LCP).

TIC—“Total Installed Cost”—(financial term) The phrase used on a project to indicate the gross cost of the finished plant. TIC will include all costs relating to the client’s front-end work, the detailed engineering and design, the purchase of all equipment and bulks, the direct field labor, any indirects, all services, all permitting, all profits, and all fees.

UDD—“Utility Distribution Diagram”—(document type) Common industry term for plot plan-oriented distribution schematic of utility systems. (Also see UFD)

UFD—“Utility Flow Diagram”—(document type) Common industry term for plot plan-oriented distribution schematic of utility systems. (Also see UDD)

Appendix D

Suggested Piping File Index

No attempt is made to suggest any kind of numbering system here. When it comes to numbering, there are just too many possibilities. This is an area that is best left up to the responsible person within each company. We will focus on four different classes of files. These classes (or catagories) of files have specific origins, purposes, users, and dispositions.

CLASS A—RETENTION FILES (ARCHIVE)

It is recommended that the files listed in this category be retained as a part of the project historical record under the piping catagory.

- Piping design criteria, Client basis of engineering design development
- Piping design criteria, Client specifications
- Piping design criteria, Client standards
- Piping project execution plan checklist
- Piping project work scope (facilities description and services description)
- Piping project execution procedures (ISO 9001 guidelines)
- Piping labor hour estimate(s)
- Piping labor hour deviation log
- Piping labor hour deviation worksheets
- Piping project specifications, client comment and approval copy
- Piping project standards, client comment and approval copy
- Piping project plot plan(s), client comment and approval copy

- Piping material cost estimate data
- Piping control level schedule
- Piping material engineering calculations
- Piping stress log
- Piping stress sketches
- Piping stress calculations
- Piping document issue schedule(s)
- Piping vendor shop fabrication status report
- Piping material certificates of compliance (mill certs)

CLASS B—DELIVERABLES

The files listed in this category are all piping specifications, standards, and drawing deliverables for the project. By definition, a copy of each of these documents is issued to the client and to the job site through some channel. These documents are, therefore, a part of the project record but are not normally retained as a part of the project archive.
(See Appendix A for the suggested list of piping deliverables.)

CLASS C—REFERENCE FILES

The files listed in this category are primarily informational and developmental. These documents are used in the day-to-day execution of the piping effort. These documents are not normally retained as a part of the piping project historical record.

- Project directory (list of company and client participants, may include an organization chart)
- Project description (the original proposal version and all revisions)
- Project execution plan checklist
- Project communications
- From client to company (piping-related issues only)
- From company to client (piping-related issues only)
- Vendor or supplier correspondence (piping-related issues only)
- Project directives
- Conference and meeting notes
- (other as required)

REPORTS

- Piping needs list
- Piping reports
- Piping weekly project engineering task force reports
- Piping monthly project and departmental status reports
- Piping deliverables status reports
- Piping procurement status reports
- Piping vendor visit reports
- Piping job-site visit reports

PIPING DEVELOPMENT DOCUMENTS—PROJECT SCOPE

- Proposal version
- Project draft review and approval versions

PIPING DEVELOPMENT DOCUMENTS—ESTIMATES

- Estimate development backup—Piping material engineering
- Estimate development backup—Piping design group
- Estimate development backup—Piping material control
- Estimate development backup—Pipe stress engineering
- Estimate development backup—Piping engineering lead

PIPING DEVELOPMENT DOCUMENTS—SCHEDULING

- Schedule development backup—Piping material engineering
- Schedule development backup—Piping design group
- Schedule development backup—Piping material control
- Schedule development backup—Pipe stress engineering
- Schedule development backup—Piping engineering lead

PIPING DEVELOPMENT DOCUMENTS—CONTRACTS

- Construction work package (CWP) list
- CWP—XXX draft
- CWP—YYY draft
- CWP—ZZZ draft
- (others as required)

PIPING DEVELOPMENT DOCUMENTS—PURCHASE ORDERS

- Approved vendor list
- Piping purchase order index
- Standard notes—Piping purchase orders
- RFQ/PO—Pipe fabrication
- RFQ/PO—Valves
- RFQ/PO—Pipe
- RFQ/PO—Fittings
- RFQ/PO—Flanges
- RFQ/PO—Assembly items
- RFQ/PO—SP items
- RFQ/PO—Engineered spring hangers
- RFQ/PO—Engineered expansion joints
- RFQ/PO—(others as required)

CLASS D—RESOURCE FILES (EXTERNAL DOCUMENTS)

The files listed in this category are all generated external to piping. These documents will include vendor drawings along with the specifications, standards, and other deliverables from all other engineering disciplines. The files listed here are not retained by piping as a part of the piping project historical record.

PROCESS ENGINEERING DOCUMENTS

- Project flow diagram symbol and legend sheet(s)
- PFD (process flow diagrams)
- P&ID (piping and instrument diagrams)
- UFD (utility flow diagrams)
- UDD (utility distribution diagrams)

CIVIL ENGINEERING DOCUMENTS

- Specifications
- Standards
- Drawings

STRUCTURAL ENGINEERING DOCUMENTS

- Specifications
- Standards
- Drawings

ARCHITECTURAL DOCUMENTS

- Building list (index)
- Specifications
- Standards
- Drawings

BUILDING SERVICES DOCUMENTS (HVAC, PLUMBING, AND FIRE PROTECTION)

- Specifications
- Standards
- Drawings

MECHANICAL (EQUIPMENT) ENGINEERING DOCUMENTS

- Equipment list (index)
- Specifications
- Standards
- Equipment data sheets
- Drawings

ELECTRICAL ENGINEERING DOCUMENTS

- Specifications
- Standards
- Drawings

INSTRUMENT ENGINEERING DOCUMENTS

- Instrument list (index)
- Specifications

- Standards
- Instrument data sheets
- Instrument outline drawings

ENVIRONMENTAL ENGINEERING DOCUMENTS

- Specifications
- Standards
- Drawings

CONSTRUCTION ENGINEERING DOCUMENTS

- Specifications
- Standards
- Drawings

(OTHERS AS REQUIRED)

- Specifications
- Standards
- Drawings

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About the Author

James O. Pennock has more than 45 years of diversified process plant engineering experience. He has been involved in numerous domestic and international projects, in addition to computer graphic software development, manufacturing engineering, and pipe fabrication shop engineering. His resume includes both home office and job site assignments on refinery, chemical, petrochemical, power, pulp/paper, utility, industrial manufacturing, and environmental projects. His experience includes model maker, designer, area supervisor, lead design supervisor, lead piping engineering, piping materials manager, engineering manager, project engineer, and piping department manager—much of this with one of the world's top engineering and construction companies. He has also developed and taught a number of piping specific training courses. He especially enjoys teaching good piping to eager newcomers to the industry. Mr. Pennock, now semi-retired, lives in Florida where he does occasional consulting work.