

1

Introduction

1.1

General remarks on process plant design

In process plants, source materials (reactants) are converted into merchantable products. Source materials and products may be gaseous, liquid or solid substances or even mixtures of these different states (suspensions, particulates etc.) Products may be intermediate or end products which are being processed step by step. The result is a whole host of possible problems or types of plants that solve these problems. The following list shows at least some typical products of process plants and their lines of business:

- chemistry: paints, plastics, fibres, fertilizers etc.
- pharmaceuticals: drugs
- cosmetics: creams, lotions, cosmetic products etc.
- refineries: fuels, basic products for chemistry, lubricants etc.
- building materials: cement, sand, gravel etc.
- food industry: fats, oils, cereals, sugar etc.
- coal: mining and processing of coal

This book deals with the activities arising during the phase of design, construction and start-up of process plants. Here, the emphasis is on *process* plants, since, in comparison with production plants, totally different planning instruments (e.g. CAD-systems) and steps (e.g. pipe design) are required. The activities are, as far as possible, described chronologically, beginning with the product idea up to the acceptance of a successfully commissioned plant. In order to keep the scope of this book within reasonable limits it cannot go into each and every detail, but instead refers to secondary literature. Importance is attached to practical orientation. Since, depending on the company, procedures regarding project management are often very different not all procedural methods can be taken into account. The focus is rather on the imparting the understanding of basic structures.

The book has mainly been written for students of process engineering and chemical engineering as well as professional newcomers of these disciplines working in the field of process plant engineering.

Nowadays, process plant engineering is characterized by globalization. Engineers are increasingly required to dispose of so-called “soft skills” apart from their respective expertise. In the field of plant engineering, this includes mainly team-building qualities, communicational and language skills. Against the background of the strictly interdisciplinary character of procedural projects, the ability to communicate between the disciplines involved in the project (process engineers, chemists, civil engineers, architects, electrical engineers, control engineers, business administrators and jurists) is of special importance. Thus, the different “languages” and aims of the individual disciplines will be addressed with an attempt to develop mutual understanding.

Apart from the technical aspects, and in order to take account of the enormous price erosion created by international competition in the field of plant engineering, the commercial aspects of project engineering will be discussed. Engineers may often aim to achieve excellent or best-quality technology, but the costs arising from this may not adequately be taken into consideration. Moreover, young project engineers, may sometimes execute disadvantageous sale contracts out of ignorance. Unfortunately it sometimes happens that even dubious requirements such as liability towards consequential loss or damage or horrendous percentages for penalties are accepted by young project engineers due to a lack of knowledge, and their sense of commercial matters therefore needs to be sharpened. This includes, inter alia, a comprehensible and simplified introduction to claims management and the basics of contract making.

Owing to increasingly strict environmental requirements, technology for environmental protection is gaining more and more importance. Processes for the purification of exhaust gases, waste water and solid waste have to be integrated into process plants in such a way that the accruing residual materials—provided they cannot be completely avoided or converted into recyclable material—are at least minimized or rendered as harmless as possible. This effort is subsumed under the term “Production-Integrated Environmental Protection” /1.1/. Depending on the country-specific legislation, environmentally relevant measures can cause the environmental-engineering components of a process plant to exceed actual production plants both in volume and in required investment. Here, the expenses for the flue gas cleaning of a garbage incineration plant have to be mentioned as an example. In addition, the expenses for so-called “authority engineering” have to be taken into account, the main goal of which is the achievement of official authorisation for the construction and operation of the designed plant.

1.2 Project

The goal of plant design is the realization of process plants within the framework of *projects*. /1.2/. Here, as a rule, two parties have to be distinguished: first the *plant operator* who wants to procure and operate a process plant, and secondly the *plant constructor* who, according to the agreed scope of delivery and service, takes

on the planning, delivery, assembly and start-up. Exceptions are some large-scale enterprises which utilise their own departments for plant design, so that both parties are represented in one company.

The two parties mentioned above follow completely different objectives: The plant operator wants to make as much profit as possible by producing and selling a certain quantity of a product in a defined quality. For this purpose, the relevant process plant has to be acquired at the lowest price possible and erected and put into operation as quickly as possible. These efforts come up against limiting factors both regarding acquisition costs and time scheduling. This point is dealt with in more detail in Chapter 2, section 2.1.3, “Costs” and Chapter 4, section 4.1.4, “Time scheduling/deadline control”.

The aim of the plant manufacturer is to keep the expenses for planning and erection of the plant as low as possible. However, restrictions are placed on this effort as well. For example, the procurement of the equipment does not allow of discretionary savings, since it has to meet the quality requirements guaranteed in the contract. The difference between the selling price achieved and the actual costs represents the profit or even the loss for the plant manufacturing company. How to keep the actual costs low is shown essentially in Chapter 4, “Project Execution”.

These different targets evidently provoke a certain conflict of interests between the parties involved. Considering the selling price of the designed process plant which is to be stipulated, this becomes clear. In order to avoid disputes that may arise from this conflict situation, comprehensive *contracts* binding for both sides are executed in the majority of cases. Since a lot of technical aspects are treated in a sales contract, too, Chapter 3, “Contract”, deals with this topic in a way that is designed to be comprehensible to engineers.

As already mentioned, the manifold procedural tasks entail a similar number of different plant versions. Apart from the kind of process plant, there are large differences with regard to size in respect to *plant capacity*. This usually refers to the annual quantity of manufactured products. According to the plant size, different planning activities and, above all, different project structures are required. For the sake of clarity, the following types of plants are going to be distinguished.

Small plants: Here, plants with a production volume of up to €500,000 are concerned. The entire planning and erection regarding assembly of these smaller plants are from one hand. Frequently they are still transportable and thus can be kept in stock. The duration of the project is rather short, i.e. up to a maximum of one year. The engineer primarily in charge of such a project, the so-called “project manager”, can carry out several such projects at the same time, often being responsible not only for the organization but also for the technical handling. There is a multitude of suppliers for such small plants, both small and large enterprises. Examples for smaller plants are more complex systems such as redundant vacuum pump units together with the respective periphery, silo plants, spray

driers with equipment or, as shown in Figure 1.1, complex metering systems (LEWA company).

Medium-sized plants: Under this category process plants with order volumes of single or double digit amounts in millions are subsumed. The term of a project has to be estimated as one to three years. The transaction is carried out by a project team under the leadership of a project manager. The tasks of the project manager are focussed on organisational matters. Depending on the agreed scope of delivery and service, the transaction comprises the handling of all steps of plant design. Such systems are supplied by medium-sized and large-scale enterprises within a certain range of plant types. Individual assembly sections, such as pipelines or E/MC-technology, can be subcontracted. Medium-sized plants often include several smaller plants integrated as components. Thus, medium-sized plants might include, for example, individual chemical plants, food production plants, sewage plants, pharmaceutical plants etc. Figure 1.2 shows the example of the Strobilurin plant of the BASF Schwarzheide GmbH with a contract value of €14.9 m. Figure 1.3 shows a photo of a combined heat and power plant of the G.A.S. Energietechnologie GmbH with a contract value of approx. €3 m.

Large-scale plants: The order volumes of such large-scale plants are approximately a billion. At any rate, the project term exceeds two years. The handling is controlled by



Figure 1.1 LEWA dosing and mixing plant for the continuous fabrication of sulphuric acid in different concentrations, e.g. for battery manufacturing.



Figure 1.2 Strobilurin plant for BASF Schwarzheide GmbH with an order value of 14.9 million €.



Figure 1.3 Combined heat and power plant in Dortmund/Derne with four modules for G.A.S. Energietechnologie GmbH (order value approx. 3 million €).

large project teams headed by several project managers. The general project manager takes on the overall responsibility which involves organisational labour only. In many cases, one or two staff members are solely entrusted with the time scheduling for which special planning tools, such as network analysis, are applied /1.3, 1.4, 1.5/. Suppliers of the process-engineering part of such large-scale plants are a few groups active in the field of process engineering. The handling is often carried out in cooperation with one or more syndicate partners with



Figure 1.4 Municipal waste incineration power plant with flue gas cleaning and waste water treatment for RWE Power AG in Essen-Karnap. The plant has a capacity of approx. 750 000 t/a. The total investment amounted to approx. 500 m €.

equal rights, for instance for the constructional part. Usually, large-scale plants are composed of several medium-sized and a multitude of small plant units. Examples for large-scale plants are power stations (see Figure 1.4), refineries, complete chemical complexes (see Figure 1.5), steelworks, etc.

Since this book is aimed to some extent at new project engineers, it deals with plant design for medium-sized plants. This automatically includes the steps required for small plants. Large-scale plants differ from medium-sized plants mainly in their higher degree of complexity. Thus project management /1.6, 1.7, 1.8/ gains even more importance. A very comprehensive depiction of the activities involved in the design of process plants is to be found in the work of K. Sattler /1.9/.

1.3

Demands on project engineers

It is quite improbable that an entrant will be immediately put onto the management of a major project. Such an entrant is more likely to be brought in as a project



Figure 1.5 Chemical complex erected in Katar by UHDE GmbH, Dortmund, Germany. The chemical complex consists of three main plants for the production of 260 000 t/a chlorine, 290 000 t/a caustic soda, 175 000 t/a ethylene dichloride and 230 000 t/a vinyl chloride. The order value was approx. 450 million US\$.

engineer. In case of a positive career s/he may work his way or her way into the project management, initially starting with rather small or medium-sized projects. Then, with sufficient experience and relevant further education in the field of project management—often within the framework of in-house training courses—s/he may be assigned to the management for a large-scale project..

Nowadays, most different demands are placed on project engineers /1.10, 1.11, 1.12/. Apart from technical qualifications, especially in plant engineering, the so-called “soft skills”, i.e. personal characteristics, are demanded more and more. Table 1.1 gives a compilation of some important demands on project engineers.

Depending on company and project, the individual demands are weighted differently. Since medium-sized and large-scale systems are always designed and handled by project teams, the demands on team spirit and communicational abilities are always of the utmost importance.

Within the framework of the contract award negotiations with subcontractors, project engineers not only have to act and negotiate respectively, they are required or assumed to have more and more basic *commercial* knowledge. Meanwhile, at least sound basic knowledge of the English language is a matter of course, since the business of process plant engineering is, to a large extent, internationally oriented. The language of projects carried out abroad is almost always English. Of course, knowledge of the respective native language is always of advantage.

Table 1.1 Job specifications for project engineers.

<i>Technical requirements</i>	<i>Personal qualifications</i>
Expert knowledge in the disciplines:	Communication skills
Chemical Process Engineering	Team spirit
Thermal Process Engineering	Interdisciplinarity
Mechanical Process Engineering	Cross communication within the project team
Biological Process Engineering	Appearance
Apparatus and Pipeline Engineering	Stress tolerance and adaptability
Pumps and Compressors	Independence
Materials Science	Loyalty
E/MC-Technology	Readiness to take on responsibility
	Assertiveness
EDP Capabilities:	Negotiating skills
Word Processing	Cost consciousness
Spreadsheet Analysis	Spoken and written English
CAD and CAE in Plant Engineering	Additional foreign language competence
Pipe Stress Analysis	Experience acquired abroad

On the other hand, companies are aware of the fact that project engineers cannot meet all demands. For this reason, the relevant further professional education should not be neglected. Proactively initiated measures like language courses at adult education centres or professional seminars at the Haus der Technik (House of Technology) in Essen, for example, or at the Technischen Akademie of Wuppertal (Technical Academy of Wuppertal) will be appropriate.

In any case, entrants should prepare themselves right from the beginning for lifelong learning and further education that will accompany their entire professional career.

1.4

Overview of activities

Plant design comprises all stages from the product idea to the commissioning and, finally, to the operation of the production facility. This, however, requires a multitude of activities to be carried out. In order to facilitate the way of approaching this matter, the complete project term is being divided into two phases:

Project planning: Within the context of project planning it is to be decided whether—and if so, by whom—a plant will be manufactured. During this phase of planning, cost forecasts and analyses play an important role. To be able to assess the production costs for the manufacturing of a planned product as exactly as possible, so-called *basic engineering* has to be carried out. This includes, inter alia,

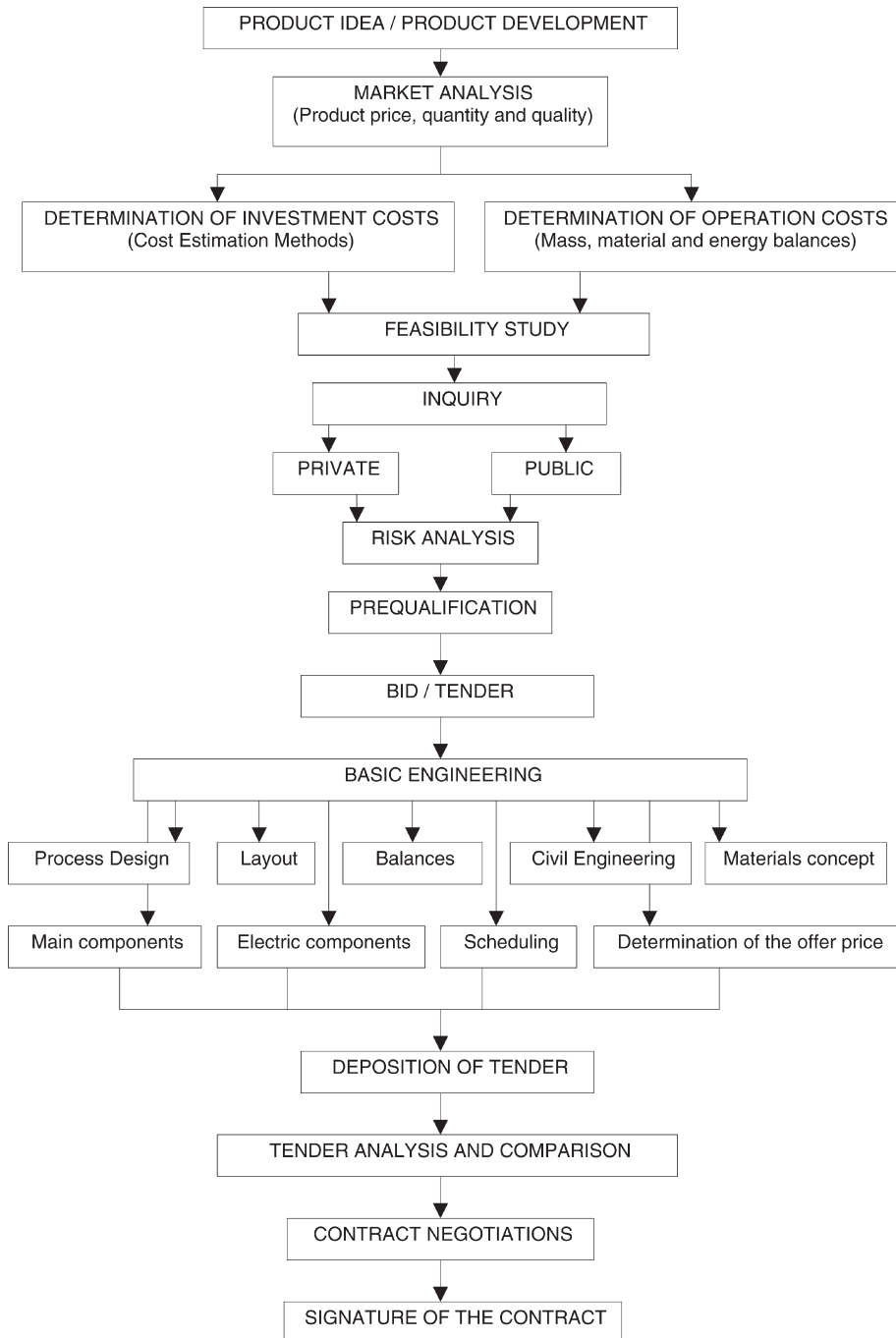


Figure 1.6 Overview of the activities during the project planning phase.

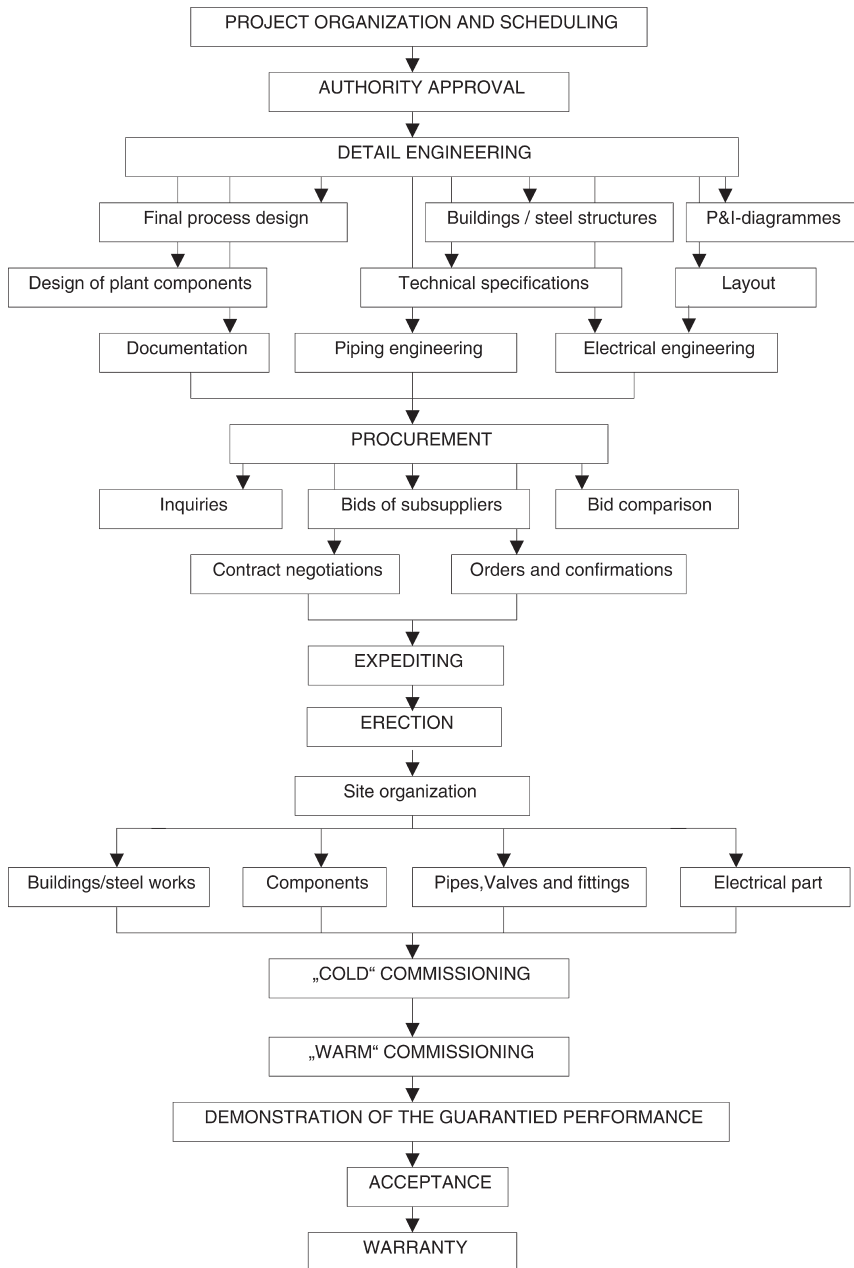


Figure 1.7 Overview of the activities during the execution phase.

the determination and optimization of the process concept with the required balancing regarding material and energy, as well as the implementation of an at least rough component and installation plan (layout). Another essential component of project planning is the *tender* and *contract award* for the procurement of the designed plant.

Project execution: Usually, the execution of a process plant project seamlessly follows the project planning, i.e. after the starting signal for the construction has been given by the competent authority. The planning activity necessary for the project execution is known as *detail engineering*. Apart from the planning steps, further activities such as *procurement* and *assembly* of the equipment as well as *commissioning* of the plant have to be carried out. With acceptance after the successful test, the project is completed. This is where the actual operation of the plant is going to start.

The interface between project planning and project execution is the *conclusion of the contract*. This means the signing of the contract worked out by the plant operator and the plant constructor stipulating all commercial and technical project matters in detail.

The most important activities during the phase of planning and execution are shown in Figures 1.6 and 1.7. The project development phase comprising the period from the idea for the project to the invitation to tender usually requires one to three years. Owing to difficulties in the field of research and development or problems arising from political arguments, to mention only two possible reasons, the phase of project development may, in individual cases, span up to ten years.

Even the phase of the contract awarding, which begins with pre-qualification and ends with the conclusion of the contract, may extend over several years, especially due to lengthy contract negotiations.

The actual phase of realization, which is equivalent to project execution, comprises two to four years and depends essentially on the scope of the project. Of course, considerable delays may also arise owing to climatic (violent storms etc.) or political difficulties (military conflicts etc.).

The operating phase of the erected and running plant ranges from 5 to 30 years, depending on the operator's philosophy.

The following chapters will describe chronologically the most important activities in carrying out medium-sized projects.

