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Königstein (Taunus) near Frankfurt/Main
Federal Republic of Germany
25 - 26 June 1970

EXPLORATION AND PLANNING OF CHEMICAL PLANTS 1/

by

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SUMMARY

EXPLORATION AND PLANNING OF CHEMICAL PLANTS [1]

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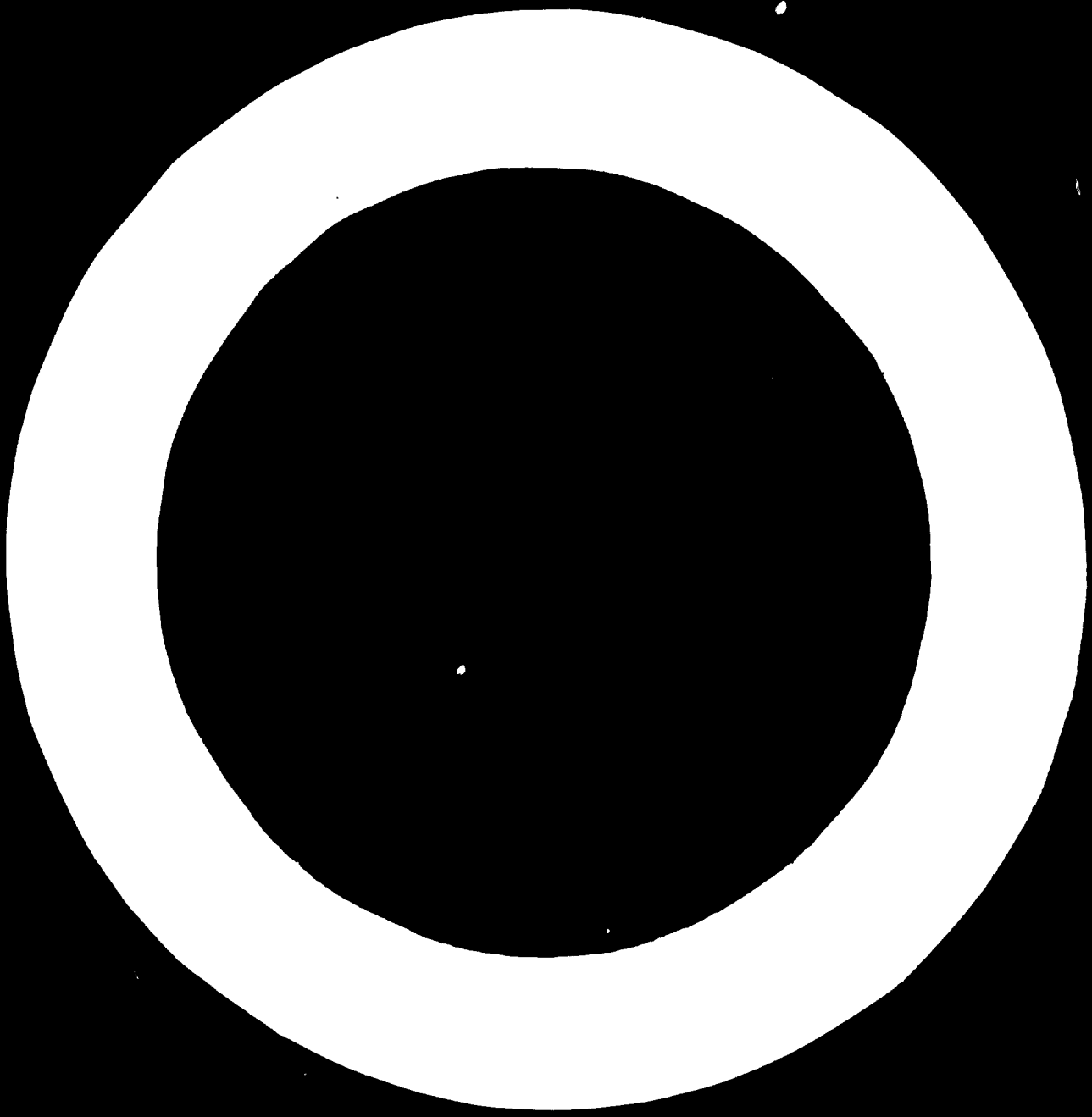
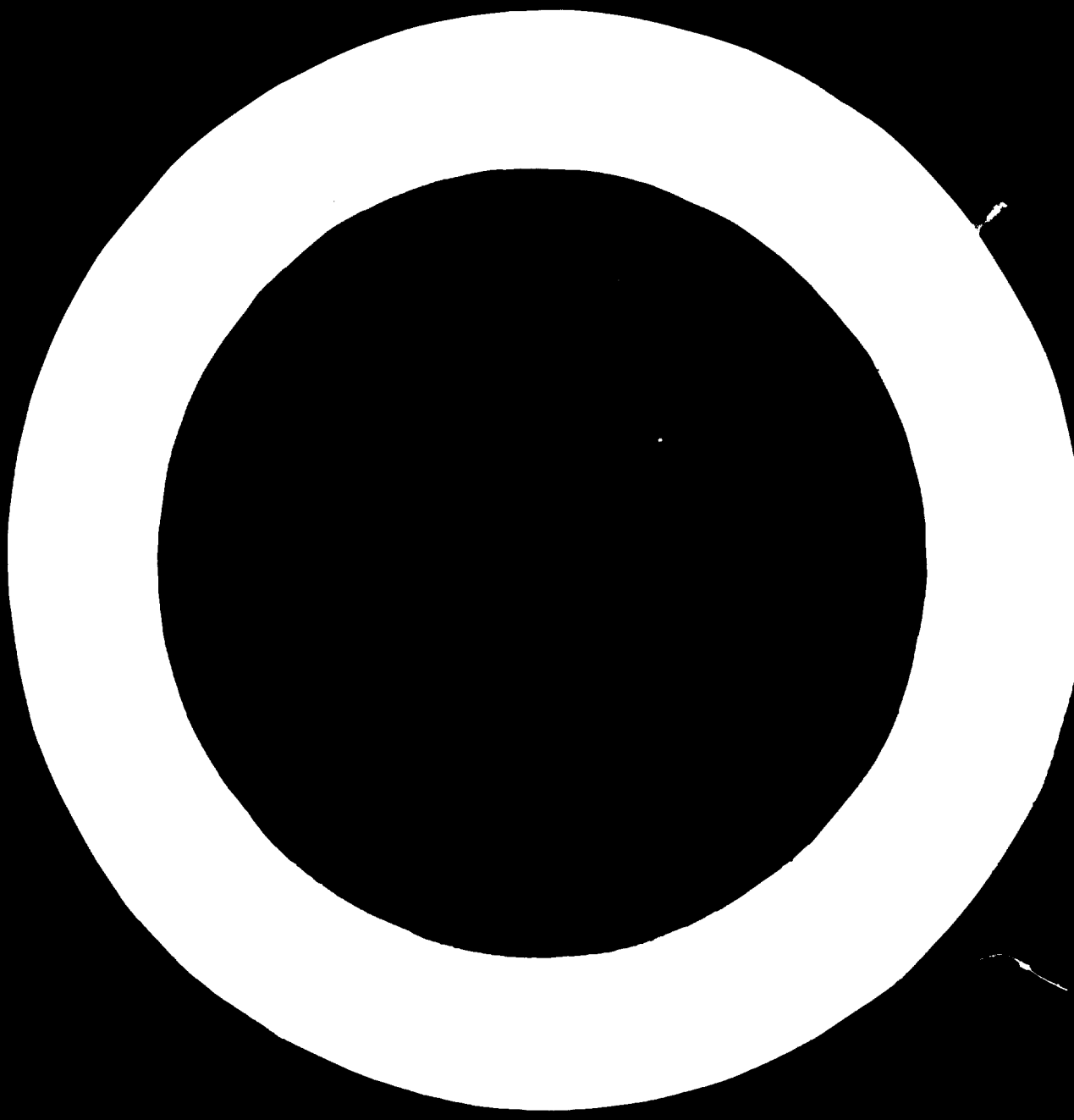




Any company deciding on a new construction project or an expansion project should be concerned very seriously with the exploration and planning for such an undertaking. Careful consideration of a project is the presupposition for the timely marketing of really competitive products.

The basis for the project concerned is the market analysis and the investigation of the manufacturing-, distribution- and sales costs. If an economic study made on this basis has shown that a sufficient profit may be expected in the future, the financing must be clarified. In case that sufficient own capital cannot be made available it must be tried to obtain financing from other sources.

Once the market analysis has provided a positive result and financing is ensured as well, planning may begin.

First of all the question of the location has to be clarified and the given suppositions such as energy- and water conditions, climate, traffic situation, official directives and tax laws must be checked. Under consideration of the given conditions and the product quality and quantity destined by the market, a production process can be selected.

Now it must be decided by whom the detail planning is to be carried out. It is the usual practice to engage with this planning such firms which are sufficiently experienced in the construction of plants. Prior to awarding the contract a detailed Inviation for Bid has to be issued in which the principle wishes of the future operator will be laid down.

The implementation of the contract comprises all steps, beginning with the organisation planning and ending with the guarantee test of the plant. The basis for the technical realisation is the P & I Diagram and for the adherance of the construction period the time schedule which can either be set up as crosswork diagram or network plan, depending on the size of the project.

The technical standard of the equipment is determined by proper design and selection of efficient sub- contractors. Great successes in purchasing were attained by using a data progressing system. After final inspection in the manufacture workshops the equipment can be despatched to the site, and erected. The application of special tools, in particular for the erection of heavy equipment depends on the selected jobsit

Before being taken into operation the plant is thoroughly cleaned and a performance test of the equipment carried out. After that the plant is started- up. A plant is only considered complete when the specified design data have been proved in a test- run.

1. Realisation of chemical projects

a) General procedure

Exploration and planning of chemical plants

Any company deciding on a new construction- or expansion project should be concerned very seriously with the exploration and planning for such an undertaking. Careful consideration of a project is the presupposition for the timely marketing of really competitive products.

1. Exploration

Exploration is defined as all investigations leading to the decisision to build a certain facility.

1.1 Market investigation

First of all, market analysis is required. It will yield information on:

Scope of demand for the respective product and development of requirements in the following years

Product capacities and market activities of competitors

Price development

The possible market share, and thus the initial capacity of the plant, is determined according to the development of requirements and activities of competitors. Allowance must be made for the future development of requirements by adjusting the initial

capacity to the growing market, right from the beginning.

Thus quite expensive extensions of capacities are avoided. The development of price is an essential part of the considerations for prospective profits.

For implementation of a market analysis three different methods can be used:

1.) Publications of governmental authorities, as ministries or planning departments, can be taken as a basis. However, consideration must be paid to the fact that usually these publications are of a general character and do not always take into account the requirements of a reliable market analysis.

2.) Larger companies have the possibility to carry out investigations themselves. This method is recommended if a very special product is concerned, the market conditions of which can only be looked into with the aid of intensive experiences. If expensive investments are concerned, a market analysis under own administration must be pleaded for, since in that case the responsibility for a proper valuation of the market should not be shifted.

3.) There exists the possibility to have the requested figures ascertained by a consulting company or by a market research institute.

1.2 **Financing**

Another important point in the exploratory phase is the question of financing. A new project may be financed with company resources or outside resources, or by both company and outside funding. Frequently there are difficulties when companies are required to seek outside financing because in-house resources are inadequate to provide the additional funding. However, in this case it is possible to obtain the assistance of a third party and to have the financing arranged by engineering consultants or to obtain advice from these firms as to which type of outside financing is most advantageous. In addition, it is possible to provide financing by founding a partnership firm or by including third parties. Individual financing conditions shall not be discussed in detail here.

2. **Planning**

Once the market analysis has provided a positive result and financing is ensured as well, planning may begin.

2.1 **Selecting a Location**

The first task should be the selection of a location. The question arises whether to build the new project "out in the fields" or whether an expansion of existing facilities should be effected. First of all it is necessary to determine the energy resources that are available at the intended location and the auxiliaries that may be acquired locally. In addition, the raw material situation must be studied. It is of great advantage if the required raw materials may be obtained locally, or if they are present as indirect

resources, i.e. in the case of natural gas or oil, for instance, a pipeline in the vicinity of the location. It is a known fact that the construction of oil refineries in the Cologne area became attractive only because they could be supplied directly from a pipeline.

Communications and transportation problems acquire significance if the raw materials are not available at the intended location, and if the finished products are not consumed in the vicinity of the production facility. For instance, to plan a plant facility at a distance of 15 km from the sea-shore must be considered false site planning if this plant must obtain all its raw materials by ship from the port facility, and if the major share of the production is exported and must again be shipped by sea. For, if only road transport to the port facility is possible, this site selection means that additional transshipment of the raw materials and of part of the production will be necessary. Even where the operator of such a plant was able to acquire the land at very favorable conditions, compared to a lot directly at the port, this advantage would be offset very rapidly by the additional cost, and in the long run might turn out to be a great cost factor in the finished products.

During the selection of a site while the project is in the planning stage, public easements should be investigated very thoroughly. For instance, in Germany they have become much more strict in recent years, for well-known reasons. Regulations and directives on air pollution, water pollution, and noise emission have resulted in stringent measures. Today it is quite possible

that a production facility may become uneconomical as a result of the cost required to comply with local public easements. In addition, government regulations on construction as well as local safety requirements must be incorporated in planning considerations. Soil conditions and construction features for the selected location must be examined very thoroughly in order to avoid later cost increases if the supporting capability of the soil should turn out to be inadequate.

Once the decision is made to build the new facility "out in the fields" rather than expanding an existing facility, special care must be taken to reserve space for any future expansion that may become necessary.

2.2 Economy study

The next planning stage should be concerned with economy study. In accordance with site conditions and the volume of the planned production a suitable production technique must be selected. This technique must be reviewed from the point of energy resources with a view to optimum design and possible interfaces with existing facilities. Depending on the structure of a plant it will in one case be better to drive the heavy machinery with steam turbines, while in another case the electric motor must be preferred. This decision must be made in conjunction with a review of total energy costs. In addition it is important in the selection of a process to allow for the shut downs required for plant maintenance, for possible catalyst and filter changes. A technique which requires a minimum of energy and investment cost may not turn out to be the most cost-effective technique if it requires twice the shut-down time.

After selecting a process it is necessary to determine the degree to which automation is required, considering available labor resources and personnel cost. However, establishing a degree of automation should not have the result that one man, instead of operating a machine must now watch a control unit. This will not save personnel cost. On the contrary, in addition to personnel cost remaining the same, the product will be burdened with the additional cost of the installed control systems. In any event, however, automation should be selected wherever it will achieve a more uniform quality of the final product. The required additional cost in that case will be offset by the elimination of complaints.

Economy studies also include selection of storage capacities for raw materials, semi-finished, and finished products. Where raw material prices are subject to great fluctuation within a certain period it is advisable to plan a storage facility of sufficient size so that raw materials must be purchased only during low-price periods. Where raw material prices are almost constant over time it is advisable to be very reluctant in the construction of large raw material storage facilities. However, storage capacities must be adequate to maintain production even if shipments become impossible for some time. Difficulties of this type may arise, for instance, when rivers freeze, main traffic arteries are snowbound, etc. Storage facilities for finished products should be so designed that the production plant can be utilized evenly even if the sale of the finished products is seasonal. In almost all instances it is more economical to absorb periods of maximum demand by an enlarged storage capacity than to design the plant for greater production capacity. In some instances the finished products

are not storable, or only in part storable over an extended period of time. In that case there should be considerations to determine whether or not semi-finished products should be placed in storage, and which could be finished for sale in an additional production phase just prior to consumption. This means that only the last finishing stage would have to be designed for maximum demand.

The orders of magnitude of production facilities, storage facilities, and other auxiliary facilities must be seen from the point of tax aspects, as well. As a result of the different depreciation rates for facilities and buildings a calculation must be made to determine the sizes that are most favorable from a tax aspect.

One very important point for economy studies is the selection of techniques and containers for packing semi-finished and finished products. A study should be made in any event to determine whether non-return or multiple-use containers are best suited for the purpose in question.

After selection of the location, determination of the process and choice of the storage facilities and auxiliary plants an estimate can be made for the product costs which are compared with the prices obtained on the market in an economy study.

2.3 Preparing an invitation for bids

Once a site was selected and a production technique decided upon, the invitation to submit bids may be prepared. Even where the future plant operators desire to build the plant in-house it is always recommended to prepare detailed specifications and a description of the plant. This will be practically equivalent to inviting a bid from another company. Where the company does not have adequate technical personnel for this purpose, or where their capabilities are absorbed by other functions, it is possible to have an engineering company prepare an invitation for bids.

An accurate and detailed invitation for bids will ease the determination of costs for the plant facilities, and almost no differences will be resulted lateron between builder and operator. In addition to the specific data included in the invitation for each individual plant, the following should always be taken into consideration:

An exact specification for the facility, allowing for the requirements of cost effectiveness, must be prepared. This specification should include the desired product outputs and qualities. In addition, certain parts of the facility and certain items of equipment should be specified in great detail in the invitation for bids. Large companies, such as ESSO, have come to the point today where they include with each invitation for bids their so-called Basic Practice, i.e. they specify exact standards for each apparatus and eac item of equipment which must be complied with in design work and manufacture. This will ensure that the completed facility satisfied ESSO's requirements in every respect. If the company does not have

this type of data available it is possible, of course, to specify in the invitation for bids that the bidder submits his own specifications for all the equipment. Major engineering companies have been developing their own standards for a long period of time which ensure an optimum in the manufacture of items of equipment.

Also, an invitation to submit bids should include a list of local conditions. It is of decisive importance that, for instance, not only the average daytime temperatures are stated but also the temperature peaks, and the specifications must state whether the planning of refrigeration facilities should be adequate for normal operation, or whether the plant must achieve full capacity even under the most unfavorable climatic conditions. In addition, the invitation for bids should include the data on relative humidity, wind velocity, and other climatic conditions, as well as on any earthquake hazards.

Raw material qualities should be specified accurately, stating any possible impurities or deviations from any standards. It happens only too frequently that a plant is designed for raw material specified in the invitation for bids, and that later the plant cannot achieve its output because the actual raw material quality does not agree with the raw material specification. As an example, we might keep in mind that metering devices cannot fulfil their purpose if the specified bulk materials such as grain or sand contain pieces of wood or other impurities as a result of transportation conditions.

Furthermore, the invitation for bids should include an exact specification of the quality of the finished products. In addition it should be specified that all consumption data be listed in the invitation. Consumption data are defined as the figures which state the amounts of raw materials, energy, auxiliary materials, etc. that are required to produce the demanded product. The invitation should state which data the builder of a plant must warrant and which values shall carry which penalties. Penalties are defined as payments to be made by the builder of a plant in the event that certain consumption data are not achieved inspite of corrective measures. This will give the contracting company assurance that its capital will not be invested in an uncertain venture.

In addition, the invitation for bids should state the period of time during which a plant must be built. It has become common practice that the party inviting bids on a plant must substantiate the desired time schedules with the aid of certain scheduling systems.

In any event, an invitation to submit bids should be so comprehensive that it allows for all important points that are necessary for the manufacture of the desired product and for the required equipment standard of the plant. Otherwise additional cost must be expected for corrective measures later which will upset the entire preliminary costing for the product. After completing the invitation, a selection of companies must be made that should be invited to submit bids. It is advisable not to invite too many companies because the review of their

bids may become such a large undertaking that the final completion of the plant will be delayed.

After the review of bids a contract may be awarded.

2.4 Contract Award

The contract may be awarded to an in-house division as a so-called turn-key contract, or to an engineering company under the same conditions. Of course it is possible to split the contract, performing part of the work in-house and contracting outside for the rest. Today the following types of arrangements are customary in international plant investment practice:

1. The contracting company purchases the basic engineering, i.e. it acquires the process design and the know-how for apparatus and the mode of operation, and builds the plant in-house on the basis of this information.

2. Using in-house basic engineering the company contracts with an engineering company for the detailed engineering, handling all the rest in-house.

3. All the engineering effort is contracted

4. In addition to the foregoing, installation is contracted, or the installation is performed in-house, contracting only for supervision of installation work.

5. Similar to installation work, construction may be contracted completely or in part.

6. Another possibility of contracting is to award a contract to a consortium of different engineering companies, or to award a contract to a so-called main contractor who in turn will award sub-contracts.

Payment for services and supplies is made under two types of systems today which may be combined.

First, there is the so-called lump sum price which indicates that the contract will be awarded at a definite price. This price may be negotiated as a firm price.

A second type of payment which has become customary in recent years is the so-called cost plus fee arrangement. This indicates that the contractor's cost is reimbursed directly and that, in addition, the builder is to receive a certain amount as his fee, i.e. as compensation for his efforts. The cost is determined on the basis of substantiating individual invoices and individual engineering services. This system is used frequently by large companies that award contract to engineering companies. The fears voiced by pessimists that this practice would practically invite the engineering companies to exceed cost estimates were not found to be true. In addition the contracting company has the possibility of taking a hand in the award of sub-contracts and to monitor cost concurrently. Where bids are invited on a plant on a cost plus fee basis an estimated total price will normally be stated, and every company concerned with engineering will use its best efforts to maintain this price estimate and, if possible, to remain below.

A company which would fail to do so could not expect to obtain a contract again. One important point in awarding contracts is to draw the boundaries between responsibilities and the parts for contracts. The cost risk of the builder of a plant will be the smaller the less he builds himself, since he must assume responsibility only for that part of the plant which he carried out himself.

2.5 Contract Implementation

Detailed planning of plants and buildings begins when the contract was awarded by the future operator. This phase may be subdivided into four stages, production technology planning, design, business administration, and time schedules. Some of these stages run parallel while others are time phased as a result of the nature of the undertaking.

Production technology planning includes, first, the exact computation of the production technique and individual items of apparatus, as well as preparation of mass balances. These computations form the basis for the so-called P & I diagram, i.e. the piping and instrument diagram. After completion of this diagram the piping lists are prepared as well as documentation on automatic control and metering, and on the electrical equipment. In an engineering company all of these data are processed by the appropriate technical branch. Any major company has a horizontal organizational structure which makes it possible to treat special problems in special departments. This avoids unproductive time, and parallel processing becomes possible. Furthermore, the P & I diagram is the basis for preparing the operating handbooks. These are part of any completed

system; They state how the plant must be operated and which points must be given special attention. Separate chapters describe plant start-up and shut-down so that the future operating personnel will have unambiguous directives. In addition the operating manual must contain the specifications for material analyses as well as all the maintenance and safety regulations that are required for operation. Design work begins somewhat later than production technology planning. Now the items of apparatus that were planned from the points of production technology are subjected to strength calculations, and appropriate design drawings are prepared. At the same time a determination is made which equipment is subject to government inspection, and who will perform such inspections. Depending on the location of the plant, German or foreign standards must be used for the strength calculations, and frequently there are standards of the operating company which must be observed in addition. Parallel to the design of apparatus the installation layout plans are prepared which in turn represent the basis for the construction design drawings. In modern industrial facility planning the equipment is no longer placed into a building; rather, the buildings are wrapped around the optimum grouping of apparatus from the point of production technology, in accordance with their function as protection for apparatus and machinery. While this will not create monoments of construction, as in former times, cost will be reduced to a minimum. Nor is it justifiable any longer to use facing of Dutch brickwork where ordinary corru-

gated siding will serve the same purpose.

Once the locations of individual items of apparatus have been established in layout plans, the pipeline drawings are prepared. These form the basis for the preparation of isometrics.

In many cases it is wise to prepare a model of the planned facility. This will make it possible to find much better arrangements for many pipelines. Also, the study of critical points which otherwise requires a great amount of time may be implemented without difficulty. In one instance alone the model saved more than DM 100.000 for pipe materials, not even including the cost on installation. Furthermore the model will allow the later plant operator to familiarize his personnel with the plant while it is being built. And in addition it is a significant aid in installation work. For a medium sized plant the cost for a model runs from 0.5 to 0.8 per cent, and for a large plant it is about 0.5 per cent of the cost of the turn-key facility. These costs are offset by shortened planning times, advantages in construction, and better arrangements for pipelines.

After completion of detail drawings the lists of materials are prepared.

Design work also includes the compilation of all specifications and other supporting documentation that determine the fabrication standards of individual parts.

The design effort ends with the preparation of documentation to support equipment installation. This includes all data which will make it possible for an outside company to submit a detailed fixed price bid for equipment installation, or to perform proper installation work without incidents.

It goes without saying that design review also includes the examination of drawings submitted for approval by the companies that fabricate the apparatus, and the review of all documentation prepared by outside contractors.

Mention should be made of the fact that the flow of these individual planning stages cannot take place separately, since one thing integrates with the other throughout the entire planning phase, Thus, installation will affect design which in turn may affect production technology which in turn may have repercussions on shipping and installation. However, in order to permit an easy grasp of this situation a planning scheme had to be selected which cannot fully represent the relationship between the individual activities.

Once the first equipment items for the plant have been completed from a design point of view, business administration planning may begin.

Depending on the type and organization of a company there is a variety of possible procurement systems. One of these systems shall be discussed here in order to demonstrate how an engineering company handles procurement today. Bids are solicited from different suppliers for all parts of an installation, and a quality and price comparison is made after

receiving the bids. After determining the most advantageous suppliers, orders are placed via a computer programme. The orders are printed by the computer. Programmed information processing has the advantage, in addition to merely printing the orders, that all the data for cost accounting are acquired without additional effort for separate data acquisition. The cost savings effect which is achieved through this modern type of contract award exceeds anything by far that is possible in business accounting through the employment of a data processing system. It should be mentioned that the individual engineering specifications are not printed by the computer but are typed by the regular method and included with the actual orders as appendices.

Once the orders have been printed, it is possible through the order data stored by the computer to obtain separate lists on payments, time schedules, costing, and the values of orders placed. This enables each individual planner to maintain strict control at all times. It is part of business administration to supervise the subcontractors during the different production phases where plant equipment is made. During production and after completion, quality checks are implemented by company personnel.

After acceptance the activity of the procurement division has terminated. Further processing is then assumed by the shipping division. They receive the shipping documents prepared by the procurement division.

Certainly not a subordinate role in building industrial facilities is that of time scheduling prior to project planning and implementation, and time schedule monitoring during project management phases. This is understandable if we keep in mind the many individual work projects that must be completed with many interfaces to other projects in order to ensure organic growth of the plant within the time schedule, from the exploratory phase to the fully functional production system. Therefor , time scheduling systems were developed that are expected to serve as tools in obtaining a clear grasp of deadlines. These are the Bar chart and the network technique.

Time scheduling extends from the beginning of the planning phase all the way to the guarantee test. All the planning stages must be monitored such as production technology, design, business administration, manufacture of the most important apparatus and machinery, in case of complicated machinery this may include the deliveries made by appropriate subcontractors and manufacturers. Subsequently the time schedule for the construction work, for equipment shipping, erection, first plant start-up, and guarantee test must be monitored.

Only with really consistent time scheduling will it be possible to recognize timing problems at an early stage and to sidestep them in such a way that the final deadline will not be endangered and costs will remain within the planned framework. Anyone can understand that cost estimates will be exceeded by far if, for instance, the construction site is started too early so that erection personnel cannot be fully utilized, but later, towards the final erection deadline, additional help must be hired in order to be able to meet the deadline.

Shipping and erection must be very carefully planned, too, in order to ensure the progress of the contracted plant within time and cost schedules. This means that shipping and erection requirements must be allowed for as early as the design stage. For instance, it was found during the construction of a plant in a European country that considerable savings in time and cost could be achieved by installing the equipment with mobile crane equipment that was flown from Germany to the construction site. In recent years the implementation of installation work for plant facilities has undergone great changes. Large equipment units can now be installed directly, using mobile cranes. The presently largest mobile crane has a carrying capacity of 500 metric tons. Within this year a mobile crane of 600 tons carrying capacity will become available in Germany. Also, the employment of load-carrying helicopters must be mentioned in this connection. With respect to shipping, care must be taken that the required items of plant equipment can reach the construction site at all. Thus there are restrictions with respect to bridge clearances, dock load capacities, discharge capabilities for port crane facilities, etc. that must be observed.

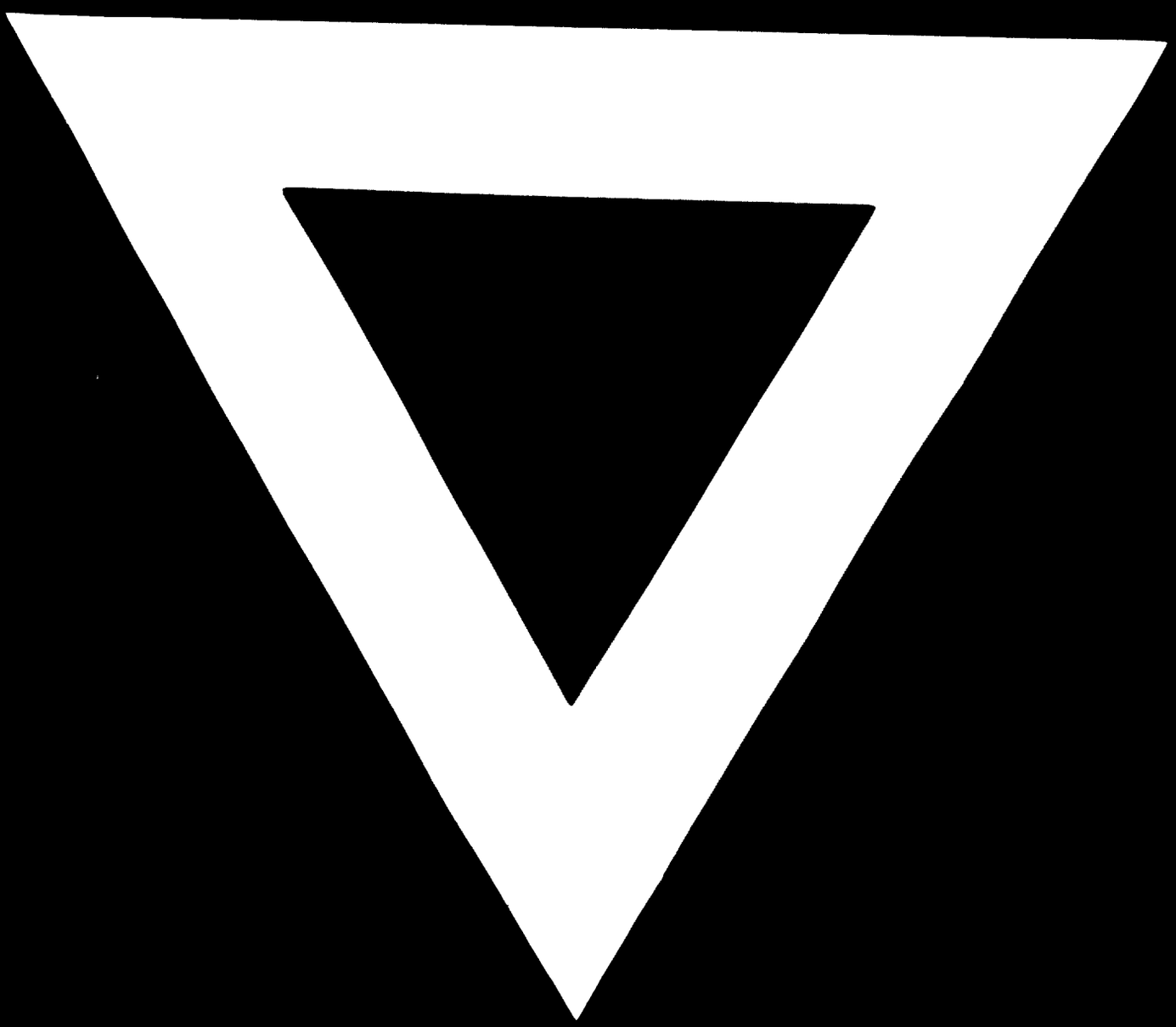
The first start-up of a new plant requires careful preparation. Only if it is certain that the required technical personnel, raw materials, and auxiliary material will actually be available at the date scheduled for starting up the plant, will it be possible for this event to take place without incidents. Care must be taken that all the items of equipment have been inspected and completed their mechanical test runs successfully,

Once the plant has been started up a performance test run will take place. The plant is not considered completed until the specified performance data were achieved during the performance test run. The instrument readings taken during a certain period of time are computed, processed, and compared with the tolerances specified in the contract.

After a completed test run the planning phase is terminated.

In view of the progressing modernization and technical innovation as well as the constantly increasing unit sizes of industrial facilities, comprehensive and careful exploration and planning have become indispensable. Only if all the items are allowed for that were only mentioned briefly in this paper, will it be possible to ensure that a plant is completed at the estimated cost and within the specified time schedule, and will achieve the desired performance.

Any company planning a new project should consider very seriously whether technical company personnel can be made available for the project concerned, and whether adequate help is availalble for implementing the plans. Unless planning work is being performed on a continuous basis it will in most cases be much more advantageous to employ an engineering company for the construction of a new plant. In that case it is not necessary to increase one's own staff, and in addition it will be possible to make use of the experience of the engineering company which will then assume, at the same time, the responsibility for implementing the plans within the cost and time schedules and for the necessary guarantees.



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