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Design and supply of 3000 litre fully automatic autoclave for the pharmaceutical industry

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Through his involvement in the initial stage of the project, the client would have been aware of:

- The expected final cost of the project.
- The expected duration for completion of the project.
- The quality of materials and finish to be supplied.
- The type of equipment to be installed.
- The general outcome of the project.

This fixed price quotation should then have incorporated a bonus/penalty clause based on completion time, where the contractor would have been rewarded for early completion or penalised for late completion of the project. The amount of the bonus or penalty shall have been about 0,5% per week up to a maximum of 2%.

With this type of contract the client would have hedged against inflation and the contractor would have been able to submit a more accurate and realistic quotation.

2.2.4 Selection of contractor

In the awarding of the contract to Kemmek (Pty) Limited, Adcock Ingram did not base their selection solely on price, but based their selection on a process as described by Harrison[6], who states that the following factors should be taken into consideration when comparing various contractors:

- The contractor's past experiences with this type of work.
- Planning and control systems the contractor intended to implement.
- The contractor's technical ability to handle the project.
- The contractor's financial and managerial ability to handle the project.

- The key personnel the contractor intended to use on the project.

2.2.5 Drawing up of contract

Once Adcock Ingram selected Kemmek (Pty) Limited to be the contractors on this project, they drew up a contract which covered the following relevant items in detail:

(i) General services to be supplied by the contractor.
(ii) Design parameters.
(iii) Equipment requirements.
(iv) Control requirements.
(v) Safety features.
(vi) Commissioning details.
(vii) Insurance covers.
(viii) Guarantees.
(ix) After sales service.
(x) Finishing date.
(xi) Price and payment terms.
(xii) Effects on contract terms due to any design changes by either party.
(xiii) Client's role in the project.

Although the contract was concise and clear, the sections on design parameters and equipment requirements were drawn up without the client being fully aware of his precise requirements for this particular project. This resulted in later design changes as described below in Section 5.2. This would have been avoided had the client and contractor worked together on the initial stages of the project on a cost plus basis as described above in Section 2.2.3.

3 PRICES AND TIME ESTIMATES

3.1 Price

When the project was initially put out to tender, the amount of design engineering and specification submitted by the client was minimal as shown in Appendix A.

As described in 2.2.3 above, the project must be sufficiently defined otherwise the contractor cannot make an accurate fixed price bid, unless he is tendering for an off the shelf project.

In this case, due to insistence by the client, the contractor submitted a fixed price. However, before submitting any fixed price, the contractor drew up a specification of his own, defining all aspects of the project and detailing the scope of his supply as shown in Appendix B. The contractor highlighted that any changes to this specification or to the scope of supply, would then result in an associated change in price and completion time. In this way the contractor safeguarded himself against any costly design changes and the client was in turn aware of the scope of supply.

Based on this specification, the contractor then:

- Obtained quotations for the various items of equipment involved in the project. He ensured that these prices were not subject to escalation for at least 12 months. Where the supplier insisted on an escalation clause, the contractor based that particular price on an escalation clause calculated according to SEIFSA[10].

- Drew up a preliminary piping and instrument drawing for the project. Based on this drawing he extracted prices for piping, tanks, instruments, valves, vacuum pumps and other associated equipment.

- Approached a sub-contractor in Cape Town, Albert Moore, for a price and tim, estimate for the complete manufacture, assembly and commissioning at their site of the autoclave with all its associated equipment. This stage of manufacture was to be under the direct supervision of the contractor, Kemmek (Pty) Limited.

- Estimated the amount of man hours required for the life of the project and assigned costs to these hours.

The contractor then submitted a fixed price to Adcock Ingram, based on a total of:

(i) The above prices.

(ii) A contractor's fee, which was approximately two percentage of the total estimate.

(iii) A 10% contingency factor based on the total price of the project.

(iv) A SEIFSA escalation clause.

The 10% contingency was included for any design changes or equipment requirements that were overlooked.

According to Cleland and King[3], the amount of contingency to be included is dependent on the degree of confidence the contractor has in his prices. This confidence is related to the understanding, clarity, simplicity and extent of definition of the project. According to various specifications, the contingency factor can vary from 5% for a well defined, simple project to as high as 25% fo. an ill defined, complicated project.

3.2 Time Estimate

In their quotation to Adcock Ingram the contractor included a completion time for the project of 20 weeks from receipt of order.

This time was estimated from the delivery times as given to him by the suppliers of the various items and from his calculations of man hours required to assemble and complete the project. These man hours were taken off a bar chart the contractor drew up when planning the life of the project as outlined in Section 6. As a safeguard he allowed a contingency factor of 15% in the time quoted for completion.

To safeguard himself and to ensure that the suppliers would meet their commitments, the contractor included penalty clauses for late deliveries in his subsequent orders to the suppliers as outlined in Section 8.4.

4 PROJECT ORGANISATION

4.1 Handling of Project

With the conception of this project Adcock Ingram had the following options:

(i) Handling the project themselves with in-house personnel and expertise.

(ii) Handling the project in co-ordination with contract project engineers with experience in autoclave design.

They selected the second option, which was the correct decision in their case as:

(i) A special project team did not have to set up within their company to handle the project.

(ii) Based on their past record, any large projects that were handled in-house tended to not get priority attention as the daily operation of the plant with its associated production problems was considered more important.

(iii) Their experience in autoclave design was not extensive.

This is also in accordance with Kerzner[7] who states that projects have a tendency to fall behind in organisations where projects are handled by functional managers in the organisation rather than by separate project teams. These projects are never completed on time as these functional managers give priority to those tasks which provide better benefits for themselves and their sub-ordinates. Thus it is essential to select a separate task force to handle a project which is sufficiently divorced from the day to day running of a plant.

4.? Work Breakdown Structure

According to Kerzner[7], for the successful accomplishment of project and contract objectives, at the project initiation a plan is required which:

- Defines all the efforts to be expended.
- Identifies the work to be done.
- Assigns responsibility.
- Establishes schedules.
- Establishes budgets.

With this project, the preparation of such a plan was the initial responsibility of the client, Adcock Ingram, until Kemmek (Pty) Limited was selected as the contractor responsible for the overall handling of the project.

The contractor should then have been responsible for:

- Describing the total program
- Planning
- Scheduling
- Evaluating
- Establishing cost controls
- Tracking performance
- Status reporting
- Objective setting
- Assigning responsibilities

In the actual case, as described in the following sections, the contractor was generally able to establish a framework, as outlined above, from which to successfully control the project.

However, as described in Section 5.2.2, one major problem did arise which resulted in a deviation from the format as outlined above. In this case, just after the contractor completed the conceptual design stage of the project, Adcock Ingram requested a different computerised system to the one specified. After all the necessary price and design changes were effected, Adcock Ingram took direct

responsibility for the supply of this computer system which was then to have been incorporated into the autoclave just before the commissioning stage of the project. This was a serious error on the part of the contractor as he lost control of one of the major sub-contractors and in turn control of that section of the project. However, once the contractor realized this oversight, this problem was rectified and the supplier of the computer fell directly under his control. This mismanagement did however result in the project being delayed by about four weeks. The main reason for this delay was a lack of communication between the supplier of the computer and the manufacturer of the autoclave.

This is in accordance with Cleland and King[3] who state that for the purposes of effective project management and coordination it is essential that the project manager maintain complete control of all aspects of the project no matter how small or insignificant they might seem.

5 CONCEPTUAL DESIGN

5.1 Initial Design for Approval by Client

After being awarded the project, Kemmek (Pty) Limited began the conceptual design of the plant for initial approval by the client before beginning any manufacture of equipment.

The following was completed:

(i) The autoclave was designed and detailed by the contractor in conjunction with his sub-contractor Albert Moore, in accordance with the client's specifications outlined in section 2.1.2 and the contractor's consequent specification as included in Appendix B.

(ii) The piping and instrument layout of all equipment included in the autoclave's framework was drawn up.

(iii) The associated area layouts were completed.

(iv) All associated holding tanks were specified.

(v) All the engineering, electrical and instrument flowsheets were completed.

Upon completion, the above designs were submitted to the client for approval.

5.2 Changes to Design

At this stage, after studying the above proposals, the client came forward with two major design changes.

5.2.1 Imported autoclave

They recommended that instead of fabricating the autoclave in South Africa the contractor should investigate the feasibility of importing a similar autoclave which is sold in Italy in an almost off the shelf condition.
Kemmek (Pty) Limited then investigated this possibility, and found that, although the autoclave itself could be landed in Johannesburg for approximately 4% cheaper than the local model, the following disadvantages existed:

(i) The design of the autoclave was not entirely suited for the client's requirements. Thus several costly changes would then have had to be done to the autoclave whereupon the cost saving would have disappeared.

(ii) The pumps, vacuum pump, valves and instruments supplied with the autoclave were not all locally available. This would thus have presented problems for future maintenance and availability of spare parts.

(iii) There would have been no local representation for the autoclave.

The autoclave as supplied by Albert Moore had the following advantages:

(i) The pumps, vacuum pump, valves and instruments would all be standardised and in accordance to equipment already in use in the client's plant. This would facilitate maintenance and avoid unnecessary stocks of spares.

(ii) For any major breakdowns, Albert Moore's maintenance team would have been locally available as they were involved in the maintenance of other autoclaves in the area among others those at the Johannesburg Hospital.

Once the above facts were presented to the client and the original proposal of using a locally made autoclave was accepted.

This study however, caused a delay to the start of the project and was also costly to the contractor.

5.2.2 Change in computer system

In the initial design of autoclave's automatic stepping system, the contractor allowed for a standard Omron controller to handle the four different sterilising programmes that were required.

However, after the awarding of the contract, the client indicated a preference for the use of a Kaye Digistrip minicomputer. The main advantage of this minicomputer was that several autoclaves could simultaneously be operated by the one system in the future, if required.

Consequently the design and cost estimates of the autoclave were adjusted to incorporate the minicomputer.

All these changes to the original design, resulted in a time delay of four weeks.

5.3 Recommended Method of Handling the Initial Design

According to Harrison[6], it is necessary to spend sufficient time and effort during the specification stage of a project on the selection of major equipment to avoid any unnecessary costly time delays later on in the project.

This was a serious error with this particular project as initially the client did not put enough thought in the specifications of the major equipment such as the autoclave design itself and the computer system.

The correct method of handling this problem would have been as follows:

(i) At the conceptual stage of the project the client should have itemised all major items of equipment which did not have any similar "off the shelf" designs on the marketplace and which were unique to this project (e.g. the autoclave, the computer system and the sterilising programmes).

(ii) Time should then have been spent on the initial design and specification of these items before proceeding with the project. At this stage it would have been advisable for the client to employ a contractor, whom he favoured to handle the project, to assist in the design of these items. In this way the client would have had the advantage of familiarising himself with the working methods and ability of the contractor without being under any obligation to award the remainder of the contract to him. The contractor in turn would then also have been involved in the initial design, specification and decision making of the project without incurring any unnecessary costs as at this stage all his time spent on the project would have been reimbursable.

(iii) After the decisions had been taken on the designs and specifications of these major items, the client should then have drawn up an enquiry for the complete project and submitted it to the various contractors for quotations. In this way the quotations then submitted by the contractors would have been more realistic as they would have been based on a more accurate and detailed enquiry.

6 PLANNING

To obtain an accurate fixed price for the project, the contractor initially drew up a bar chart, as shown in figure 6.1. This chart was used to indicate the multiple activities and manpower requirements of the project.

Once the project began he used this bar chart to monitor progress.

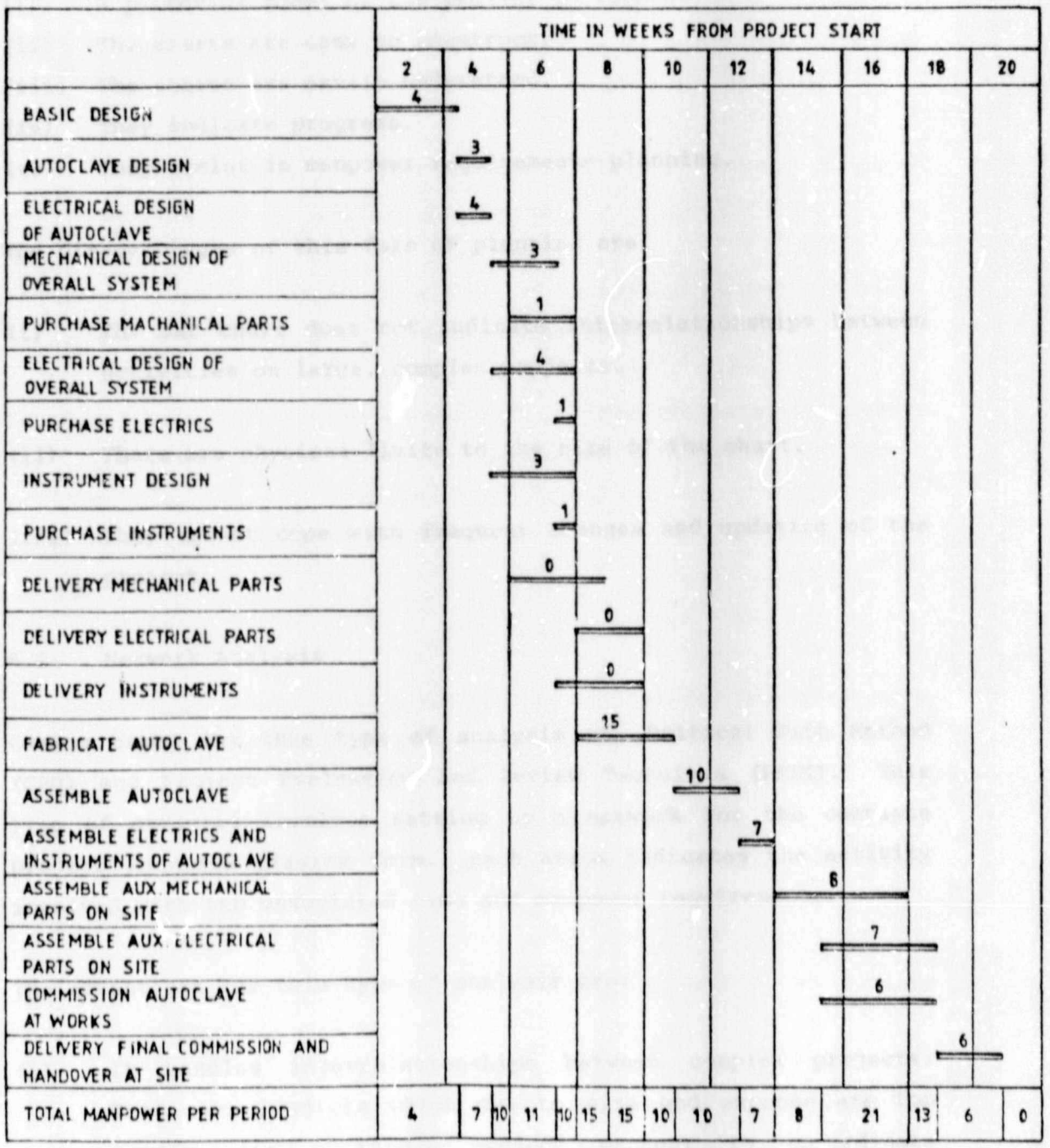


Figure 6.1. Bar Chart

Kerzner[7] has shown that the two most common techniques used for project planning are bar charts and network analysis methods.

6.1 Bar Charts

Bar charts are satisfactory for the smaller type project. Advantages of bar charts are:

(i) A pictorial model of the project is formed.
(ii) The charts are easy to construct.
(iii) The charts are easily understood.
(iv) They indicate progress.
(v) They assist in manpower requirements planning.

The disadvantages of this form of planning are:

(i) The bar chart does not indicate interrelationships between activities on large, complex projects.

(ii) There are physical limits to the size of the chart.

(iii) They cannot cope with frequent changes and updating of the project.

6.2 Network Analysis

Common names for this type of analysis are Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT). This type of analysis involves setting up a network for the complete project in arrow diagram form. Each arrow indicates the activity involved with its associated time and manpower requirements.

The advantages for this type of analysis are:

(i) It handles interrelationships between complex projects. These are projects which due to size and expense are too complex for a single project manager to co-ordinate efficiently. With such projects, the various activities are treated as seperate project packages, with each package

being co-ordinated by its own project manager. The subsequent overall co-ordination of these project managers can then efficiently be executed by a single responsible person.

(ii) It defines activities which are critical to the overall time of the project and indicates the available spare time on the other activities.

(iii) It can handle large, complex projects with a large number of activities.

(iv) It can easily be computerised and thus supply relevant information for project management.

The basic disadvantage of this type of technique is that it tends to be too complicated for use on small projects.

Based on the above, for small and medium sized projects, bar charts are recommended as a planning technique. However, in larger projects with several thousand activities, network analysis planning techniques are recommended.

6.3 Planning Method Used

In the actual situation, the decision to utilise the bar chart as a method of planning the project was correct as:

(i) The project was relatively uncomplicated and the various activities that were to be performed were easily identified and defined.

(ii) The manpower requirements for each activity were easily allocated.

(iii) It was simple to understand and follow the progress of the project using the pictorial model of the bar chart.

(iv) The bar chart was easily updated in situations where there were time delays as the particular activities responsible for these delays were redrawn and the manpower requirements for that particular period recalculated.

The number of times changes and updatings were required was relatively infrequent.

(v) The bar chart accurately highlighted the period of maximum manpower requirement early on in the project and the contractor could thus allocate his work force accordingly between the various projects.

(vi) There was no need to computerise any information on this project.

7 PROGRESS

7.1 Drawings

Upon the receipt of the official order from the client, the contractor immediately started the drawings required. Special emphasis was initially placed on drawings of those items which were associated with long delivery times.

The major drawings which were completed and the order in which they were done were:

- General arrangement of the autoclave.
- Piping and instrument drawing.
- Electrical drawing.
- Service connections.
- General layout.
- Holding tanks and other associated equipment.

7.2 Design Phase

It is essential to ensure that, as the design of a project proceeds, the project estimate becomes more refined and accurate and that the level of uncertainty and the number of unknowns become less as more information on the project becomes available.

According to Hackney[5], it is possible to identify various stages in most design processes which will ensure that this refining of the estimate and this specifying of the project will occur on time.

These stages are obviously dependent on the characteristics of the project. It is essential at the start of any project to define similar milestones to those outlined below which are appropriate to the project. Progress and performance of the project team will then be measured against such a schedule. Generally for a mechanical project of this size, the following stages exist:

- At about 15% of the project life, design work is 20% complete, vessels and equipment are 80% specified, area layouts are 70% complete and all major orders are placed.

- At about 25% of the project life, design work is 40% complete, 70% of materials and equipment are ordered, area layouts are completed and vessels and equipment are completely specified.

- At about 45% of the project life, design work is 75% complete, construction work has begun and the budget is finalised.

The above situation generally existed with this project and as can be seen from the bar chart in Figure 6.1 the project proceeded according to the following schedule:

(i) Three weeks from project start (15%):

- The basic project design was completed.
- The equipment specifications were completed.
- The autoclave design was started.
- The electrical design was started.

(ii) Five weeks from project start (25%):

- The autoclave design was completed.
- The mechanical, electrical and instrument designs were 50% completed.
- All major mechanical items such as the autoclave, pumps, valves, vessels and pipes were ordered.

(iii) Nine weeks from project start (45%):

- All major mechanical, electrical and instrument designs were completed.
- Fabrication of the autoclave had begun.
- All orders were placed.
- The construction and assembly work on the project began.

8 PROCUREMENT

Initially, for the purposes of submitting a fixed price to the client for this project, the contractor obtained budget prices for all the equipment and materials from various suppliers.

However, when he was ready to place the official orders, he generally followed a set procedure as outlined below.

8.1 Enquiries

Based on the specifications drawn up, the contractor issued enquiries to selected suppliers for all the equipment and materials he required.

8.2 Quotations

Where possible, for all major items, quotations from three different suppliers were requested. These quotations were then evaluated and compared to the anticipated budget price. In cases where the prices exceeded the budget, the requirements were either modified or the increased costs were accepted by the contractor.

8.3 Selection of Suppliers

In selecting the various suppliers, the following considerations were taken into account:

- Price.
- Quality.
- After sales service.
- Financial stability and reputation of supplier.
- Standardisation of equipment with that which already existed on site.
- Local availability of spares.
- Technical competence.

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