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Kiran Golwalkar
Consulting Chemical Engineer
Nagpur
India

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*Dedicated to my teachers who taught me at the engineering institutes, my colleagues who were very cooperative and explained the process plants at the start of my career, and the workers from whom I could learn practical things.*

# Preface

It gives me great pleasure to present this practical guide to the technical and purchase managers of the chemical process and related industries for the procurement of equipments. It was observed that considerable time is wasted in unnecessary correspondence with the vendors/manufacturers of plant and machinery in clarifying the exact requirements of the purchaser if these are not clear while floating inquiries. This sometimes led to project delays, cost overruns, inability to stabilise plant operations in time and therefore inability to meet commitments made to the customers.

It is felt that timely and correct procurements of the right type of equipments/ machineries with all the required features and constructed with the appropriate (suitable for the intended use) materials of construction (MOC) can ensure a smooth and safe scheduled start-up of the project at the budgeted cost (or minimising cost overruns).

Procurement of the right equipment enables safety in operations and can minimise breakdowns and environmental pollution. In addition, it would be easier to maintain product quality and reduce the cost of production.

I have attempted to explain when to procure new equipment, how to prepare specifications for floating inquiries, and guidelines for detailed technical discussions with vendors in the chemical and related industries.

The guidelines presented cover the common equipment used in chemical plants and related industries and effluent treatment facilities such as pumps, blowers, reactors, heat exchangers, waste heat recovery boilers, heat and acid resistant lining as well as auxiliary equipments and utility services such as water treatment plants, cooling towers, refrigeration systems, DG sets, etc. The management will find judicious investment in essential facilities like maintenance equipments, proces control lab, fire fighting, personal safety devices, elevated storage for water useful for safe and efficient working of the plant and hence have been included.

It is hoped that technical and purchase managers will find this book useful for procuring and/or replacing equipments, process technology, raw materials etc. at reasonable cost and will help the projects to be started on schedule. The book is also intended to serve the engineering students in technical institutes and universities and young engineers starting out in their careers for making them familiar with practical aspects of various equipments and machineries before they assume responsibilities in chemical plants.

The book gives a checklist to the plant managements for procurement of the correct equipment in an efficient timeframe insuring that projects are not delayed. It can also increase the readers' understanding for posing the right inquiries to engineers, plant managers, and product vendors when acquiring industrial equipment and supplies.

Suggestions and constructive criticism for improving this book are welcome from persons associated with the chemical process industries. The guidelines are *suggestive* rather than *stipulative*. Obviously, individual requirements will vary as per specific situations.

K. R. Golwalkar

# Acknowledgement

My aims in writing this book were:

- To familiarize the readers (*including students in technical institutes*) with the basic working principles and practical aspects of many items/systems used in industries
- To provide the readers with check lists/guidelines for floating inquiries for them
- To enable short listing and final selection of vendors for procurement of/purchasing these equipments (by discussing with the vendors the practical aspects of their safe, efficient operation, ease of maintenance and commercial matters)

## Sources of my information

I have referred to standard text books, Chemical Engineers' Handbook etc for process information, basic working principles and general description about the items/equipments as well as advertisements in trade journals and from material uploaded on the internet by manufacturers for promoting sales of their products.

Since, the practical aspects for procurement are not generally available, in standard textbooks, Chemical Engineer's Handbook, etc., this information was developed, modified and presented in a simplified manner for the reader. Reference listing is provided wherever the material from other sources was used as a starting point.

Subsequently, check lists/guidelines were prepared for the selection and procurement. These are based on my own experience of working in many chemical industries in India and other countries for procurement, erection, commissioning and operation.

The inputs from the engineers and technicians at these plants have been very useful in preparation of these guidelines. The technical literature (*given to me by sales engineers of several companies*) and the discussions with many vendors have also been referred to.

I am grateful to the senior professionals who spared their valuable time, reviewed the book and gave some very constructive suggestions.

Mr Mandar Bokare (*my ex-student*) had also been very helpful in preparing the manuscript and I thank him for the same.

I am grateful to Respected **Mr Michael Luby**, Senior Publishing Editor, Engineering,and Respected **Ms Merry Stuber**, Associate Editor, Engineering of Springer Science+Business Media, and Respected **Ms Sakshi Narang** (Production Editor) and **Mr Vivek Pradhan** (Project Manager), Springer Production for their support and guidance and thank them for the same.

## References

I have referred to the following sources for writing the book.

1. Chemical Engineers' Handbook-for material conveying systems, heat recovery systems, cyclones, scrubbers, evaporators, thermal and mechanical compressors etc
2. Own experience of operating various chemical plants in India, Kenya, Thailand, Indonesia and visits to industrial exhibitions in India for equipments, instruments; and technical information/ brochures collected
3. Class notes by my own teachers
4. Personal correspondence and discussions with senior engineers and representatives of manufacturers of catalysts (Catalyst India Ltd, Mont-Edison at Jakarta), Refractory materials (ACE-Calderys Refractories, SKG Refractories), fabricators of mechanical equipments (VK Engineers, India and many others), Scrubbing systems and Candle Demisters-(Evergreen Technologies) ….
5. Technical literatures and advertisements placed in various technical journals (Chemical week, Chemical Engineering World) by manufacturers/fabricators for pumps, blowers, agitated reactors
6. Information uploaded on the Wikipedia/Internet by various manufacturers/fabricators for pumps and blowers, Waste Water Treatment Plants (figures for Dissolved Air Flotation by renowned vendors Pan American Environmental, Hydro Systems Supply, EDUR were also referred), Tower packings (Topack Ceramic Industries, Nilgiri Chemical Stoneware) Steam Operated Chilled water Plants (Thermax C and H div), Gas Induction Reactors (Omega-Kemix, Amar Equipments)
7. Technical literatures from Vendors of Instrumentation systems (KD Instrument, ENDEE Engineers)
8. Offers from and personal discussions with Manufacturers of Waste Heat Recovery boilers (Thermal Systems-(Hyd) India, AVU Engineers, A.P. India)

I have tried to present the *guidelines for procurement* of the various equipments and systems by referring to the information/working principles of the various equipments uploaded on the Internet by above renowned manufacturers. However, the reader is advised to contact these companies for more detailed proprietory information and procuring the required equipments as per need

I do not claim that all the various equipments are designed by me and the information given in this book is entirely my own. Hence I am grateful to all the above sources. If I have missed some names due to oversight, the omission is not intentional; and sincerely regretted.

K. R. Golwalkar

# Contents

# About the Author

Kiran R Golwalkar is a consulting chemical engineer based in India and has experience of erection, commissioning, operation of many chemical plants in India, Kenya, Thailand, Indonesia. He can be contacted on the e-mail…. krgolwal@gmail.com

# Process Equipment Procurement: Need and Options

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## 1.1 Introduction

Chemical industries have to face problems due to stiff global competition, availability of cheaper products, increasing cost of raw materials and power, reduced availability of water, increasingly stringent laws for pollution control, labour problems, operational disturbance due to occasional power failures, etc.

It is therefore imperative that a close look is taken at the capital investment requirement for procuring equipment. Purchase of high-capacity units may not be the right choice in certain cases due to many practical difficulties in procurement and the additional (*hidden*) costs involved.

These can be due to incorrect specifications, long delivery schedules, non-availability of some critical components or spares in time, delays in erection or commissioning, difficulties faced during operation and maintenance, and the need for occasionally inviting outside experts.

Such problems ultimately result in cost overruns of the project. The accumulating interest burden due to delayed commissioning of the project results in lower rate of earnings from the industry.

The situation can get aggravated further in case the production run is not stabilised soon or the finished product is not as per required *marketable* specifications. It becomes necessary to store the off-spec product till the time the product meets the specifications given by customers. The lower grade product will have to be sold at a much lesser price (sometimes even at a loss) or reworked upon to improve the quality (if possible by recycling or other means) or disposed of in some other way acceptable to statutory authorities.

In many industries, the old plant and machinery are allowed to run as such and decisions for procurement of new plant, machinery, know-how and technology are postponed "to save" capital investment. However, this can only temporarily save the outgo of funds while the inefficient operations of the old equipment continue to cause losses.

An attempt is therefore made to present some guidelines to the management of chemical industries for taking decisions in the matter of procurement of process



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know-how, technology, better equipment and other related items. These guidelines can be used for obtaining offers/quotations correctly and quickly in order to shortlist the vendors. These can reduce likely delays in equipment procurement, erection and commissioning.

Hopefully the decision makers will find them useful and apart from preventing (or minimising) cost overruns and project delays they will also help in achieving safer, more efficient and economical operation of the process plants.

## 1.2 Procurement of an Entire Manufacturing Facility or Technology

Situations when it becomes necessary to procure an entirely new plant or replace most of the equipment or install additional new equipment are:

a. Revamping (major modifications) of the old plant has become necessary.
   - When the existing plant is not able to produce at the required rate, as per quality at a reasonable cost or is causing environmental pollution
   - When a better product is available in the market at a lower price
   - When the existing unit has become old and breakdowns are frequent
   - When it is unsafe to run the present plant

b. A common situation could be that the old plant is lying idle for some time due to some of the following reasons:
   - The cost of production was high
   - It was unsafe to operate
   - Some critical spares were no longer available
   - There were labour problems
   - Consumption of raw materials and power was high
   - It was generating more effluents and thus causing pollution
   - It was running batchwise and hence production rate was low
   - There were frequent breakdowns
   - The quality of product was poor

Management shall consider the programme for procurement of new units after the below revival steps are carefully discussed with plant engineers and purchase and sales officers.

- Investigate all the reasons before deciding to go for new equipment
- Analyse cost of production
- Make all equipment safe to operate
- Critically examine designs of all important equipment and develop new designs for important spares—*this may not be possible always*
- Negotiate with labour
- Carry out energy audit and take appropriate steps
- Check catalyst activity and residual life; check Effluent Treatment Plant

- Convert to continuous operation
- Implement regular condition monitoring and preventive maintenance programme
- Implement process control programme at every step of production (analysis of raw material, reactor operation, calibration of instruments, replacement of catalyst, filtration of raw material/product streams, purification steps for final product, etc.)

## 1.3 Options to Be Considered

a. Procuring an entire plant on "turnkey basis" (including detailed know-how)
b. Obtaining an old plant in either idle or working condition and revamping it (carrying out the necessary changes as per need) —the required know-how may or may not be obtained from outside
c. Obtaining process know-how (operating conditions), technology (detailed engineering design) and only certain key equipment. Balance facilities to be created by modifying existing equipment or fabricated in-house by purchaser's own technicians

Options for procurement from an outside party (*outsourcing the plant equipment with services to run and maintain—either fully or partially*)

- BOT: Build, operate (till performance guarantee terms are met) and then transfer immediately to purchaser
- BOOT: Build, own, operate and transfer to purchaser as per agreed schedule
- BOM: Build, operate and maintain on behalf of the purchaser, who agrees to pay some fees or shares the profit generated. The vendor recovers the cost from this. The ownership is transferred to purchaser after the vendor has recovered his costs fully along with profit. The purchaser does not invest funds initially but gets the benefits—at reduced rates
- BOOM: Build, own, operate and maintain for some years for an agreed fees as per agreement between purchaser and external vendor
- BOMT: Build, operate, maintain and transfer to purchaser as per agreed schedule

### 1.3.1 Procurement of an Entire Plant on "Turnkey Basis" Procuring an old plant and Revamping it

**Important Selection Criteria and Steps**
The purchasers will have to do some important jobs themselves:

- Obtaining all statutory permissions to establish and operate and arranging land, power, water supply and all necessary infrastructure.
- Disaster management plan report and environmental impact assessment should be ready before setting up a new project along with all the above statutory permissions.

- The selected process technology should be the latest and should suit the purchaser's local conditions and availability of raw materials, power, water and skilled workforce. The manpower available with the purchaser should be able to easily understand the process technology and operate and maintain it.
- It should be safe to operate the plant in the local climatic (ambient temperatures, rainfall, etc.) and geographical area where it will be located, along with the quality and quantity of water locally available.
- The process design and technology should be such that locally available raw materials (if cheaper) can be used as far as possible.
- Generally, an operating range of 70–130 % of the capacity shall be available, i.e., it shall be possible to operate the plant efficiently and safely even in underload conditions (up to 70 % when the demand for products is less, raw materials or utilities are not available) or in overload conditions (up to 130 %) of rated capacity when higher demand for product is to be met urgently.
- Consumption of raw materials, power, steam and water should be lowest or comparable with the best in industry. Specific consumption of all inputs per unit of output should be economical over all operating capacity ranges.
- The breakeven point (BEP) should be reached at the lowest capacity possible. Otherwise, one has to operate the plant at higher capacity just to break even.
  - *In case, there is not much demand in the market due to some reason, it may become necessary to sell the product at a reduced price. The other option of not selling at a reduced price causes build-up of unsold products, which have, however, already consumed resources.*
- A rule of thumb is that the cost of raw materials and utilities should not exceed 50 % of the selling price if a reasonable return on investment (ROI) is desired. Hence, while procuring a new production plant and technology, one must use this rule of thumb.
- The quality of final product should be easily marketable and meet the specifications (domestic and international) at the minimum and maximum production rates, i.e., when the plant is running at a lower or higher capacity than the rated one—within limits of operating range.
- The possibility of sudden or frequent interruptions in the power supply should be considered informed to the vendor, who should incorporate warning alarms, safety devices and interconnections in the designs. Vendor should demonstrate satisfactory working of all such systems prior to handing over the plant to purchaser.
- *These arrangements will have to be done by the management themselves if the revamping is being done.*
- It should be possible to recycle or purify the off-spec product (if produced during plant upsets) in the process plant and convert it to marketable-grade product once again, without causing any process disturbance or maintenance problems.
- The plant should not cause any environmental pollution. If the plant produces certain pollutants, there should be an in-built mechanism for effluent treatment. Cost of operation of the ETP and rendering the effluents harmless for meeting the

pollution control norms should be minimum. Vendor shall be asked to include the ETP also in the scope of his offer.

- It should be possible to run the plant on a continuous basis (instead of frequent stoppages due to changeover or resetting of the machines) with minimum manpower requirement for both operation and maintenance.
- In case of batch production units, the time, energy, manpower, etc. required to restart and bring up the reactors to optimum process conditions should be minimum (e.g. time required to empty, wash and recharge the reactor for the next batch should be minimum).
- It should be possible to carry out maintenance jobs while the plant is running. Critical pieces of plant and machinery should have standby units installed at the right locations so that they can be immediately used. Quick changeover should be possible, with minimum stoppage, while the plant is running. *Alternatively, process bypass routes (ducts or piping) should be available to enable taking out such units for cleaning or for maintenance work.*
  - Spares for two years smooth operation should be procured when the plant and machinery is being ordered from abroad. Performance guarantee conditions must include a clause for technical guidance/supply of spares for at least one year for all items purchased.
  - As far as possible, a satisfactorily running unit based on similar process and technology should be visited before finalising the purchase of the entire plant or any critical item.
- Vendors should provide free training to purchaser's technicians for operation and maintenance as well as handling emergency situations for all items purchased.
- At many locations, steady power supply may not be always available. There should be no detrimental effect on the product's quality due to power tripping/short-duration power failures.
- Dangerous process conditions, which can jeopardise safety of men and machines and can cause environmental pollution, should not develop during power tripping/short-duration power failures ( *no overflow of tanks/sudden release of gases into atmosphere/formation of explosive mixtures, etc. should occur*).
- Individual equipment and plant layout should be designed (by the vendor) while keeping this specific requirement in view, e.g. reserve tanks with chilled water should be available in the plant when highly volatile liquids are being condensed. In case of power failures, the reserve of chilled water will not allow temperature of the liquids to rise fast. Also, the condensers should have cooling jackets, which will remain full in case of pump stoppages during power failures. The above design considerations will prevent escape of volatile liquids.
- *Purchaser must consider the cost of providing diesel generating sets of adequate capacity to provide power, at least, for emergency needs.*
- *A word of caution: in spite of the provision of a diesel generator set it does take a few minutes to start supplying power from it and bring back the process operation to normal values by readjustment of the valves/pumps operation.*

- Purchaser should have free access to latest developments in technology. This can be ensured by separate agreements, which should also include clause for technology transfer in future.
- There should be no legal impediment for the purchase of the plant or transfer of the process know-how and technology from the government of the vendor's country.
- Any long-term payment of licensing or royalty fees shall be clearly indicated by the technology supplier.
- The purchaser (*who is buying designs and process technology know-how*) may carry out innovations by his own research and development efforts in the original items, designs and technology. In such cases it is advisable to have an agreement with the original plant supplier that such innovations shall be a joint intellectual property. It can then be sold to a third party with permission from the original plant supplier on reasonable terms.
- Such agreements should be made in the beginning itself to avoid misunderstanding later regarding sharing of profits from sale to third parties.

### 1.3.2 Purchase of Know-How

In certain situations it may be a better option to purchase the know-how instead of buying a complete set of equipment or a completely assembled plant. Some of these situations are as follows:

- When the existing machinery is consuming excessive power and raw materials, running at a lower production rate, producing more effluents (causing environmental pollution), the quality of products is not satisfactory, is becoming cumbersome to operate and/or maintain existing machinery and the revival steps taken in-house are not able to improve the conditions

OR

- A second-hand plant is available for an attractive price and it will be possible to recondition it and operate profitably if reliable know-how can be obtained for the revival. *The existing plant or many of its units may have to be disposed of in this case*
- The present technology has become obsolete and better machines are now available, which can run with less breakdowns and manpower and are more efficient
- When reliable vendors are not available
- Manufacturing shops of reliable vendors are too busy and will not be able to deliver the required items in a reasonable time
- Very high or unrealistic prices are being quoted by most of the vendors
- Vendor is reliable but does not possess the necessary facilities for manufacturing all the items/components required
- Commercial terms (high cost, long delivery period, improper performance guarantees) quoted by vendor are not acceptable

- Plant expansion or diversification is to be done but only limited funds are available
- Any further modifications of existing equipment with the available know-how in-house is not possible
- Obtain only know-how and the necessary equipment or machines. Balance facilities to be created by modifying existing equipment or fabricated in-house by purchaser's own technicians
- Purchaser is able to obtain services of experienced and reliable consultants, who have designed, fabricated and operated similar equipment with satisfactory results at lower cost. Purchaser can modify existing units in small incremental steps with assistance from such consultant
- The broad process to manufacture the product is known but certain specific details (e.g. exact pH/concentration/temperature to be maintained) are not known. These details can be obtained through consultants and the plant can be run accordingly on trial. The operating conditions, product quality, production rate and consumptions of raw materials, utilities, etc. can be observed. Based on these observations the plant management can then carry out the necessary modifications and upgradations in the existing plants or procure balance equipment as advised by consultants with appropriate inputs from his own engineers
- ***A word of caution:*** *purchaser is at a risk if the consultant wants to try his new unproven ideas. There is also risk of getting inefficient technology instead of a proven one*
- Purchaser has experienced and knowledgeable shop floor engineers with some in-house facilities for fabrication. They are confident that by making small changes or by providing additional features to existing machinery, the required performance can be obtained by small incremental investments. This can minimise additional capital required, maximise use of existing units and minimise the stoppage of the running plant (since major changes are not taken up all at one time). *However, this will take considerable time—even a few months*

### 1.3.3 Options for External Procurement

Procurement from an outside party: outsourcing the work fully or partially

The following options are to be considered for external procurement or minimising initial investment by the purchaser. Enquiries are to be floated and offers are to be obtained.

- BOT: Build, operate (till performance guarantee terms are met) and then transfer immediately to purchaser
- BOOT: Build, own, operate and transfer to purchaser after a certain agreed period
- BOM: Build, operate and maintain on behalf of the purchaser, who agrees to pay some fees or shares the profit generated. The vendor recovers the cost from this. The ownership is transferred to purchaser after the vendor has recovered his costs fully along with profit. The purchaser does not invest funds initially but gets the benefits—at reduced rates

- BOOM: Build, own, operate and maintain for some years for an agreed fee as per agreement between purchaser and external vendor
- BOMT: Build, operate, maintain and transfer to purchaser after a certain agreed period

**Advantages to Purchaser** This enables the purchaser to save initial investment as well as efforts of setting up the plant from initial stages till it achieves steady performance. It also enables the purchaser to pay attention to some other (important) jobs at hand.

Purchaser may only provide infrastructure at the site for constructing the plant and machinery, unskilled labour, liaison with statutory authorities, make available raw materials and utilities and arrange to sell the product *if it meets specifications given by customers*.

Vendor shall be responsible for erection, testing, commissioning, initial trial runs, plant stabilisation and reaching the guaranteed performance of the plant with respect to production rate, quality of product, consumption of raw materials and energy and environmental pollution control.

All equipment and plant assemblies should be handed over by the vendor to the purchaser at the end of the contracted period in perfect working order except normal wear and tear. This must be however agreed upon in the initial contract itself. Vendor may be asked to replace worn-out components or spares by buying from the equipment manufacturer or their authorised sales agencies only.

Operation of the facilities is to be strictly done as per guidelines given by the purchaser. Maintenance of the facilities should be carried out as directed by purchaser/ as per standard maintenance guidelines given by original equipment manufacturer.

**Advantage to Vendor** He gets an opportunity to undertake trials of some new process or designs developed by him. He can develop some new business without the risk of marketing his products since his products are already being tried out at the purchaser's plant.

*The vendor can also be assured of reasonable profit by such an arrangement*.

**Risk to Purchaser** When the vendor is asked to supply some critical part of the plant, there is a possibility of loss of production or goodwill, product not meeting the specifications required by clients, timely delivery not being done by the main production plant if satisfactory work is not done by vendor or there are deficiencies in his equipment.

*There is also a chance that movement of vendors' personnel in the purchaser premises can cause safety issues or leaking out of certain know-how from the main plant.*

The vendor will not generally have ultimate ownership of the equipment and therefore may not operate and maintain very carefully unless penalties are specified in the agreement.

However, the responsibility for mishaps, compliance with statutory regulations, labour problems, loss of goodwill in the market, etc. ultimately rests with the