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Practical Guidelines for the Chemical Industry

Operation, Processes, and Sustainability in Modern Facilities

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This work is dedicated to the designers of chemical plants; as well as technicians and engineers working in chemical industries and the managements who will use the guidelines for their safe, pollution free and efficient running; and the teachers who will use them to train their students for successful careers in these industries.

Preface

Safe, pollution free and efficient running of chemical industries is vital for the economy of a nation and getting employment for the population. Chemical industries produce refinery products and petrochemicals (such as diesel, petrol, lubricants, ethylene, propylene, benzene); inorganic chemicals (sulphuric acid, oleum, chlorine, caustic soda, fertilisers, alum, paints, titanium dioxide, etc.); products such as polyethylene, polypropylene, polyvinyl chloride; etc. They also produce large quantities of specialty chemicals such as catalysts, surfactants, specialty polymers, coating additives, and oilfield chemicals which are used for specialised applications; synthetic fibres for clothing; paper for printing and writing, lubricants for machineries, agricultural chemicals (such as herbicides, fungicides, and insecticides); food preservatives; and active pharmaceutical ingredients which are necessary for ensuring food and health care for the nation. A large world market is generally available due to chemical industries.

The managements of these industries will have to consider production of quality products, expansion of capacities, diversification to new products, improvement of operational efficiency, modernization and revamping in certain cases, and acquisition of idle plants in order to maintain and improve operations, attain higher market share, and build up reputation in international markets.

Chemical industries have many process units and machineries which are to be operated (mostly continuously) in a carefully controlled manner. The operating conditions and process parameters are to be controlled by proper feed rates of raw materials, heating/cooling of the reactors, flow of absorbing liquids and gases to the absorption towers, and operating the process units in a safe, energy efficient manner without causing environmental pollution.

Incorrect control of operations can result in loss of production and unsafe conditions (*may even result in accidents*); environmental pollution, poor quality of products, higher consumption of raw materials and energy; and higher cost of maintenance due to more breakdowns of process units and machinery. Apart from these, the products may even get rejected in the market and the manufacturing organisation can run into a loss. These can have a negative impact on the organisation.

This book provides practical guidelines to correctly select a safe and efficient process for manufacture, as well as process units which need to be designed, fabricated, operated, and maintained properly to work efficiently without causing environmental pollution in order to make available quality products at reasonable costs to the customers.

It also gives general practical guidelines for important matters like operational safety, use of pressure vessels, selection of appropriate materials of construction for process units, efficient handling of process fluids, using proper heating and cooling systems, disposal of dangerous wastes, etc. These guidelines are therefore applicable to most of the chemical industries for sustainability in modern facilities.

Engineers and technicians working in industries like petroleum refining, fertilisers, chlor-alkali manufacture, synthetic fibres, etc. can use the basic information provided in this book along with manuals and instructions for the specific industries.

Nagpur, India — Kiran R. Golwalkar
Mumbai, India — Rashmi Kumar

Who Can Benefit from This Book?

This book has been written and the information in it is compiled for those working in chemical industries and for those interested in academics. It will be found useful for successful careers in units manufacturing various chemicals, fertilisers, and pharmaceuticals, for pollution control, etc.

Guidelines are given for establishing production units, their safe and smooth operations, for maintaining, expansion, and modernization, and related important activities such as:

- Statutory compliances
- Selection of process technology and equipment
- HAZID, HAZOP, and ensuring safety
- Management of human resources
- Pressure vessels
- Selection of process piping and pumps
- Selection of Materials of Construction for various units
- Selection of heating and cooling systems and equipment
- Cogeneration of steam and power
- Reducing breakdowns of equipment
- Reducing cost of production
- Process control
- Project activities for expansion, modernization of existing plants, revival of idle plants, relocating a plant
- Facilities for Effluent Treatment and Air Pollution Control
- Disposal of corrosive, toxic, inflammable waste

It is therefore intended to serve as a reference book for chemical and other plant engineers as well as other technical personnel, for managements of chemical industries as well as students of chemical and mechanical engineering. It is hoped that the book will be found useful by all of them. It has been written and compiled after getting inputs from academic personnel and industrial professionals.

Suggestions from readers for improvement of the book are welcome.

Sources of Our Information

This work is based on the knowledge and experience gained during working in chemical industries in India and abroad for manufacture of sulphuric acid, carbon-di-sulphide, oleums, alums, organic dyes, and destruction of hazardous wastes. The plants for these were installed in GRASIM Industries (India), Gopal Anand Rasayan (India), V K Engineers (India), EAHCL (Kenya), Thai Rayon (Thailand), Parksons Dyestuff Industries, and SMS Infrastructure (India).

Experience was also gained during erection, commissioning, and operation of these chemical plants, their modernization, and troubleshooting by the authors. These chemical industries had various process units such as refractory lined furnaces, hot gas filters, liquid sulphur filters, catalytic converters, waste heat recovery boilers and economisers, absorption towers, refractory lined electric furnaces, distillation columns, refrigeration units, effluent treatment plants, air pollution control facilities, heat exchangers for various duties, etc.

There used to be detailed discussions and regular interactions with the personnel at these industries on matters related to procurement of equipment, erection, safe operation, environmental pollution control, capacity expansion, and modernization. The knowledge and information received from senior managements, operating and maintenance engineers, and other personnel in these industries was very useful for the present work and is gratefully acknowledged.

The authors were also engaged in carrying out teaching assignments at universities for graduate level students for subjects such as Inorganic Chemical Technology, Process Equipment Design, Mass Transfer Operations, Plant Erection and Commissioning, and Environmental Pollution Control which are related to chemical engineering.

Various standard textbooks, ***Perry's Chemical Engineers' Handbook***, ***Coulson and Richardson's Chemical Engineering Design***, Vol 6, R. K. Sinnott, web sites of equipment manufacturers and Engineering Toolbox, our own study notes, and books authored by the same author and published by Springer International were referred while writing and compiling information for this book.

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We sincerely thank **V K Engineers**, MIDC Tarapur, India (manufacturer of equipment for chemical plants), India office of **TLV International** (manufacturers of steam traps and related equipment) for permitting to use information for heat exchangers, jacketed reactors, and steam traps, and Editor of *Engineering Toolbox* for permitting us to use information published by them for properties of fuels, materials of construction, etc.

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Kiran R. Golwalkar and Rashmi Kumar

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Kiran R. Golwalkar is a consulting chemical engineer in private practice in India. He worked for many years in the field of commissioning, operating, modernising, and diversifying of chemical plants in India, Kenya, Thailand, and Indonesia. He has also served as a visiting faculty member in chemical engineering institutes in Mumbai, Nagpur, and Pune in India.

Rashmi Kumar is Assistant Professor of Chemical Engineering (D J Sanghvi College of Engineering, Mumbai) and has a long teaching experience of about 25 years.

Chapter 1
Management Functions

Abstract Chemical industries are very important for the economic progress of a nation. They are also very useful for a comfortable life of the citizens, since they assist in meeting the requirements of food, clothing, and health products. Modern Management and responsible engineers in chemical industries shall understand and execute important activities necessary to establish, operate, and maintain these industries in a safe, pollution-free, and an economically efficient manner. Research and development activities shall be carried out for the progress of the organisation.

Keywords Successful managements · Arranging funds for various activities · Market survey · Selection of process and technology · Procurement of plant units and machinery · Manpower planning · Water budgeting · Efficient maintenance · Aims for research and development

1.1 Introduction

Chemical industries are very important for the economic progress of a nation and for meeting the requirements of food, clothing, and health products for ensuring a comfortable life for the citizens. Modern Management and responsible engineers in chemical industries shall always aim to operate and maintain these industries in a safe, pollution-free, and efficient manner, while manufacturing the products as per specifications at a reasonable cost.

The revenues obtained should be judiciously allocated for ensuring safe operations, environmental pollution control, energy efficiency of the industry, and for procurement of all necessary inputs like raw materials, spares for machineries for steady production, and packaging items for safe and proper transport of finished products to the customers.

Reasonable allocation shall also be done for innovation in working, improvement in existing technology, and development of new products and processes.

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1.2 Successful Managements

The Promoters and Board of Directors shall proceed for Formation of Management team with experts from different fields. These experts shall be professionally qualified, experienced, and trustworthy individuals for carrying out various activities required for establishing the industry. They should be familiar with the typical nature of chemical plants which are generally run continuously and are prone to accidents, (there are exceptions also); they have chances of causing environmental pollution and are dependent on steady supply of water and power. Managements have to address the following issues for successfully establishing and running the chemical industries. This book gives guidelines for looking into these matters (given as check points in the next few chapters).

- Arranging funds for various activities
- Market survey (to understand requirements of quality and quantity by the customers).
- Selection of process and technology for meeting the above requirements.
- Getting statutory permissions and consent to establish and to operate (please see Sect. 9.1 for details)
- Procuring plant units and machinery.
- Planning for skilled and unskilled workforce.
- Arranging site infrastructure; supplies of water, power, raw materials, fuels, and fire fighting equipment.
- Erection and commissioning of process plant; and stabilising the production runs.
- Efficiently and safely operating the chemical plant without causing environmental pollution while ensuring manufacture of the products as per specifications and delivery schedules given by customers.
- Maintenance of process plants and auxiliaries to ensure safe and smooth working.
- Generating sufficient revenues to meet expenses and getting reasonable profit.

Additionally, as a part of Corporate Environmental Responsibility (CER) and Corporate Social Responsibility (CSR) the organisation must adopt practices and procedures to control pollution, eliminate waste and emissions, conserve forests, have funds allocated for rehabilitation and resettlement of displaced persons, sanitation, health, education, and skill development. All CER activities should aim to mitigate any damage to environment caused by the company and at the same time maximise the efficient use of resources.

1.3 Arranging Funds for Various Activities (While Minimising Capital Requirement)

Investment in plant and machineries as well as working capital are required for various activities such as market survey, land acquirement, obtaining licenses for various clearances; designing, fabrication, and procurement of machinery; construction

of the site infrastructure, erection and commissioning of plant units, arranging supply of raw materials and utilities; effluent treatment, air pollution control, and disposal of dangerous wastes; product marketing (storage, quality check, and transportation) and employing manpower.

Requirement of funds for these activities are to be estimated and arrangements are to be made for the same. This can be done through own capital investment, floating equity shares, preference shares, and debentures; getting loans from banks and financial institutions; and bonds with fixed interest, which are some of the means for raising funds. Management can also explore the possibilities of getting government grants or subsidies (for setting up the industries in certain areas or for certain products for export) and raising funds through venture capital, which can reduce the amounts of loan to be taken. Requirement of capital can also be reduced if some second-hand (old) equipment are available in usable condition, which can be procured at lesser cost. They may be repaired or modified to suit the requirement.

Financial consultants may also be engaged for further advice in these matters.

Management shall carefully monitor all activities in order to establish and run a well-equipped plant to ensure production of a better product at minimum cost.

1.4 Market Survey

Market survey is to be carried out for a correct assessment of consumers' preferences; and an investigation into the state of the market (*for the product being considered for manufacture*) is to be done to find out the availability of similar or alternative products (their quality and unit costs) from competitors. The survey should obtain correct information about any special needs of the customers for quality, *type of packaging generally preferred* by the customers, and the consumption patterns. It can be done by collection of samples from other suppliers or buying of small quantities for analysis in own laboratory to confirm their quality. The tolerance limits for impurities (as mentioned in the specifications given by customers) shall also be carefully looked into.

It helps to identify the requirements and opportunities in the market. This plays a key role in estimating the demand for the product with required specifications. It helps to decide the manufacturing capacity of the plant for the product (with the particular qualities that have to be ensured during production). The plant is to be run accordingly to meet the specified quality and demand in the market.

Sale of Products

Cost of manufacturing the product will depend on the special characteristics/quality of the product, production capacity planned and quantity as well as delivery schedules (as specified by clients), efficiency of the process for manufacture, and costs of various inputs.

Cost of the delivered product (landed cost at delivery point) includes cost of special containers, safe transportation, *cost of unloading at points of use,* and transit

insurance. Safe handling and dispatch of products must be ensured by proper packaging and careful transport to points of use at a reasonable (competitive) cost. These costs are generally borne by the supplier.

However, the selling price depends on the terms and conditions of sale and a reasonable profit margin required by the management.

1.5 Process Selection

It is advisable to choose from a variety of processes (which are feasible and available) for the manufacture of a product. Some of these processes could be based on drastic operating conditions of pressure, temperature, handling of corrosive or dangerous materials, high concentrations, etc. These shall be considered for initial evaluation of processes for shortlisting. It should be an industrially proven process as far as possible, except when a new process developed in the laboratory is to be adapted.

Example *65% Oleum can be manufactured by adding 25 % oleum to liquid SO_3 in a circulation tank* ***or*** *by absorbing SO_3 vapours in a circulating stream of cooled 65% oleum to which 25% oleum is added at a controlled rate. The concentration is maintained at 65% and the product is transferred to storage. The latter method is safer as handling of liquid SO_3 (which is dangerous) is not required.*

The process to be used for manufacture of the products should be safe to operate, should have less drastic conditions of operations of pressures and temperatures (i.e. not necessary to use very high temperatures or pressures), shall not require handling of dangerous (toxic / inflammable) materials as far as possible, shall not have many side reactions/by products (which can reduce the yield of the main product), and generate minimum effluents.

HAZID study shall be carried out before final selection of the process

It shall normally result in a high degree of conversion of raw materials into the product (with minimum need for further concentration or purification). The technical team in the organisation must be familiar with the process.

Managements shall carefully study the Basic Engineering Package (BEP) prepared by their own technical team or by the consultants appointed. The BEP should give process description, process flow sheet, rated production capacity, broad specifications of equipment, typical plant layout, time required for implementation, manpower required, approximate consumptions of raw materials and utilities, etc. to enable estimation of economic viability. This shall be confirmed by estimation of competition i.e. overall production statistics and product specifications of competitors.

1.6 Selection of a Proven Technology

After a proper study of the BEP and its acceptance by the technical team, the senior management shall instruct preparation of Detailed Engineering Package (DEP) . This should be based on a technology which should be a proven one with plants of comparable capacity operating successfully for at least three years. These shall be based on raw materials which should be regularly available at reasonable costs. If the raw materials are not available as per specifications, additional equipment shall be included in the plant technology for their purification (by drying/calcinations/ filtration, etc.).

The DEP must give detailed mass and energy balance, detailed fabrication drawings and detailed specifications of all equipments (including operating conditions and materials of construction), P & ID, Proposed layout for the plant, enquiry document sheets for various equipments, procedures for erection and commissioning, operating and maintenance procedures etc.

The plant design should have scope for future expansion of capacity, diversification to more products, and should be energy efficient.

The plant must be safe to operate and maintain; should be suitable for operation at a capacity lower or higher than rated capacity i.e. should have sufficient turn down ratio while meeting product quality as per client requirements; and without causing environmental pollution when the plant is run at a little overload (say, about 20% above the rated capacity) in order to meet sudden high demand in the market from a very important customer or for export. The plant design should have flexibility of operation (say, about 20% below the rated capacity of production also) even when certain raw materials may not be available exactly as per required specifications, or are in short supply.

The conversion of (yield) raw materials shall be maximum, thus reducing the requirement of and expenses on raw material. Requirements of utilities and other consumable inputs (e.g. property modifiers, stabilisers, and spares for machineries etc.) shall also be minimum.

The technology used should not cause environmental pollution (generation of effluents should be minimum and those which can be easily taken care of). This minimises expenses on effluent processing. It will be easier to comply with the norms prescribed by the statutory authorities for pollution control when such technology is used.

Plant equipment should be able to withstand adverse weather conditions.

Handling of raw materials, operation of process units and machinery, and dispatch of finished products shall be mostly automatic. This can reduce requirement of labour for the plant.

- Such technologies can minimise/reduce the cost of production and hence the product can become competitive in the market.
- There shall be no infringement of patents. The technology should not violate any statutory rules and regulations.

1.7 Procurement of Plant Units, Machinery, and Their Installation

The proposed layout of the process plant as given in the DEP should comply with the Statutory Rules and Regulations for safe working of personnel in the premises as well as surroundings. It should be designed to safely store all dangerous, corrosive, inflammable, and toxic materials that may have to be handled.

After acceptance of BEP and DEP inquiries are to be floated for purchase/supply of equipment required for the plant. Offers are to be obtained for each item of equipment from at least three parties. Vendors shall then be shortlisted on the basis of their technical capability, past experience, and timely delivery. Final purchase orders are issued after detailed technical and commercial negotiations. The technical team may allow certain deviations to the vendor/fabricator if they make good suggestions for improvement in the design. The final design can include such small changes. Genuine difficulties in fabrication can also be considered.

Certain costly equipment or machinery could also be taken on lease if they can considerably increase the efficiency, but funds are not available at present.

Example A waste heat recovery boiler (instead of an air-cooled heat exchanger for process gases) can make steam available without consumption of fuel, but will be quite costly. It can be taken on lease from a party and the cost can be paid through savings generated by using the steam that can become available as a by-product.

HAZID and HAZOP studies should be carried out while selecting the process, technology, and during procurement, installation, and operation of these equipment to ensure safe working of the plant *without causing environmental pollution.*

1.8 Manpower Planning

The organisation structure shall clearly define the relationship between senior executives, plant manager, shop floor engineers, operating and maintenance personnel as well as other departments like marketing, stores, administration, research and development, materials procurement, and human resources. An organogram shall be created for the smooth functioning of the organisation.

Chemical industries need skilled manpower (engineers to build and manage the plant), operators and technicians (to operate and maintain the process units and machinery); scientists (for research and development purposes), experts for financial planning, cost accountants (in order to study various costs incurred), and marketing personnel (for market survey and final product marketing).

The persons to be engaged for skilled jobs need proper understanding of the process and machinery, their operating methods and maintenance procedures.

Sufficient manpower shall be engaged if the operations are complicated or involve many steps; if there are considerable physical distances between process units, machinery, and control systems; and as leave relievers.

Semiskilled workers should be very cautious and remain alert always. Their work includes unloading of bulk raw materials and chemicals required for manufacture; packaging finished products and loading for safe transportation.

Unskilled employees are also required for the performance of simple duties, which could be activities of a routine and repetitive nature although familiarity with the occupational environment is necessary. Their work may thus require, in addition to physical exertion, familiarity with variety of articles or goods. They are usually employed under contract for transportation, loading, and unloading under supervision, and cleaning or assistance for maintenance.

Careful planning of safe work environment, safety devices, and equipment is necessary for the process plant with proper protection and appropriate working and rest hours for workers.

Managements shall also consider carrying out skill upgradation programmes for the workers through training courses. Refresher courses can also be arranged for the personnel. Such activities can increase the efficiency of the work force. They can improve the safety, pollution control, product quality, and organisational efficiency.

1.9 Arranging Site Infrastructure

Management should arrange site office, security, firefighting equipment, communications with head office; and proper facilities for the storage of raw materials, all necessary spares; and make arrangements for sufficient power, water, and fuels for setting up the plant and for the smooth operation.

1.10 Erection and Commissioning

This can be carried out after getting statutory permissions for establishing the plant, followed by procurement of process units and plant machinery, making arrangement for site infrastructure, and engaging appropriate manpower/external contractors

1.11 Utilities Planning

Utilities and energy are major contributors to expenses for production by the plant. The cost of utilities can be reduced by proper plant design to minimise power, steam, and water consumption, by maximising efficient energy recovery, and

optimising co-generation of power and heat, optimum use of compressed air, and careful use of auxiliary equipment which consume power.

1.12 Water Budgeting

Water is required in a process plant for the formation of products (by chemical combination), for the crystallisation of the products, for making solutions, for generation of steam, make up to cooling towers, flushing of process units, etc. The requirement of fresh supply of water for the plant should be minimised by reducing the consumption wherever possible and minimising wastage. This can be done by recycling of condensate to boiler feed, treatment of waste water and maximising its recycling for process, scrubbing systems, as make up to cooling towers, etc. Arrangements for rain water harvesting should also be installed. These actions can reduce the need for fresh supply from external sources as well as the cost of treatment of raw water.

Treated wastewater that cannot be reused for process or as make up to cooling towers shall be used elsewhere in the premises. Zero Liquid Discharge is now mandatory, and all efforts should be done for ensuring this. If this cannot be done even after best efforts, the effluent shall be disposed through Common Effluent Treatment Plants (CETP) statutorily authorised. However, conditions laid down by the CETP are to be complied with before the effluent is accepted by them for treatment (Fig. 1.1).

1.13 During Regular Operations of the Process Plant

Following matters are to be monitored regularly by plant engineers (both operating and maintenance engineers) and senior management for the safe, pollution-free, and efficient working of the plant. The marketing department can also provide useful inputs for product quality and manufacture.

Essential check points are given when the plant is operating (guidelines for plant engineers), and for maintenance (guidelines for maintenance engineers) for the following:

- Compliance with all statutory matters and instructions from government and local authorities e.g. for pressure vessels, storages of fuel and dangerous items; electrical installations and maximum demand on power supply grid to name a few.
- Proper operation and maintenance of effluent treatment plant (ETP) and air pollution control (APC) units; safe disposal of solid/hazardous wastes; and ensuring sufficient stocks of neutralising and treatment chemicals to meet instructions from pollution control authorities
- Meeting specifications and delivery schedules for the products

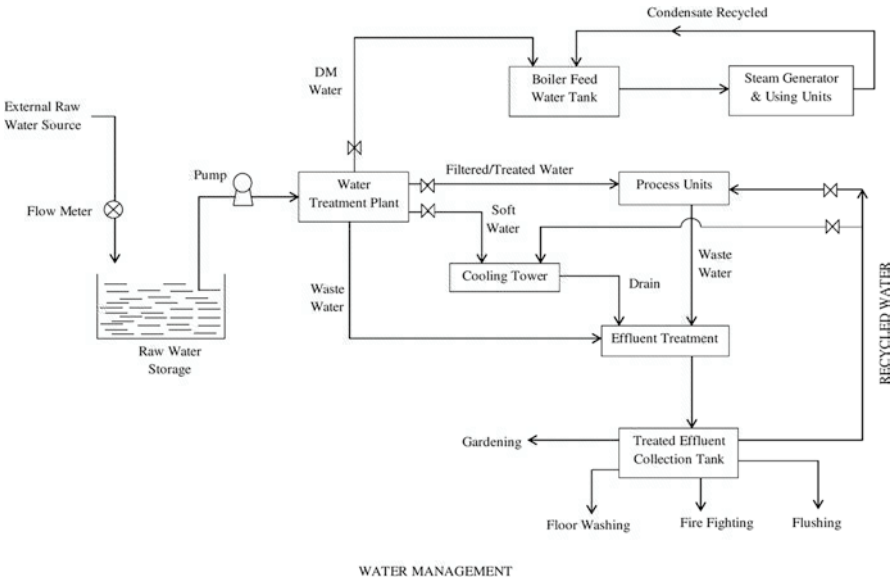

Fig. 1.1 Water management for a chemical plant

- Proper production planning in the case of batch production plants.
- Thorough cleaning and maintenance of process units and important machinery (pumps, blowers, reactors, condensers, and heating and cooling systems.)
- Minimising cost of production by controlling consumption of all inputs such as raw materials, catalyst, property modifiers, utilities and fuels, packaging items, and manpower.
- Inventory control of all essential inputs and spare parts.

1.14 Maintenance of Process Units and Machinery

- Proper maintenance is essential to make the plant safe, to reduce pollution, to increase yield from inputs, and to improve product quality. It is advisable to establish necessary facilities for maintenance in the beginning itself, since there could be minor requirements for repairs during commissioning and while stabilising the plant operations.
- Efficient management of maintenance constitutes the following: (1) preventive activities to minimise breakdowns, (2) timely repairs and/or replacement of damaged units, (3) thorough inspection, cleaning, servicing, and internal repairs of important equipment during annual shutdown for overhaul, (4) inventory control of spares and proper storage of all other inputs, (5) developing spares in-house, (6) reconditioning of certain machinery to reduce dependence on external agencies, and (7) better training for operating and maintenance personnel.

1.15 Aims for Research and Development

- Improvement in product quality
- Innovation in the process plant itself for making it safer; to minimise environmental pollution and to make it more energy-efficient.
- Reduction of consumption of raw materials and utilities.
- Reduction of maintenance problems.
- Development of new products, better effluent treatment, efficient energy recovery, use of cheaper raw materials, better design and materials of constructions (MOC) for critical parts, regeneration of spent catalyst, and other consumables if possible.

References/for Further Reading

1. "Process Equipment Procurement in the Chemical and Related Industries" Kiran Golwalkar, Published by Springer International Publishing, Switzerland.
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Chapter 2
Hazid, Hazop, and Ensuring Safety

Abstract It is essential to recognise the hazards and chances of accidents in a chemical industry before establishing and operating it. A detailed study shall be carried out of all materials that will be handled, the reactions and operations, and the various equipment that will be installed in the plant. Technical teams shall be formed for such detailed study. It should have knowledgeable and experienced designers, operating and maintenance personnel from different disciplines. They shall give suggestions after study of the P & ID for safely running the plant operations.

Keywords HAZID · Hazard analysis · Classification of hazards · Hazards identification · Prevention of dangerous situations · Ensuring safety in plant · HAZOP (hazard and operability) study · Formation of a technical team · Case studies

2.1 Introduction

For a proper and rational plant design it is very important to recognise the dangers involved in a chemical project before making any substantial investment in procurement of process units and machinery. It is necessary to consider the safety issues also. The technical team appointed by the management shall recommend appropriate preventive measures and safety factors during process and equipment designs for minimising hazards such as fire, explosion, and personal hazards from inflammable and toxic materials.

2.2 Hazard Analysis: HAZAN

This shall be based on a thorough study of the production process conditions, the reactions that will take place, properties of materials (and a study of their Material Safety Data Sheets) that will be handled, the generation of dangerous effluents, the

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quantities stored at site, and an examination of the probability of occurrence of dangerous incidents

Details of all main equipment in the plant, piping, control systems and the auxiliary facilities provided should also be studied to visualise the chances of occurrence of hazardous events.

It is imperative that the equipment are designed, fabricated, and tested as per applicable codes and standards and as per good engineering practices. The plant layout shall be designed for safe working. Appropriate instrumentation, control systems, and safety devices shall be provided as per statutory rules and checked regularly.

Factors such as improper plant design, faulty organisation of jobs, employing insufficiently skilled workers for a job (which needs skilled persons), unsafe working conditions, poor lighting, and dusty and noisy environment can also make the workplace hazardous. Hence the management should prioritise operational safety and health of workers; and improve the efficiency of both the workers and the plant.

Detailed Study

The detailed study will enable identification and analysis of the more likely causes and consequences of the hazardous incident that may occur.

Thereafter estimate the consequences to employees (persons present in the premises); people who are present nearby but outside the premises and the surrounding environment away from the place of incident.

A visit may be undertaken to a similar operating plant to observe the safety precautions and important features of plant equipment designs.

2.3 Check Points for HAZAN Study

- Analyse the hazards in the process, equipment, and operation of the plant.
- Identify the likely causes/mistakes during operation/unintended outcomes of operation that may result in development of dangerous situation.
- Identify ways to minimise process and equipment hazards due to corrosion, fire, explosion, and personal hazards from fumes and poisonous materials.
- Prevention and control: This refers to that phase of process design which can minimise/control the fire until available extinguishing facilities can work effectively for complete extinguishment of the fire.
- Assess the risks from such dangerous situations and whether the consequences will be severe (loss of lives) or quite damaging (loss of production due to major breakdowns).
- Suggest, evaluate, and plan the detection, prevention, and damage control measures.