SECTION I

PROCESS EQUIPMENT OPERATION

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INTRODUCTION

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A *process* is an amalgamation of machines, methods, materials, and people working in concert to produce something. Generally, the end product is something tangible: fuel, food, textiles, building materials—the list is exhaustive. The end product from a process can also be intangible: a bond, software, laws. It is difficult to say where a person begins and a process ends. Human beings are dependent on processes to live, as we are dependent on water to live. The first known process was probably irrigating fields to grow crops. Many argue that this process began over 20,000 years ago, others that it was closer to 50,000 years ago. Every few years a discovery is made that puts the date back even further as well as the place of origin: Africa, Asia, the Middle East? Needless to say, humans have been trying for a very long time to reduce labor and add comfort through the systematic use of materials and machines to implement a process to achieve a desired goal. Consider the following incomplete list of materials and machines. All required a process.

- Machines
  - *Primary machines*: simple machines that rely on their own structure to complete work: lever, pulley, inclined plane, hammer
  - *Secondary machines*: simple machines that rely on an accompanying machine: screw, wheel, axle, saw
  - *Tertiary machines*: complex machines that require a contribution from a compliant machine: gear, valve, pump, furnace, bearing, engines, boiler
- Materials
  - *Primary materials*: material used in the unprocessed state: water, wood, pitch, clay, stone, sand, wax, bone, fiber
  - *Secondary materials*: material developed from a combination or treatment of primary materials: leather, cement, paint, pigments, cloth, metal, glass
  - *Tertiary materials*: materials made from chemical manipulation: alloys, polymers, semiconductors, composites

A process does not become successful without observation and communication. One of the most important devices developed for a process was the *pump*. The first piston pump was invented by Ctesibius of Alexandria, a Greek physicist and inventor born around 300 B.C. One of his better known engineering efforts was improvement of the water clock. A water clock keeps time by means of dripping water maintained at a constant rate. His ideas of refinement of the water clock allowed for accurate timekeeping. The accuracy of his water clock was not improved upon for 1500 years. The second invention he is noted for is the water organ, the precursor of the hydraulic pump. This was a mechanized device in which air was forced by water through organ pipes to produce sounds. At first glance one would be in error not to think of the vast number of applications such a device could have. There are hundreds of different pumps in any given process plant. The concept of conveying gas or liquids without a pump is unheard of

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today. This invention resulted from observation of one of his first inventions—a counterweighted mirror.

Ctesibius was born the son of a barber, and like many good sons he tried to follow in his father's footsteps. Perhaps it was a good thing that he spent more time thinking about how to improve his father's trade than in clipping bangs. He invented a device: a mirror placed at the end of a tubular pole, with a lead counterweight of the exact same weight placed at the other end that allowed the mirror to be adjusted for each customer. He noticed that when he moved the mirror, the weight bounced up and down while making a strange whistling noise. He theorized that this noise was air escaping from the tube. He tinkered with various dimensions and escape holes, which led to other observations and inventions using the power of pressure, gases, and liquids to achieve certain results. Without these musings the piston pump might never have came into being.

Pumping water for consumption, irrigation, and washing changed human society. If a stable water source was found, the water could be transported with minimal labor—all that was needed was a pump. People no longer had to move repeatedly to new areas to find food and water. They could stay put, farm, and live. In doing so, cities were established. With a high concentration of people, the odds of more improved processes increased exponentially. With the increased demand for improved comfort and greater commercial profits came a higher concentration of thinkers. Some people despise the modern city, but it must be admitted that cities are responsible for generating many of the ideas that make the rest of society flourish.

Mechanical means to move gases and fluids are essential in any process plant, but so is chemical manipulation. Perhaps the first known form of manipulating something chemically would be the cooking of food. With cooking, meats, grains, and vegetables become easier to digest and transport, and spoilage is reduced. Adding heat requires a fuel source and a means to control the thermal output. Being able to heat a substance in a controlled fashion on a larger scale introduced materials such as alloys, glass, and a whole host of chemicals. This process required furnaces and valves, among other devices. The second great feat of chemical manipulation is fermentation followed by distillation. Fermention of grains and berries has been carried out for tens of thousands of years. Humans are not the only creatures to enjoy a good "buzz." Many animals will have a party ingesting fermented berries and fruit. The ethanol produced provides a feeling of euphoria. One cannot blame any creature for wanting to feel better, but hopefully, it doesn't get in the way of the success of a species. To be able to separate alcohol from water requires observing condensation, fashioning a controllable heat source, and qualitative analysis. Alcohol is not just for drinking; it is actually a very valuable solvent, and the principles needed to understand how to make and distill alcohol are the very reasons that humans have become so successful. Without knowledge of the principles of fermentation and distillation, our heat, shelter, clothing, transportation, medicines, food, and materials would not exist as we know them.

The most influential industry to date is petroleum refining. Distillation is the main process in petroleum refining. Pharmaceuticals, building materials, solvents, plastics, and various fuels are all a result of the controlled distillation of crude oil. All this came about from the refinement of fermented grain. In fact, it is fair to say that without fermentation, we would not have progressed much further than the Cro-Magnons. Think about that the next time you sip a beer or enjoy a glass of wine or Scotch.

The effort that unfolds over the next several hundred pages is an undertaking that convinced over thirty of the world's top academic and engineers to embark on a project that is encyclopedic in nature. Talented and practicing experts in process plant engineering from Asia, Africa, Europe, the Middle East, and North America have contributed chapters to this book: all intended to help the reader to understand and implement best practices in process plant equipment operations, reliability, and control. The book is a comprehensive text that will provide the reader with access not only to fundamental information concerning process plant equipment but also with access to practical ideas, best practices, and experiences of highly successful engineers from around the world. The book is divided into three sections: Section I, Process Plant Equipment Operations; Section II, Process Plant Reliability; and Section III, Process Measurement, Control, and Modeling. An overview of the main highlights of the various chapters follows.

Section I: Process Equipment Operation

Chapter 2: Valves This chapter provides an introductory description of control valves, their types, and selection criteria, sizing procedures, operating principles, and maintenance and troubleshooting methods. It also describes common problems suffered by control valves and their remedies. Procedures for preventive and predictive maintenance of control valves and nonintrusive methods for detection of valve stiction are also discussed briefly.

Chapter 3: Pumps Water and other liquids are the lifeblood of many industrial processes. If those fluids are the blood, the plumbing system makes up the veins and arteries, and the pump is the heart. This chapter touches briefly on several types of industrial pumps, but deals primarily with the most common type, the centrifugal pump. Most of the principles apply to other types of pumps, but regardless of the type of pump in use, the pump manufacturer's manual and recommendations should always be followed.

The chapter also provides the following: general terms commonly used in the pump industry; brief information on several different types of pumps that may allow a user to identify what type of pump is either in use or needed for a particular application; basic component descriptions common to centrifugal pumps; instructions on how to read a typical pump performance curve; categories of different types of pump applications; how to size and select a pump properly, including net positive suction head calculations and considerations; proper pump maintenance; and basic pump troubleshooting guidelines.

Chapter 4: Pipes Pipelines are one of the main methods of transporting oil and gas worldwide. Historically, pipelines have been the safest means of transporting natural gas and hazardous liquids. The integrity, safety, and efficiency of a pipeline system is important and key to operators. Based on these considerations, this chapter covers mainly pipe types and pipe selection strategy, including pipe strength, toughness, weldability, and material; pipeline network design; pipe problems; pipeline inspection; and pipe maintenance.

Chapte 5: Cooling Towers Cooling towers are the most basic type of evaporative cooling equipment used primarily for process water cooling purposes in many chemical plants. Their principal task is to reject heat to the atmosphere and they are deemed a relatively inexpensive and reliable means of removing heat from water. Basically, hot water from heat exchangers or other units will be sent to a cooling tower and the water exiting the tower (which is cooler) will be sent back to the heat exchanger for cooling purposes.

Chapter 6: Filters and Membranes Filters and membranes are used in vast industrial processes for the separation of mixtures, whether of raw process media materials, reactants, intermediates, or products—comprising gases, liquids, or solutions. This chapter identifies gas and liquid filtration covering solid–liquid separations, solid–gas separations, solid–solid separations, liquid–liquid separations, and liquid–gas separations. It includes membrane technology such as microfiltration, reverse osmosis, ultrafiltration, and nanofiltration. It is a complete reference tool for all involved in filtration as well as for process personnel whose job function is filtration.

Chapter 7: Sealing Devices This chapter covers a variety of gasket types, compression packing, mechanical seals, and expansion joints. Discussed are materials of construction, principles of operation, and applications of sealing products. Wherever there are pumps, valves, pipes, and process equipment, there are sealing devices. Although relatively low in cost, sealing devices can have huge consequences if they don't work as needed or if they fail. All these devices are used in process industries and are critical to plant safety and productivity.

Chapter 8: Steam Traps A steam trap is a device attached to the lower portion of a steam-filled line or vessel which passes condensate but does not allow the escape of steam. It is also a piece of equipment that automatically controls condensate, air, and carbon dioxide removal from a piping system with minimal steam loss. Hot condensate removal is necessary to prevent water hammer, which is capable of damaging or misaligning piping instruments. Air in the steam system must be avoided, as any volume of air consumes part of the volume that the system would otherwise occupy. Apart from that, the temperature of the air–steam mixture normally falls below that of pure steam. It has been proven that air is an insulator and clings to the pipe and equipment surfaces, resulting in slow and uneven heat transfer. This chapter covers the various types and classification of steam traps and their installation, common problems, sizing, selection strategies, application, and maintenance.

Chapter 9: Process Compressors This chapter deals with compressors used in the process industry. Basic theory with practical aspects is provided in sufficient detail for the use of process industry personnel.

Chapter 10: Conveyors This chapter takes into account the types of conveyors been manufactured by modern industries to meet the current challenges encountered in conveying operations. It enumerates their usefulness, what conveyors are, industries that use them, conveyor selection and types, and safety and maintenance.

Chapter 11: Storage Tanks Storage tanks pose a complex management problem for designers and users. Because of the wide variety of liquids that must be stored, some of which are flammable, corrosive, or toxic, material selection for tanks is a critical decision. This chapter provides general guidelines that will aid in the selection of the proper type of storage to be used in a particular application. Various codes, standards, and recommended practices should be used to supplement the material provided. Manufacturers should be consulted for specific design information pertaining to a particular type of storage.

Chapter 12: Mixers Effective mixing of solids, liquids, and gases is critical in determining the quality of food, pharmaceuticals, chemicals, and related products. It is therefore essential that research and development scientists, process and project engineers, and plant operational personnel understand the mixing processes and equipment. Mixing processes may be batch or continuous and may involve materials in combination of phases such as liquid–liquid, liquid–solid, liquid–solid–gas, liquid–gas, and solid–solid (free-flowing powders and viscous pastes). An understanding of mixing mechanisms, power requirements, equipment design, operation and scale-up, and maintenance will lead to maximizing the mixing performance and enhancing business profitability.

Chapter 13: Boilers A boiler is process equipment comprising a combustion unit and boiler unit, which can convert water to steam for use in various applications. Boilers are of different types and generally work with various fittings, retrofits, and accessories. Boiler efficiency is achieved by skillful maintenance practices, including preventive and repair maintenance, in addition to use of only suitably conditioned water as feed water.

Section II: Process Plant Reliability

Chapter 14: Engineering Economics for Chemical Processes This chapter presents basic tools and methods used traditionally in engineering to assess the viability and feasibility of a project. Presented first are the tools available to represent money on a time basis. Next, the mathematical relationships frequently used to model discrete cash flow patterns are presented. The equivalence between the different discrete models is included on this section. The various indexes available to select the most profitable project between a set of alternatives are then presented. In this section, the payback period, the minimum acceptable rate of return, and the internal rate of return are introduced. An illustrative case study showing the application of these concepts is presented at the end of this section. The methods available to perform cost estimation and project evaluation are presented next, including several examples to show the application of cost estimation techniques. Companies execute engineering projects based on the revenues expected. Accordingly, they invest time and money in the process of selecting the project that would return the maximum revenues and satisfy such project constraints as environmental and government regulations. Therefore, the tools, techniques, and methods presented in this chapter would be used by engineers to assist them in the selection of the most suitable engineering project and to accurately estimate the costs associated with the project.

Chapter 15: Process Component Function and Performance Criteria This chapter explores the basic and advanced concepts of material transfer and conveyance equipment for air, steam, gases, liquids, solids, and powders. Also included are the engineering considerations for the component construction for material transfer. Each component section consists of a portion dedicated to selection specifications, reliability and cost savings, various maintenance approaches, and process development and improvement of transfer systems.

Chapter 16: Failure Analysis and Interpretation of Components This chapter highlights the fact that understanding how a component or device fails is essential in developing a scheme as to how to increase reliability and system robustness and ultimately reduce operational costs. There are essentially only four reasons for failure: the material, the methods, the machine, or the man. To identify the source of failure requires an understanding of the signs of the various sources. This chapter provides a fundamental explanation of failure by helping organize information to make the failure assessment a logical process.

Chapter 17: Mechanical Integrity of Process Vessels and Piping This chapter builds a focused and practical coverage of engineering aspects of mechanical integrity as it relates to failure prevention of pressure boundary components in process plants. Principal emphasis is placed on the primary means of achieving plant integrity, which is the prevention of structural failures and failure of pressure vessels and piping, particularly any that could have significant consequences. It provides practical concepts and applicable calculation methodologies for the fitness-for-service assessment and condition monitoring of process piping systems and pressure vessels.

Chapter 18: Design of Pressure Vessels and Piping This chapter covers the basic principles behind the design equations used in pressure vessels, and piping design codes. The design procedures for vessels and pipes are outlined. Numerical examples have been used to demonstrate some of the design procedures. This chapter is not intended to replace design codes but rather to provide an understanding of the concepts behind the codes.

Chapter 19: Process Safety in Chemical Processes In this chapter risk analysis and equipment failure are provided; process hazard analysis and safety rating are studied; safe process design, operation, and control are highlighted; and risk assessment and reliability analysis of a process plant are examined.

Section III: Process Measurement, Control, and Modeling

Chapter 20: Flowmeters and Measurement There are many different methods of measuring fluid flow, which are useful but can be very confusing. The objective of this chapter is to unravel some of the mysteries of flow technology selection and teach how different flowmeters work and when and when not to use them. This chapter covers the basics, including terminology, installation practices, flow profiles, flow disturbances, verfication techniques, flowmeter selection, and troubleshooting.

Chapter 21: Process Control Process control is used to maintain a variable in a process plant at a set point or cause it to respond to a set point change. The most common method used in process control is the PID (proportional, integral, and derivative) control algorithm. This algorithm and how it is used are discussed in this chapter.

Chapter 22: Process Modeling and Simulation This work serves as a guide and deals with the basic requirements for developing a model of a process. It covers the basic steps necessary for developing either a dynamic or steady-state model of a process. The case studies provided are made as simple as possible and make it possible for students and nonexperts to develop a simple model of a process that will help them investigate the behavior of either the entire process plant or a unit operation of interest.

As any experienced bushman on the Savannah knows, you can only eat an elephant one bite at a time. It is suggested that you take your time and read and digest each chapter carefully. Feel free to write in the margins, highlight passages, and quote as you see fit (but please use sound judgment concerning copyright laws!). Most important, use this work as a tool. Information can develop into knowledge with proper application. With proper application and sound judgment, wisdom can come forth. This work is the beginning of a very wise approach.