Bison Engineering and Evaluation Firm

a division of

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# Development of an Engineering Project

# A Handbook for Provisional Engineers

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# Summary

As a consultant company, BEEF, Inc. solves chemical processing problems and implements their solutions for our governmental and industrial clients. The solution to a client's chemically-related problem is a technical process and its supporting physical system. In the Process Engineering Department, a four (or five) -member project team of provisional engineers, under the guidance of a project supervisor, conducts a technical analysis of a process design that will effectively solve a client's chemically-related problem.

The provisional engineers in a project team have two major responsibilities—solve open-ended technical problems and report their solutions to our company and our clients. However, these engineers are new employees in the Process Development Department; they have limited experience as technical problem solvers, report writers, and team players. This handbook helps our new provisional engineers learn how to do the company's business. Specifically, it defines the organizational structure of our company, describes how it functions, and outlines the technical, communication, and teamwork activities of our provisional engineers.

After reading this handbook, our new provisional engineers can draw the following conclusions about the development of an engineering project at BEEF, Inc.:

1. Our corporate organization supports a decision-making methodology, called the engineering development process, to solve the complex chemical processing problems of our clients. The first stage in that methodology is process development.

2. As members of the Process Engineering Department, four engineers must organize a project team, analyze the technical process, and report the solution to a client's chemically-related problem.

3. As problem solvers, our new provisional engineers acquire a technical knowledge base using problem-based learning and apply the problem-solving methodology of understand the problem, model the phenomena, devise a plan, carry out the plan, review the problem solution, and report the problem solution, in order to analyze a technical process which will be supported by a physical system.

4. As report writers, our new provisional engineers learn how to prepare an informal memorandum report and document their problem solutions to meet company standards.

5. As team players, our new provisional engineers practice their interpersonal skills using the five tenants of cooperative learning, in order to develop better analytical, creative, and critical thinking skills and to obtain a deeper understanding of the technical material.

New provisional engineers need to develop their abilities as problem solvers, report writers, and team players. The following recommendations will help them begin the learning process:

- Attend the two-hour cooperative learning sessions in our continuing education program.
- Apply the principles of problem-based learning and the problem-solving methodology.
- Develop the necessary technical, rhetorical, teamwork, and professional skills.

Because most engineering problems require complex solutions, our new engineers learn that a purposeful plan is needed to handle the complexity. This handbook describes plans to do your technical, communication, and teamwork activities effectively. You must work hard, pay attention to detail, take pride in your work, and observe professional ethics in order to become a professional engineer.

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# Introduction

As new provisional engineers, welcome to BEEF, Inc., the Bison Engineering and Evaluation Firm, a division of Hawbawg Chemical Company. We are a consultant company that solves chemical processing problems for governmental institutions and industrial companies. Since our clients lack the technical expertise, they hire us to recommend and implement solutions to their chemical processing problems. We communicate these solutions to them in the form of technical reports.

Within our company, each client's problem is treated as an engineering project with a project supervisor and a four (or five) -member team. You are a member of one of those teams. The success of any engineering project is directly related to your effectiveness as a problem solver, communicator, and team player. During our 14-week continuing education program, the Company provides you with guidance in these important activities. You will be introduced to engineering systems analysis, computer-aided design, problem solving, technical report writing, electronic communication skills, ethical and legal issues, and teamwork.

As a new employee in this company, you need to seek answers to the following questions, in order to become an effective technical problem solver, communicator, and team player:

- What is BEEF, Inc.?
- How does it function?
- What are your technical responsibilities?
- What are your communication responsibilities?
- What are your teamwork responsibilities?
- How is your professionalism evaluated?

To be an effective engineer in any company, you must be both a problem solver and a communicator while working in a project team. Excellent problem solvers are not good engineers, if they cannot communicate their results in a professional manner. Likewise, excellent report writers are not good engineers if they cannot effectively solve problems. Furthermore, engineers must be able to function in a team environment. Therefore, for you to become a professional engineer, **you must develop** your abilities as a problem solver, communicator, and team player.

This handbook about engineering projects for our new provisional employees helps to develop your technical, communication, and teamwork abilities by answering the above questions. First, it begins with a background chapter on the systems approach to engineering, our organizational structure, and the communication process. Second, the discussion chapter outlines your team's engineering project, describes your technical, communication, and teamwork activities, and discusses your professional responsibilities. Third, conclusions are drawn and recommendations are made about your participation in our company's business. Finally, appendices are provided on the topics of units conversion, your technical journal, bibliography information, the rough draft, and project assessments.

# Background

What is engineering? What is a system? What is a process? What are their connections to problem solving? How is BEEF, Inc. organized to solve chemical processing problems? What is your role as a new provisional engineer in our organization? This chapter of the handbook answers these questions.

## Engineering

Engineering is the profession that applies the knowledge of pure sciences, such as physics, chemistry, biology, etc., to benefit society. Engineers plan, design, construct, and assist in the operation and maintenance of systems and processes. They are creative problem solvers. They look for better ways to use existing resources, to manufacture products for society, and to reduce the pollution of our environment.

As stated earlier, BEEF, Inc. is a consultant company that solves chemical processing problems. We provide the engineering expertise and muscle that most governmental and industrial institutions lack. BEEF, Inc. employs five types of engineers, as shown in Table 1. Because the solution of most engineering problems involves complex systems and processes, a team of engineers, each with different specialties of engineering, is needed to handle the complexity of a problem. As a new provisional engineer in our company, you will work in a four-member team to develop your teamwork skills and help solve the complex chemical processing problems of our clients. The effectiveness of your team depends upon your ability to learn, to cooperate, to work hard, and to understand the five types of engineering: chemical, civil, electrical, and mechanical engineering and computer science and engineering, as summarized in Table 1. Classic encyclopedias [McGraw-Hill, 1987 and World Book, 1990] and online resources [Brittanica, 2018 and Wikipedia, 2018] provide you with an overview of these five engineering disciplines. It is a good idea to acquaint yourself with these five branches of engineering using Table 1.

## System and Process

The general definition of a system is either "an assemblage or combination of things or parts forming a complex or unitary whole" or "any formulated, regular, or special method or plan of procedure" [Random House, 1975, p. 1335]. The first definition is object-oriented; the second is method-oriented, and it is often called the systems approach. The general definition of a process is "a systematic series of actions directed to some end." As a verb, it means "to handle (persons or matters) in a routine, orderly manner" [Random House, 1975, p. 1055].

For this handbook, a system is a human-made object that is composed of components and serves a useful purpose. The components of any system can themselves be systems, usually called subsystems. A system supports a process, a systematic series of actions, or it processes something in a routine, orderly manner. For example, a chair contains a back, a seat, and legs. It supports or aids the process of reading, eating, and relaxing. An automobile engine is a system that processes fuel and air to provide the power that propels a car; it supports the process of combustion, the burning of fuel and oxygen. A car is a system that aids the process of traveling from one place to another.

## Table 1. Five Major Branches of Engineering

| Engineering Branch | Date Organized | Focus |
|---|---|---|
| Civil Engineering | 1785-95 | Involves the planning and supervision of such large construction projects as bridges, canals, dams, tunnels, and water supply systems. Civil engineers also cooperate with architects to design and erect all types of buildings. Other civil-engineering projects include airports, highways, levees, irrigation and sewage systems, pipelines, and railroads†. |
| Mechanical Engineering | 1790-95 | Involves the production, transmission, and use of mechanical power. Mechanical engineers design, operate, and test all kinds of machines. They develop and build engines that produce power from steam, gasoline, nuclear fuels, and other sources of energy. They also develop and build a wide variety of machines that use power, including air-conditioning, heating, and ventilation equipment; automobiles; machine tools; robots; and industrial-processing equipment. Mechanical engineers are involved in every phase of development of a machine, from the construction of an experimental model to the installation of the finished machine and the training of the workers who will use it†. |
| Electrical Engineering | 1880-85 | Deals with the development, production, and testing of electrical and electronic devices and equipment. Electrical engineers design equipment to produce and distribute electricity. This equipment includes generators run by water power, coal, oil, and nuclear fuels; transmission lines; and transformers. Electrical engineers also design and develop electric motors and other electrical machinery as well as ignition systems used in automobiles, aircraft, and other engines. They work to improve such devices as air conditioners, food processors, and vacuum cleaners. In electronics, they play an essential role in the production of communication satellites, computers, industrial robots, medical and scientific instruments, missile control systems, and radar, radio, and television sets†. |
| Chemical Engineering | 1900-05 | Deals with the large-scale processing of chemicals and chemical products for industrial and consumer uses. Chemical engineers are concerned with the chemical processes that change raw materials into useful products. They plan, design, and help construct chemical plants and equipment and work to develop efficient and economical production methods. Chemical engineers work in such industries as the manufacturing of cosmetics, drugs, explosives, fertilizers, food products, fuels, plastics, and soap†. |
| Computer Science and Engineering | 1950-55 | Computer science deals with the theory and methods of processing information in digital computers, the design of computer hardware and software, and the application of computers‡. Computer engineering involves the development and improvement of computers, storage and printout units, and computer information networks. Computer engineers design the features of computer systems to suit particular operations†. |
| †Information extracted from [World Book, 1990 and Random House, 1975] | | |

As stated earlier, engineers plan, design, construct, and assist in the operation and maintenance of systems and processes that benefit society. Most systems contain electrical, mechanical, chemical, and computer subsystems. Also, they function in some physical environment designed by an engineer. For example, the automobile is a system composed of subsystems. The battery, distributor, and spark plugs are part of an electrical subsystem that provides the spark to initiate the process of combustion. The transmission, axle, and wheels are components in a mechanical subsystem that processes power into speed. The carburetor, fuel tank, and cylinders are components in the chemical subsystem that support the combustion process. The cruise control subsystem contains a computer, speedometer, and gas pedal that support the process of maintaining a constant speed. Finally, the automobile travels on roads and bridges that are designed, built, and maintained by civil engineers.

## Problem Solving

The creation of a process and its supporting system is a complex problem-solving activity that involves creative and critical thinking. Creative thinking produces ideas. Critical thinking evaluates those ideas; it is purposeful, reasoned, and goal directed.

All engineering problems have an initial state and a goal state. For example, an electric utility company needs to reduce the atmospheric emission of sulfur dioxide from the flue gas of its coal-fired generation system. The problem is to develop a process, a systematic series of actions that reduces the emission of sulfur dioxide to the atmosphere. The starting or initial state of this problem is that the sulfur dioxide concentration of the flue gas is above the Environmental Protection Agency (EPA) standard for the emission of sulfur dioxide. The final or goal state is a physical system that, once incorporated into the company's generation system, will reduce the sulfur dioxide concentration in the flue gas to below the EPA standard. Many alternative solutions exist for this problem, such as transporting the flue gas to another facility for processing, replacing the furnace to burn oil or natural gas, or installing a gas absorption column to scrub the sulfur dioxide from the flue gas using water. All of the possible solution paths from the initial state to the goal state would be the design and construction of all possible physical systems. As in this example, most engineering problems are ill-defined or open-ended. Their goal is vague or incomplete, and many alternative solutions exist that could solve the problem. In the above example, the challenge for the engineer is to develop the "best" physical system that reduces the sulfur dioxide emission.

Because building and testing all of the alternative solutions is economically prohibitive, engineers solve ill-defined problems by using the following decision-making methodology, often called the **engineering development process**:

1. recognize the problem,
2. formulate alternative solutions,
3. analyze each alternative solution,
4. select the "best" solution based on realistic constraints,
5. devise a plan for the "best" solution,
6. construct the "best" solution,
7. review its worthiness.

This methodology is a critical thinking activity that is goal directed. It provides a step-by-step structure that helps engineers to reach the final goal for any ill-defined problem. Although these steps or stages are sequential, feedback exists between stages. For example, while analyzing a specific alternative solution, an engineer might creatively think of an idea for another alternative solution or obtain a better recognition of the problem.

As with most engineering firms, our company uses this decision-making methodology, which is a problem-solving process, to handle the complexity of the ill-defined problems provided by our clients. The remainder of this chapter of the handbook discusses how this methodology fits into our organizational structure and how you accomplish your responsibilities as a new provisional engineer in that structure.

## Organization

BEEF, Inc. is a consultant company that solves chemical processing problems for governmental institutions and industrial companies. Once our clients have identified their need or problem, they employ us to recommend a feasible solution to that problem; they then approve or reject our recommendation; once it is approved, we design a detailed plan for the solution; we implement the solution for them; and, finally we monitor the solution and evaluate its performance. Since our clients' problems are ill-defined or open-ended engineering problems (i.e., ones with alternative solutions), our engineering task is to find the "best" solution and recommend it to our clients.

As with most engineering firms, BEEF, Inc. solves its engineering problems using a systems approach as illustrated in Figure 1. BEEF, Inc. is the overall system or organization. The components of the system are our divisions. We have divisions in Process Development, Systems Development, Systems Implementation, Systems Evaluation, and Client Relations. Although they are not shown in Figure 1, the Financial, Personnel, and Continuing Education Divisions are also an integral part of our organization. The BEEF organization of Figure 1 supports the problem-solving process, described above as the decision-making methodology, to find the "best" solution to a client's chemical processing problem. As illustrated in Figure 2, this problem-solving process is a four-step strategy with feedback, and it is an adaptation of Polya's "*How To Solve It*." [1957], as applied to complex engineering problems. The problem-solving steps are (1) understand the problem, (2) devise a plan, (3) carry out the plan, and (4) review the solution. In Figure 2, the boxes represent activities in the problem-solving process, and the lines represent things. The activities are subsystems that support sub-processes, and in this case, they are called divisions. A division processes an input thing in order to produce an output thing. The step of "understand the problem" in Figure 2 represents Steps 1 to 4 in the previously-described engineering development process.

In Figure 2, the Process Development Division obtains a better understanding of the chemical processing problem and develops a conceptual representation of the solution to that problem, called a process design. This process design is a conceptual model, expressed on paper, of the "best" process and its associated system. In the electric utility example, the conceptual model might be a flowsheet diagram of the processing steps needed to reduce the sulfur dioxide emission using a gas absorption column. Because the development of a process is a complex activity, the Process Development Division is divided into two departments—Research and Development (R&D) and Process Engineering, as shown in Figure 1. The Research and Development (R&D) Department obtains a better understanding of a chemical processing problem, particularly one that requires the use of new technology. It investigates new ideas and provides essential technical data for the Process Engineering Department. Using bench-scale and pilot-scale equipment, the scientists and engineers in the R&D Department investigate several possible solutions at the request of the Process Engineering Department. In the above example of an electric utility company, the R&D Department might investigate the use of a gas absorption process to remove

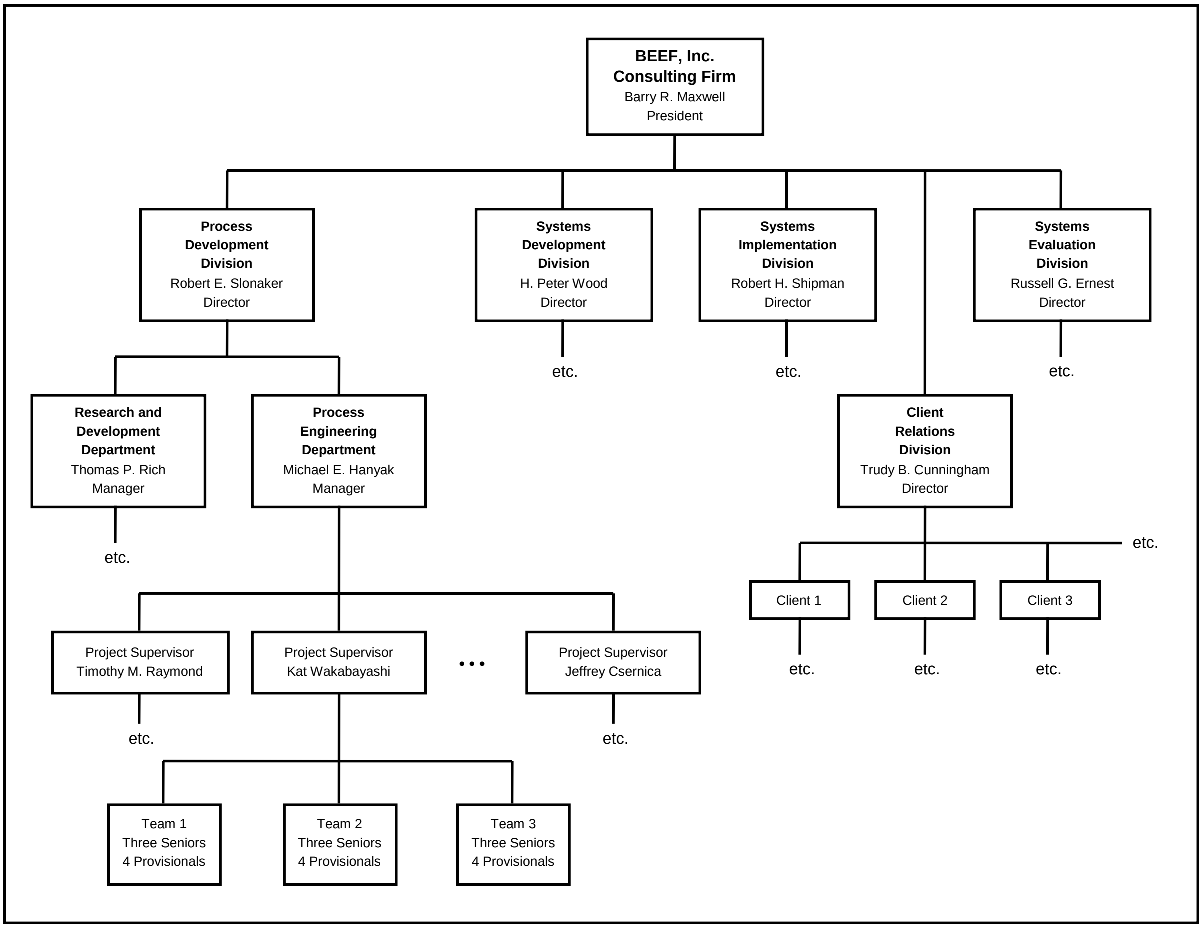


Figure 1. The Organization for the Bison Engineering and Evaluation Firm

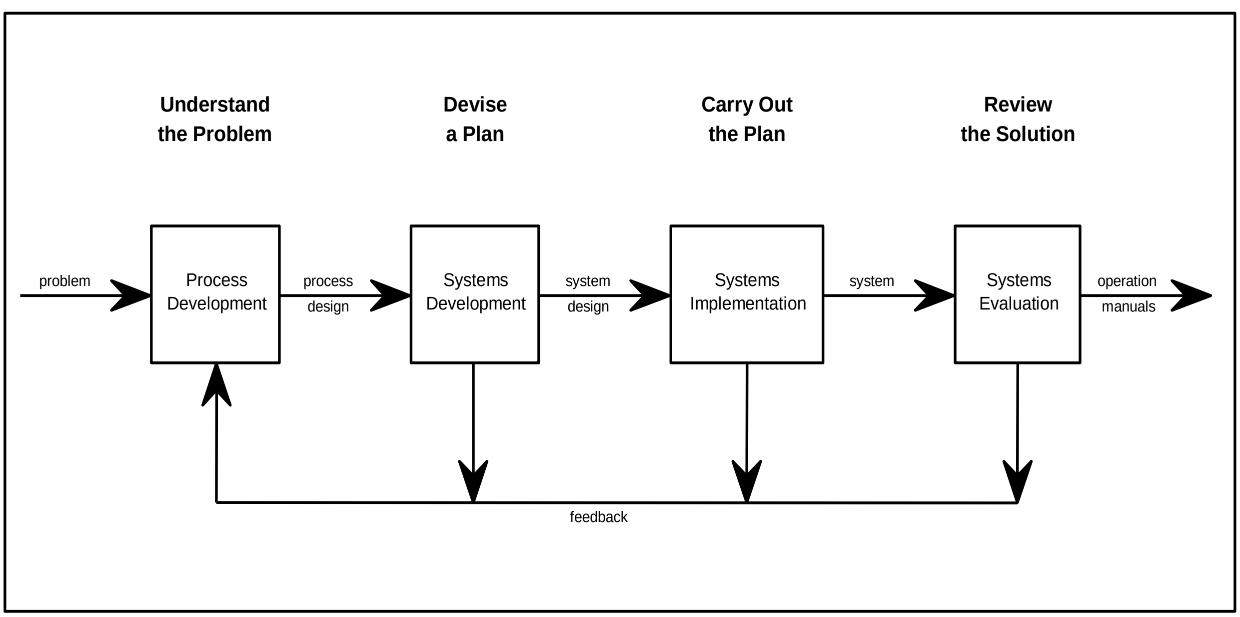


Figure 2. The Problem-Solving Process used by BEEF, Inc

sulfur dioxide from a flue gas. Using small-scale equipment, they would determine a range of feasible operating conditions for the absorption process, such as temperature, pressure, liquid absorbent, and concentration levels. These technical data are then used by the Process Engineering Department to complete its task.

Using the technical data provided by the R&D Department and any additional data obtained from the technical literature, the Process Engineering Department develops, on paper, a large-scale solution for the chemical processing problem. It formulates many alternative processing solutions, evaluates each alternative solution, and selects the "best" solution. Generating alternative processing solutions is a creative thinking activity involving the synthesis of components to form a whole system. For engineers to be creative, they need to pool their knowledge and skills of their domains and work in teams, because most solutions require complex systems. The alternative solutions are the process designs of those physical systems that potentially can solve the chemical processing problem. A process design is a representation, expressed on paper, of the structure or form of the physical system that supports the process. In the electric utility example, the three process designs are the transportation of the flue gas to another facility, the modification of the furnace to burn oil or natural gas, and the operation of a gas absorption column to scrub the sulfur dioxide from the flue gas. These three alternatives are but a small sampling of the many ideas that could be formulated.

Because building and testing all alternative processing ideas is economically prohibitive, the Process Engineering Department mathematically models each solution in order to determine its measure of performance, like efficiency and/or cost. Using paper, pencil, and computer in the analysis stage of the decision-making methodology, process engineers apply the basic laws of physics, chemistry, biology, and/or economics (e.g., the fundamental laws of mass, energy, and forces) to determine the needed performance factor for an alternative solution. In the electric utility example, engineers would mathematically model the process designs for transportation, modification, and operation. Using the mathematical results, they would then estimate the construction and operating costs for each alternative processing solution. The selection of the "best" solution is based on a variety of realistic constraints such as efficiency, economic factors, safety, reliability, aesthetics, ethics, and social impact. Of the three alternative process designs in the electric utility example, the gas absorption process might be the "best" one, because on paper it meets the EPA emission standard for sulfur dioxide and is the cheapest to construct and maintain.

As shown in Figure 1, a project team contains three senior engineers, and they report to a project supervisor, who, in turn, reports to the Manager of Process Engineering. This manager assigns a project, a client's problem, to a supervisor and one or more senior teams. Each project team of three senior engineers applies Steps 1 to 4 of the engineering development process to solve the client's problem. To assist a senior team, the project supervisor assigns a technical analysis task, which is a subpart of Step 3, to a provisional team of four new engineers. The completion of this analysis task helps the senior team to complete the larger problem presented by the client. The project supervisor acts as a mentor and coach for both the senior and provisional teams. Once the senior team solves the complex chemical processing problem, they prepare a formal technical report recommending a process design and its associated system. The provisional team's technical solution to its assigned task becomes an appendix in that technical report. The project manager and supervisor review this report, and they may request revisions to it. Once they approve the technical report, it is submitted by the Director of Process Engineering to the client through the Director of Client Relations. After reviewing the project team's recommended solution, the client either approves the solution or asks for further clarification. The project team addresses the client's questions and prepares a revised technical report. When the client's final approval is obtained, the team's process design in the form of a formal technical report is submitted to the Systems Development Division for further processing.

Using the information in the project team's technical report, the Systems Development Division converts the process design into detailed plans called a system design, as indicated in Figure 2. The process design is a conceptual model of the process that solves the chemically-related problem; the systems design is a detailed plan of the system and its components that support the process. In this division, the engineers devise, on paper, the detailed designs of all the electrical, mechanical, chemical, computer, and building subsystems. The technical drafters express these designs in the form of blueprints. This information is necessary for the construction of the real system that solves the chemical processing problem.

Using the system design as a plan, the Systems Implementation Division supervises the construction of the actual system on the client's property. Our engineers are involved in all phases of this construction process. They request additional assistance from our other Divisions, as indicated by the feedback lines in Figure 2.

Once the system is built, the engineers from the Systems Evaluation Division begin the operation of the process and make any necessary adjustments in that process, so that the system actually solves the chemical processing problem. Furthermore, these engineers prepare operation manuals and train the client's employees in the daily operation of the process and its system. Our company completes its contract with the client when the Systems Evaluation Division turns over the responsibility of the daily operation of the process to the client. As shown in Figure 2, our problem-solving process terminates with the operation manuals.

The final Division in Figure 1 is Client Relations. It has two major responsibilities—find new clients and interface with those clients. Although this Division is not explicitly included in Figure 2, its technical sales personnel, composed mostly of engineers, are integral parts of the problem-solving process, because they provide the necessary communication link between clients and all Divisions of BEEF, Inc.

In summary, the corporate organization in Figure 1 supports a decision-making methodology used by BEEF, Inc. to solve the chemical processing problems of our clients. As engineers, we handle the complexity of solving these problems by sub-dividing the critical thinking process into (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) reviewing the solution, as illustrated in Figure 2. Since our client's problem is usually open-ended, we formulate alternative solutions, evaluate each of these solutions, select the "best" solution, and recommend its implementation to our client. The solution to a client's chemically-related problem is a technical process supported by a physical system. We communicate this solution to our client in the form of a technical report.

## Communication Process

The communication process is a systems approach that meets the needs of an organization. Engineers are problem solvers and communicators in that process, as illustrated in Figure 3. As stated by Mathes and Stevenson [1991, p. 7], "As a professional you need to view your communication activities as your own 'products' or 'output' ... . That is, in your organizational role you receive input, usually as some form of communication, perform some professional tasks, and then communicate to provide the output as a result of those tasks. Your professional and communication activities essentially 'transform' input to output for your unit in the organization." In essence, your technical and communication work is not done in a vacuum. The organization has a problem that needs to be solved; you and your team are asked to solve it and report your solution. Your supervisor and manager read your conclusions and recommendations and then make decisions that evoke further actions.

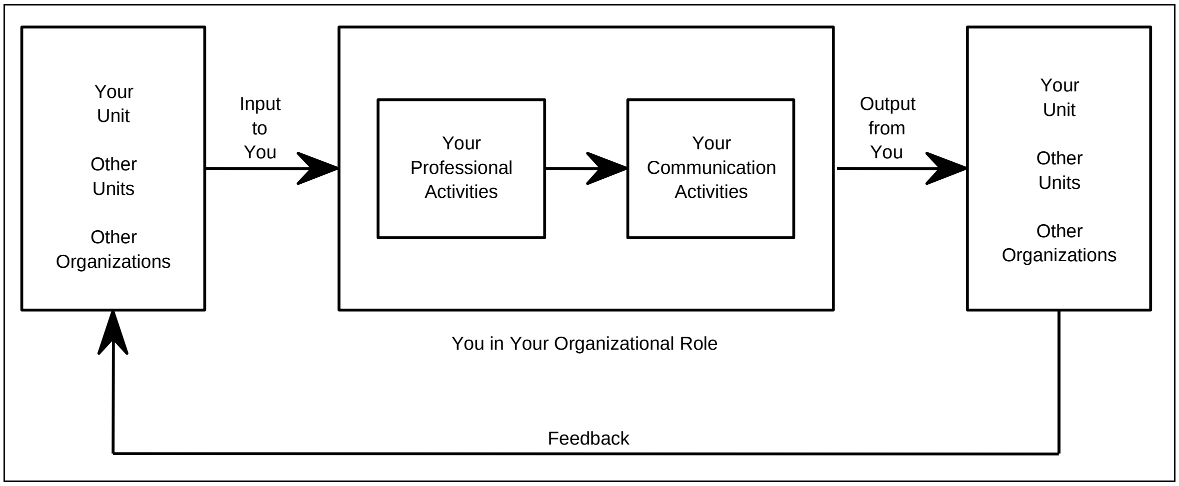


Figure 3. The Organizational Communication Process [Extracted from Mathes, J. C. and D W. Stevenson, *Designing Technical Reports: Writing for Audiences in Organizations*, Second Edition, Macmillian, Inc., New York, NY, 1991, p.7 and modified.]

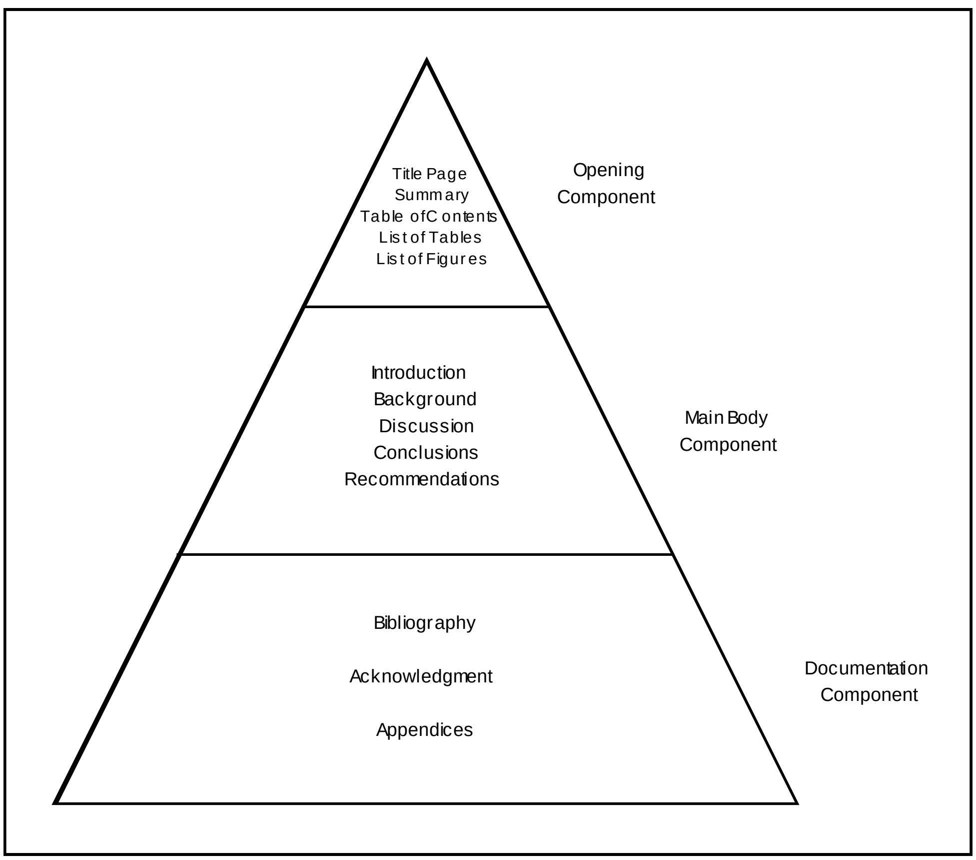


Figure 4. The Three Basic Components of a Technical Report [Extracted from Mathes, J. C. and D W. Stevenson, *Designing Technical Reports: Writing for Audiences in Organizations*, Second Edition, Macmillian, Inc., New York, NY, 1991, p.90 and modified.]

For our senior and provisional engineers, their unit in the communication process of Figure 3 is the Process Engineering Department; the other units are the remaining departments within the divisions of our organization; and the other organizations are our clients. Also, we sub-contract vendors to help us complete the implementation of our projects. They supply either equipment and/or labor. In our organization, the formal instruments of communication are the memorandum, the letter, and the report. For daily internal company communications, you use the memorandum. You use a letter for external communications outside of BEEF, Inc. Project teams use technical reports to communicate their problem solutions. Depending upon the complexity of the solution to the problem, they will write either an informal or formal report.

As a provisional member of a project team in the Process Engineering Department, your professional activities of Figure 3 result in a solution to an assigned technical analysis task. In effect, your team is helping senior engineers who are developing a process design that solves a chemical processing problem for a client. To complete your assigned task, your project team must articulate and define your technical analysis problem, gather the appropriate information and data, create an alternative flowsheet solution, determine its material and energy requirements, and estimate the "best" operating conditions based on economic factors. Your team completes your assigned task over a 14-week period and then writes an informal memorandum report that presents your team's technical solution to your team's project supervisors. Your project supervisors evaluate your team's report before forwarding it to a project team of senior engineers.

As describe earlier in this chapter, a provisional team is working on a sub-task in the analysis of one alternative solution to a client's problem. Basically, they are doing a subpart of Step 3 in the decision-making methodology called the engineering development process. A senior team is applying Steps 1 to 4 of this methodology to the client's problem. They present their solution as a formal technical report, in which one of the appendices is the provisional team's informal report. The importance and general format of a formal technical report is described next. This description provides a perspective for provisional engineers, who in three years will be senior engineers.

With respect to Figure 3, the major communication activity of the senior teams in the Process Engineering Department is to present their complex technical solutions as formal reports. In effect, the senior team members are report writers that affect change in the organization by both informing and persuading their readers. A technical report must address the needs of a "heterogeneous" audience; their needs are diverse as well as numerous. Effective reports have three basic parts: an opening component or overview, a main body component, and a documentation component, as illustrated by the pyramid in Figure 4 [Mathes and Stevenson, 1991, pp. 89-92]. They are structured to move from general to specific information, because the reader wants to know the "big picture" before the details. This Handbook is structured in the style of a formal technical report, as outlined in Figure 4.

In Figure 4, the opening component is for decision makers. As stated by Woolston, Robinson, and Kutzbach [1988, p. 6], "For decision makers, the 'bottom line' is the most important part. They want to know the conclusions and recommendations. Everything else is secondary, because their purpose in reading a report is to get information that will help them make a decision. They do not have time for a leisurely stroll through your reasoning or problem-solving process; they need to know the answer." Therefore, the decision makers read only the opening component; they rarely read the remaining components of the technical report. For the opening component in Figure 4, the team writes a title page and a summary containing the problem statement, the solution, and the major conclusions and recommendations. The team also prepares a table of contents, a list of tables, and a list of figures.

In Figure 4, the main body and documentation components are for advisors, designers, and implementors. As stated by Woolston, Robinson, and Kutzbach [1988, p. 6], "They need to know what went into reaching your conclusion, and they need to know the details of implementing it. ... These people will read and digest the detail sections in your report, but usually only in their own areas of expertise. Thus, the engineer in charge of production will study the design specifications, the accountant will pore over the proposed budget, and the market analyst will consider the sales projections. But nobody will read your whole report, word for word, from beginning to end, except you and your typist." For the main body component in Figure 4, the team writes an introduction, background, discussion, conclusions, and recommendations. For the documentation component, the team prepares a bibliography, an acknowledgment, and appendices.

Although Figure 4 presents the format for a formal technical report, it equally serves to illustrate the format of an informal technical report. In our company, this type of report is a 3-to-5-page memorandum with attachments. The memorandum has an open component of date, to, from, and subject headings. Its main body contains the problem statement, general solution procedure, major results, conclusions, and recommendations. Its attachments are the documentation that supports what is presented in the main body. Basically, the memorandum report is structured to move from general to specific information, because the reader wants to know the "big picture" before the details, which are the attachments. Your team of four provisional engineers will use the informal memorandum report to present your team's solution to your assigned technical analysis task.

Figure 3 illustrates the organizational context of the team's problem solving and report writing. Equally important are the legal and social contexts of your activities as a problem solver and report writer. Since any engineering organization interacts with outside organizations and directly or indirectly with the public, you shouldn't overlook the potential legal implications of your technical and rhetorical activities. As stated by Mathes and Stevenson [1991, p. 12], "Legal actions can be based on personnel issues, environmental issues, and intellectual property issues as well as product liability issues. Environmental concerns such as toxic waste disposal of any byproducts of a manufacturing process have an ethical dimension as well as legal dimension. Even where legal concerns seem not to be important considerations, the social context introduces your ethical concerns as a professional. Your reports are your imprint on the organization and therefore on society, indirectly and directly. When your written documents are preserved long after you have been promoted, changed jobs, or even retired, they are your legacy as a professional. ... the memos and reports you write as a professional will endure and must therefore serve their function whenever they are retrieved." In effect, what you do or don't do as a problem solver and report writer can have a profound effect on you and the organization at any time in the future.

In summary, the communication process in any organization requires you to be both a problem solver and a communicator. Your technical reports must inform and persuade a diverse audience of readers. Also, your reports must be written to consider legal and ethical issues, both in the short and long term. The specific details of your technical and communication roles as a new provisional engineer in the Process Engineering Department of BEEF, Inc. are discussed in the next chapter of this handbook.

## Summary

This background chapter of this handbook has described engineering, system and process, problem solving, the organization, and the communication process. They are integral parts of BEEF, Inc. They function, in concert, to solve the complex chemical processing problems of our clients. All of our engineers must develop their critical thinking skills as problem solvers and communicators. As reported by Diane F. Halpern in *Thought and Knowledge: An Introduction to Critical Thinking* [1989, pp. 29-30], "No one can become a better thinker just by reading a book. An essential component of critical thinking is developing the attitude of a critical thinker. Good thinkers are motivated and willing to exert the conscious effort needed to work in a planful manner, to check for accuracy, to gather information, and to persist when the solution isn't obvious and/or requires several steps." … "Developing a critical thinking attitude is as important as developing thinking skills. Many errors occur not because people can't think critically, but because they don't. One of the major differences between good and poor thinkers, and correspondingly between good and poor students, is their attitude." In our organization, you must develop a critical thinking attitude; that is, you must be willing to plan, be flexible in your thinking, be persistent, and be willing to self-correct. You cannot become a critical problem solver, communicator, and team player without this sort of attitude.

# Discussion

As stated in the background, an engineering system supports a process, or stated another way; an engineering process is supported by a system. As illustrated in Figure 2, the development of a system follows the development of its process. Why is the process design done before the system design? Because the process design sets the requirements, the limits and constraints, on the system design. In the electric utility example, a project team in our Process Engineering Department might design a gas absorption process to reduce the sulfur dioxide emission. This engineering process would be represented by a flowsheet diagram, a conceptual model; the engineering system might be a gas absorption column. Besides designing the flowsheet diagram, a project team of senior engineers would also determine the process requirements, size the equipment (e.g., the diameter and height of the column) and estimate the cost of construction and operation for that process flowsheet. These process and system requirements are the information needed by the Systems Development Division to do the detailed design of the physical system; that is, the gas absorption column.

As new employees in the Process Engineering Department of BEEF, Inc., our provisional engineers assist project supervisors by working in a four-member team to determine the "best" process requirements for a process flowsheet to manufacture a specific chemical product. Your team's technical solution to this assigned task will provide important information to a senior team. You and your team members are introduced to the fundamental concepts of process engineering in our 14-week internship program, conducted by our Continuing Education Division. The general structure of this bi-weekly program is defined in Table 2. As a new provisional engineer, your previous knowledge and experiences are limited; therefore, the problem-based learning program of Table 2 is designed to allow your team to learn to cooperate and determine the process requirements for specific, chemical-related problems.

**Table 2. Bi-Weekly Problem-Based Learning Activities for New Engineers**

| Day | Activities | Focus of Project Problem Work |
|---|---|---|
| Monday | 60-min. Small sessions<br>50-min. Problem work | Team members present their conceptual diagrams for each project problem. The team cooperatively evaluates each diagram and develops plans for the mathematical model. |
| Wednesday | 60-min. Small sessions<br>50-min. Problem work | Team members present their mathematical model for each project problem. The team cooperatively evaluates each model and develops plans for the mathematical algorithm. |
| Friday | 60-min. Small sessions<br>50-min. Problem work | Team members present their mathematical algorithm for each project problem. The team cooperatively evaluates each algorithm and develops plans for the numeric solution. |
| Monday | 110-min. Lab | Team members cooperatively conduct an experiment in the Unit Operations Laboratory. This laboratory addresses one of the problems in the project assignment. |
| Wednesday | 60-min. Small sessions<br>50-min. Problem work | Team members present their numerical solution for each project problem. The team cooperatively evaluates each solution and develops plans for heuristic observations. |
| Friday | 60-min. Small sessions<br>50-min. Problem work | Team members present their heuristic observations for each project problem. The team cooperatively evaluates each observation and then plans for the next project assignment. |

Processing engineering is the application of the concepts of mass and energy balances and phase equilibria to the various equipment (such as reactors, pumps, and separators) in a flowsheet diagram for a chemical process. The necessary knowledge and experiences to apply these concepts are covered in the bi-weekly session as outlined in Table 2. Basically, your team of provisional engineers will meet six times every two weeks for 14 weeks to share, solve, assess, and plan as you work towards completing your technical analysis of a flowsheet. Finally, your project team will prepare an informal memorandum report on the "best" operating conditions for that flowsheet. This section of the handbook outlines your engineering team project, summarizes your technical activities, presents your communication activities, and defines your teamwork activities. It concludes with your professional responsibilities and how they are assessed.

## Engineering Project

Your team's project assignment is to analyze a process design (i.e., a flowsheet configuration for a client) that manufactures a specific chemical product. Specifically, your team is to determine the process requirements for manufacturing styrene monomer from methanol and toluene. Your team's technical analysis task for this process design answers the following basic questions:

1. What are the flowsheet and constraints for the process design?
2. What are the material and energy requirements of the process design?
3. What are the "best" operating conditions, based on economics, for that process design?

Over a 14-week period, your project team will be assigned sub-projects by your project supervisor, in order to help you work towards answering the above questions. Your team will document your solutions to the sub-projects using memoranda. Based on these memoranda, your team will write an informal memo report to document the process design analysis for your company and a senior design team.

When working on the sub-projects, the members of your project team will **rotate their responsibilities** bi-weekly for each sub-project. This rotation allows each team member to experience all the technical, communication, and teamwork activities associated with the major project. The lines of responsibilities for a bi-weekly sub-project are defined later in this Discussion chapter. After the completion of all the sub-projects, each team member will have experienced all lines of responsibility at least once over the 14-week internship.

In chemical process engineering, a process design does not spring fully developed from the brows of engineers, but evolves in small steps toward a satisfactory solution. Over a 14-week period, your project team will develop a process design based on a **first feasible solution and simple models**. To obtain the necessary knowledge about doing process engineering, your project team has access to the following literature:

- *Elementary Principles of Chemical Processes*, by Felder, Rousseau and Bullard
- *Companion in Chemical Engineering: An Instructional Supplement*, by Hanyak.
- *Chemical Process Simulation and the Aspen HYSYS Software*, by Hanyak.

Additional literature material can be found using the electronic retrieval systems at the Bertrand Library, our company library. You will also use the Moodle course management system to electronically share information with your project supervisor, your team members, and other team members.

Engineers do their technical and communication activities in **parallel**, which is contrary to the idea that the technical work must be completed before the communication work begins. The communication process of Figure 3 may foster this misconception, because it indicates that your communication activities are done after your technical activities. In parallel with your technical activities, you are writing drafts of various parts of your team's final report using the sub-project memoranda. In Figure 3, the communication activities culminate when you take your written memos and summarize their content into a coherent and **professional-looking** informal technical report.

Whether engineers are solving a technical problem or a communication problem, they are using a goal-oriented process. To move from the initial state to the goal state of any problem, you must know what the goal is for that problem. In any process whether it is problem solving in Figure 2 or written communication in Figure 3, you have ordered sub-processes that have sub-goals. Before you do sub-process 1, you need to know the sub-goal of sub-process 2; before you do sub-process 2, you need to know the sub-goal of subprocess 3; and so forth. In other words, what you must do to accomplish a sub-process is dictated by the sub-goal of the next sub-process. Specifically, what you must do for your technical activities is driven by what you need in order to accomplish your communication activities. The activities of your technical, communication, and teamwork processes are outlined next. Finally, your professional responsibilities to be successful at these activities are then described.

## Technical Activities

As a new provisional engineer in the Process Engineering Department of BEEF, Inc., your technical responsibility is to analyze a process design for one of our clients. In order to meet that responsibility, you will have to master many technical skills as a learner and problem solver. This section of the handbook outlines those activities that help develop your technical skills.

- **Acquire a knowledge base.**

You need to know the concepts of engineering systems, systems analysis, and decision making. These topics are presented, and illustrated by examples, in the problem-based learning sessions of Table 2. In the laboratory sessions, you must learn and understand how to plan, conduct, and document experimental work. You acquire a technical knowledge base through textbooks, articles, web-based materials, your team's notes, and your technical journal. You must develop an attitude that fosters learning in a team environment and also on your own. "Knowledge is not acquired by osmosis, but by discipline and hard work" [Colson and Eckerd, 1991, p. 103]. The bi-weekly sessions of Table 2 will outline concepts and learning processes; but, you and your team must apply them to acquire the knowledge base.

In our continuing education course for provisional engineers, you and your team will acquire a knowledge base using problem-based learning (PBL). PBL is an instructional, learner-centered strategy that uses a problem situation to drive the learning activities on a need-to-know basis. For each bi-weekly sub-project of six problems, your team will apply the following stages of PBL to solve each problem:

1. Identify relevant knowledge the team can apply.
2. Determine the knowledge the team must acquire.
3. Prioritize the team's learning needs.
4. Develop a feasible learning plan.
5. Work independently to acquire new knowledge.
6. Share that knowledge at the next team meeting session.
7. Use the pooled knowledge to solve the technical problem.
8. Assess the problem solution and your teamwork skills.

This strategy moves our provisional engineers towards the acquisition of knowledge and skills through a staged sequence of problems presented in context of the major project. Your project supervisor will act as a mentor and coach providing your team with associated learning materials, guidance, and feedback.

For each problem in a bi-weekly sub-project, your team explores a problem by first identifying the relevant knowledge you can apply and then pinpointing the knowledge your team must acquire. The team then prioritizes the learning needs by setting goals and objectives and determines a feasible learning plan. Such plans often require the team members to tackle different learning tasks. The team members work independently, researching and preparing for the next team meeting where they will share their new knowledge. The pooled knowledge is then applied to solve the problem. As a final step, your team assesses their teamwork skills and their success in solving the problem.

As you might have gathered by now, this continuing education course does not use the traditional mode of instruction, which is a passive learning environment where the instructor writes on the board and the students take notes. The course is a student-centered, instructor-coached, active learning environment, one that is succinctly captured by the following Chinese proverb:

**Tell me and I will forget;**
**Show me and I may remember;**
**Involve me and I will understand.**

Extensive pedagogical research has shown that students learn more by doing, particularly in a cooperative team environment [Felder and Brent, 1999]. Problem-based learning tends to motivate students by giving them a specific context in which to embed knowledge. Furthermore, you and your team members will experience deep, not surface, learning by using reciprocal teaching and peer tutoring. The success of our company's business is directly connected to your ability to function effectively in a team environment using problem-based learning. Mastering PBL lays the foundation for lifelong learning, an important skill to have in your engineering toolbox of technical abilities.

In a PBL environment, a considerable amount of communication takes place between engineers, teams, and project supervisors. Effective communication requires that everyone is working from a common set of nomenclature. You and your team will be working with such process quantities as length, mass, time, temperature, pressure, composition, and flow rate. These quantities are needed to mathematically model the material and energy requirements of chemical process equipment. You need to learn the symbols and units associated with various process quantities. You also must be able to convert from one set of units to another, such as from kilograms per hour to tons per year. Appendix A in this handbook contains a standard methodology that our company uses for units conversion. Additional materials on nomenclature and units conversion are provided in Chapter 3, Appendix A, and Appendix B of the *Companion in Chemical Engineering: An Instructional Supplement* by Hanyak [2011]. To master the nomenclature and the units conversion methodology, you and your team must take the initiative and learn them under the guidance of your project supervisor.

- **Apply a problem-solving methodology.**

As new engineers, your project team will analyze the material and energy requirements for many chemical processing problems. The project team will apply the following methodology to solve these well-defined problems:

| | **Activity** | **Outcome** |
|---|---|---|
| 1. | understand the problem | conceptual model |
| 2. | model the phenomena | mathematical model |
| 3. | devise a plan | mathematical algorithm |
| 4. | carry out the plan | numerical solution |
| 5. | review the problem solution | heuristic observations |
| 6. | report the problem solution | formal documentation |

This methodology provides a step-by-step structure that helps engineers to reach the final goal, a single correct answer. Although the steps or stages are sequential, feedback exists between stages. For example, while reviewing the problem solution, an engineer might observer the need to calculate another quantity that was forgotten in the original mathematical model.

The application of this problem-solving methodology is described in Chapter 1 of *Companion in Chemical Engineering: An Instructional Supplement* by Michael Hanyak [2011]. You are to consult this chapter to learn how to apply this methodology to a simple example problem. You and your team will use the problem-solving methodology extensively in the problem-based learning sessions and in the completion of your bi-weekly sub-project assignments.

- **Develop basic mathematical analysis skills.**

In the analysis of the process requirements for a chemical flowsheet, engineers apply mathematical models such as the conservation of mass and energy. You must master the mathematical analyses associated with process material and energy balances and phase equilibria. You and your team will use the problem-based learning sessions to acquire the necessary mathematical analysis skills.

Also, you must develop your abilities to use computer analysis software such as Microsoft Excel, MATLAB and HYSYS. Excel and MATLAB are used to solve algebraic equations and plot their results. HYSYS is a process simulator that solves the material and energy requirements of a chemical process flowsheet. *Chemical Process Simulation and the Aspen HYSYS Software* by Hanyak provides a set of tutorials to learn how to use this process simulator. To master these software analysis tools, you and your team must take the initiative and learn them on your own under the guidance of your project supervisor.

- **Develop basic economic analysis skills.**

One criterion for the "best" operating conditions of a chemical process flowsheet is its economic impact on the organization. You will use such economic topics as raw material costs, utility costs, equipment costs, product sales, and net profit in the problem-based learning sessions. Your project team will apply these economic topics to recommend the "best" flowsheet operation for a chemical processing problem. When you become a senior engineer, you will learn to apply other criteria such as efficiency, safety, reliability, aesthetics, ethics, and social impact to selection of the "best" solution for a process design.

- **Develop computer word-processing skills.**

As an engineer, you have a communication responsibility to produce professionally-written memoranda and reports, whether they are on a process analysis study or a laboratory investigation. The writing process, whether done individually or as a team, is done in Microsoft Word. You are required to write all of your memoranda and reports using this word processor. Questions about Word can be directed to student assistants employed at the L&IT Tech Desk or to fellow colleagues. You can also consult the help function in Word, support forums on the internet, or register for one of the L&IT workshops on Microsoft Word to answer your questions.

- **Develop computer drawing and graphing skills.**

In your technical memoranda and reports, you will need to incorporate drawings and graphs. You can use the Insert/Object command in Microsoft Word to make drawings. In this handbook, the drawings in Figures 1, 2, 3, and 4 were developed using the Microsoft Drawing program, which is accessed through the Insert/Object command. For the graphing of technical data, you can use the Microsoft Excel or MATLAB program. L&IT has introductory handouts on all of these Windows or

Mac programs. To master computer drawing and graphing skills, you must take the initiative and learn them on your own.

## Communication Activities

As a new provisional engineer in the Process Engineering Department of BEEF, Inc., your team's major communication responsibility is to report the process requirements of a process design to your project supervisor. In order to meet that responsibility, you have to keep you own technical journal, develop your electronic communication skills, develop your information retrieval skills, write technical memoranda, and develop you basic revision skills. This section of the handbook outlines those activities that help develop your communication skills.

- **Keep your own technical journal.**

As stated by Woolston, et al. [1988, Ch. 6, p. 151], "The writing that engineers and scientists do can be legally crucial, ... . Your writing constitutes part of the legal record of a project and might end up as evidence in litigation. Thus, part of your job responsibility as an engineer or scientist is to make your writing precise and to keep accurate records of what you've written." Mathes and Stevenson [1991, pp. 455-469] present six basic precepts that engineers need to observe, in order to protect their readers, their company, and themselves in the legal context. These precepts are as follows:

- Don't assume confidentiality.
- Write so that your documents can continue to function effectively for years.
- Don't promise what your company cannot deliver.
- Write adequate instructions.
- Warn your readers of dangers.
- Be accurate and complete.

These basic precepts apply to all of your written documents—letters, memoranda, laboratory notebooks, technical journals, as well as technical reports. Please read these two literature sources to learn about your legal responsibilities [Woolston, et al., 1988, Ch. 6 and Mathes and Stevenson, 1991, Ch. 15].

A technical journal is a three-ring binder of bound pages with tab separators in which you can keep your daily technical and rhetorical work. Each member of your team must keep his or her own technical journal. A technical journal allows you to keep precise and accurate records of what you are doing. Because no one can remember everything precisely, a written record at the time something happens is the only way to insure accuracy of the event. Obviously, engineers have an ethical responsibility to keep written records that are precise and clear in their technical journals.

In order to develop good documentation habits, **you must maintain** your technical journal. Appendix B describes a procedure for the regular keeping of your technical journal. Please consult it. You will keep such information as notes, handouts, bibliographical information, homework assignments, laboratory data, observations, and tests in your journal. This information becomes an accurate record of your technical and rhetorical work, provided you develop a regular habit of placing information into the journal. Furthermore, you will be able to write precise and clear technical documents because all of the necessary information will be in your technical journal. Your project supervisor and/or the teaching assistant will periodically review, evaluate, and sign your technical journal.

- **Develop electronic communication skills.**

The analysis of a chemical process design will pose many challenging technical and economical questions for you and your project team. You are to consult additional online resources to help you seek the necessary information and advice needed to answer these challenging questions. These electronic resources include general search engine results of various forms, online databases, and online magazine and journal articles. Email is the default communication mode to be used by you, your team members, and your project supervisors.

Furthermore, your project supervisor will be able to report information to and ask questions of **all members** of the Process Engineering Department through the Moodle course management system. You need to know how to use this electronic resource, because you will be using it regularly throughout this continuing education course. Your project supervisor will instruct you in the use of the Moodle system.

- **Develop information retrieval skills.**

In the team project, you must gather information in order to understand and analyze the chemical processing problem. The manual entitled *Chemical Process Simulation and the Aspen HYSYS Software* by Hanyak provides the basic information your team will need to determine the process requirements for manufacturing styrene monomer from methanol and toluene. Your project supervisor will coach you on any additional information you might have to retrieve from the Bertrand Library or the internet. All information you collect must be either recorded or enclosed in your technical journal.

Since your project team will compile a bibliography for inclusion in your informal technical report, you must collect the essential bibliographical information on a literature source when you are looking at it. Do not rely on your memory; record the essential information in your technical journal or use RefWorks, a web-based bibliography and database manager that is available through Library and Information Technology (L&IT) at Bucknell University. Accuracy is **paramount**, because the readers of your report may want to consult the original sources of your information. The necessary bibliographical information that you must record can be found in Appendix C.

- **Write a technical memorandum.**

In preparing written documents, you wear three hats—planner, writer, and reader. As a planner, you determine the function of a document and then design its overall structure. As a writer, you draft a document by getting words on paper efficiently and incorporating tables, figures, and equations. As a reader, you revise a document to achieve clarity and conciseness for your intended audiences. The primary document for communication by our new provisional engineers in the Process Engineering Department is the memorandum.

Your project supervisor will issue a memorandum that assigns to your team a technical project consisting of six problems. Your team will document its project solution using the informal memo report, which has a structure according to Figure 5.

- Cover Sheet
- Team's Project Memo { two to three pages }
  - Header Information
  - Purpose statement (for each problem)
  - Solution Method and Major Results (for each problem)
  - Major Conclusions (for each problem)
  - Questions and Closure
  - Bibliography, if needed
- Project Assignment Memo
- Team's Problem Solutions

Figure 5. The Basic Components of an Informal Memo Report

In Figure 5, the cover sheet is an assessment and evaluation form that will be provide to your team. The team's project memorandum basically summarizes your team's major results and conclusions for two specifically-identified problems. In this memo, your team will explicitly refer to the attachments that give the reader more detailed information. The attachments are the project assignment memo issued by your project supervisor and your team's formal solutions to all of the assigned problems. When the problem is a laboratory experiment, the problem solution is a copy of the completed laboratory checklist form provided by the teaching laboratory assistant. This form is an assessment of the team's documentation in their laboratory notebook for that experiment. For a bi-weekly project <u>only</u>, a team's timesheet concludes the attachments to the team's project memorandum.

Pink cover sheets are available at the ENGR100 student mailboxes on the second floor of Dana Engineering Building. Your project supervisor will provide you with an electronic copy of the standard company memo from which your team can begin to prepare its project memorandum. As indicated above, the team's project memo is two to three pages in length for a bi-weekly or one-week project assignment. Its header contains the date, to, from, and subject, as illustrated by the example in Figure 6.

| | |
|---|---|
| **To**: | George Teacher, Project Supervisor<br>Process Engineering Department |
| **From**: | Joe A. Smith, Kay E. Jones, Bob I. Rogers<br>Project Team 2, Provisional Engineers<br>Process Engineering Department |
| **Subject**: | Team Project Report 4 |

Figure 6. Sample Header of a Memorandum

Only those team members who have participated in the preparation of the informal memorandum report are to provide their names and sign their initials above those names. In the first paragraph of the project memo, your team provides the purpose of the memo by presenting the organizational context, the technical investigation, and the communication purpose. The following example illustrates a purpose statement for a memo:

> "A former engineer in the Process Engineering Department, James E. Bond, worked on our steam generation project. However, his documented solution for the material and energy balances is invalid. In your memorandum of 26 August 2010, you asked our team to analyze his solution and then determine the necessary stream flow rates for the steam generation plant. We have completed your request and our solution is summarized below. Four attachments are included to support our findings."

For each indicated problem in the project assignment memo, your team presents the solution method used and summarizes the major results. Tables, figures, and, only when necessary, equations are to be used in this summarization. Next, your team presents the major conclusions that are supported by the attached problem solution. After the specifically-indicated problem solutions have been summarized, your team closes the memo by possibly asking questions of your project supervisor for further clarification on the project assignment. Your last statement may be an offer for further contact. It should also indicate the total time spent by the team only on a bi-weekly project and reference the team's attached timesheet. Finally, you provide a bibliography for any literature cited in the memo text.

Our company has standards on the preparation of a project memorandum and its attached problem solutions. Your team is to consult Appendix D to learn about our typographical standards and the preparation of tables, figures, and equations. The standard format for a formal problem solution is described later in this chapter under the heading of "Professionalism," as well as in Appendix E.

- **Develop basic revision skills.**

The professional quality of your final document is strongly connected to your revision skills. Poorly-prepared documents usually reflect poor revision skills, and they give your reader an impression of sloppy and unprofessional work. Excellently-prepared documents reflect your attention to detail and professional caring; that is, you take pride in your work. Revision is more than checking for spelling, punctuation, and grammar accuracy. It also involves re-ordering ideas to make them more logical to the reader and/or rewriting sections that are not clear and concise.

Taken literally, revision means "re-seeing" what you have written. Thus, when you revise your work, you need to "see" it again from different perspectives. First, you need to see it from the organization's point of view—have you accomplished the project assignment in a professional, thorough way that demonstrates that you have done your technical work, drawn your conclusions logically, and presented the results in a manner acceptable to an engineering firm? Second, look at it from your point of view—have you put on paper precisely what you intended to say? Finally, you need to look at it from the reader's point of view—have you presented the information in such a way that a person outside of your mind-set can take in the information? That is, will it be logical and clear to the reader?

Throughout all of these revision steps, you are encouraged to use the experience of your other team members and your project supervisor—as your outside readers. By sharing your work with them, you will receive feedback on clarity, conciseness, and logical presentation of ideas. Before you present them with your written work, you should follow the "Rough Draft Revision" steps described in Appendix D.

## Teamwork Activities

As a new provisional engineer in the Process Engineering Department of BEEF, Inc., your team responsibility is to work effectively with your other team members to achieve a common purpose while practicing the five tenets of cooperative learning. As stated earlier, your team's purpose is to determine the process requirements and "best" operating conditions for a specific flowsheet design, the production of styrene monomer from methanol and toluene. What is cooperative learning and why should you practice it?

Cooperative learning is a pedagogical framework to practice teamwork. It allows you and your team members to develop and gain confidence in your team skills. Felder and Brent [1999] present the following description:

> "*Cooperative learning* is instruction that involves students working in teams to accomplish an assigned task and produce a final product (e. g., a problem solution, critical analysis, laboratory report, or process or product design), under conditions that include the following elements [Johnson et al., 1998]:
>
> - *Positive interdependence*. Team members are obliged to rely on one another to achieve the goal. If any team members fail to do their part, everyone on the team suffers consequences.
> - *Individual accountability*. All team members are held accountable both for doing their share of the work and for understanding everything in the final product (not just the parts for which they were primarily responsible).
> - *Face-to-face promotive interaction*. Although some of the group work may be done individually, some must be done interactively, with team members providing mutual feedback and guidance, challenging one another, and working toward consensus.
> - *Appropriate use of teamwork skills*. Students are encouraged and helped to develop and exercise leadership, communication, conflict management, and decision-making skills.
> - *Regular self-assessment of team functioning*. Team members set goals, periodically assess how well they are working together, and identify changes they will make to function effectively in the future."

During your 14-week internship, your team will practice the above five tenants in the problem-based learning sessions of the continuing education course. Your project supervisor will guide your through many technical exercises that are designed to incorporate the five tenants.

The practice of cooperative learning has many benefits beyond being a training ground for teamwork. Felder and Brent [1999] describe these benefits as follows:

> "An extensive body of [educational] research confirms the effectiveness of cooperative learning in higher education. Relative to students taught conventionally, cooperatively-taught students tend to exhibit better grades on common tests, greater persistence through graduation, better analytical, creative, and critical thinking skills, deeper understanding of learned material, greater intrinsic motivation to learn and achieve, better relationships with peers, more positive attitudes toward subject areas, lower levels of anxiety and stress, and higher self esteem [Johnson et al. 1998; McKeachie 1999]."

These benefits or traits from cooperative learning are significant practical skills needed by a professional engineer. BEEF, Inc. hires engineers that possess these professional traits, because they tend to be the most productive members of our workforce. Your 14-week internship in our Process Engineering Department provides you with the opportunity to develop those same professional traits. This section of the handbook outlines those learning activities that help develop your teamwork and professional skills.

- **Understand the learning styles of all team members.**

People think, learn, and approach problems differently. These varied *styles* give diverse teams the potential to be far more effective than individuals working alone. Unfortunately, those same distinctions can lead to friction and confusion among team members, especially those relatively new to teamwork activities. Therefore, students must recognize that styles other than their own exist, and that a mixture of preferred styles could ultimately be beneficial in a team setting.

The Felder/Silverman Model explicitly addresses preferred ways in which people learn and process information. As described above, in a teamwork setting knowledge and recognition of individual and team preferences (and weaknesses) can be very helpful. The Felder/Silverman Model classifies students as having possible learning preference within each of the following five pairs:

- sensing/intuitive
- visual/verbal
- inductive/deductive
- active/reflective
- sequential/global

This model is described by several web links at the home page of Professor Richard Felder (http://*www4.ncsu.edu/unity/lockers/users/f/felder/public/*). His web pages contain a paper- and web-based, 44-item questionnaire that students can self administer to assess their own preferred learning styles within the five pairs. Under the guidance of your project supervisor, you and your team members are required to read the Felder and Silverman article [1988] on the learning and teaching styles in engineering education, complete their learning style questionnaire, and then discuss your results as a team.

- **Understand the dynamics of teamwork.**

A team is not the same as a group. The term "group" implies little more than a collection of individuals. As provisional engineers, you probably have had some experiences, good or bad, of working in groups, but you have had little or no experience functioning in teams. You may fear or not like working in teams. Although this feeling is natural, you can overcome this individualistic tendency and learn that "two or more heads are better than one." The five stages of development that most teams work through will help you to understand the dynamics of teamwork.

As described by Phillips [1997], the Tuckman model identifies five distinct stages—forming, storming, norming, performing, and adjourning—in the evolution of the team as a social system. During the forming stage, team members are typically uncertain about what they are supposed to accomplish, how they (as individuals) should contribute to the discussion, and how well the team members will get along. During the storming stage, tension within the team may manifest itself as outright hostility as members question whether other members are doing what they are supposed to be doing, cliques form, and personality conflicts arise. Conflict is alleviated during the norming stage, as members affirm expectations on how the team should pursue its task and how team members should behave. As the name implies, the performing stage is characterized as a period of genuine progress towards team goals. Members understand and are committed to their individual responsibilities and to the team's overall success. Team members know how to work together and to deal constructively with unexpected events. The adjourning stage is when the team has accomplished its mission and disbands.

You and your teammates should be aware of these stages so you do not become demoralized by the low productivity and personality conflicts that may occur in new teams. The fifth tenant of cooperative learning, regular self-assessment of team functioning, provides a mechanism for you and your teammates to address issues that may arise while your team evolves through the five stages. Your project supervisor will suggest team building exercises to your team. Your team has a professional responsibility to learn how to become an effective force in the Process Engineering Department.

- **Develop a project team contract.**

Navigating the evolutionary road of team development is made easier when the team members have a shared ownership of how the team is to function and what to do when issues arise. Your team must develop its own written contract that states the rules of conduct, the roles of responsibilities, and the policies to handle detrimental issues. Once this contract is prepared and reviewed by your project supervisor, all members of the team must sign the contract and provide copies to each team member and your project supervisor.

Your team must consult four resources that have good ideas from which your team can develop its own contract. First, the Felder and Silverman article [1988] on the learning and teaching styles in engineering education explains the diversity of preferred learning styles that you will experience in your team. Second, the Phillips article [1997] explains the Tuckman model of five distinct stages—forming, storming, norming, performing, and adjourning—of team development. Third, the Pennsylvania State University resource "Puzzled About Teams" provides important insights to help you formulate your team's contract. It is available on Bucknell's Moodle system under the CHEG 200 course. Although your project supervisor will provide guidance, your team must take the initiative to develop its own contract. Finally, Oakes, Leone, et al. [2000, Ch. 20] present attributes for successful teams as well as for individual members.

When your team practices the fifth tenant of cooperative learning, regular self-assessment of team functioning, you can use the team contract as an assessment instrument by periodically reviewing the contract to evaluate how your team is performing. Furthermore, your project supervisor can use it to mentor your team if and when you are having difficulties.

- **Practice leadership in the team roles.**

As anyone who is familiar with team sports knows, individual players have specific roles. For example, in American football, the quarterback throws the ball and a receiver catches it, and if a player fails in his or her role, the whole team suffers. The same principle applies with our provisional project teams. You must accept your professional responsibility that team roles are necessary for successful teams.

Usually on a Friday, your project supervisor will issue a memorandum that assigns to your team a bi-weekly project consisting of six problems. One problem will help you to address your team's major project of determining the process requirements and "best" operating conditions to manufacture styrene monomer from methanol and toluene using the HYSYS processor simulator. Four problems focus on manually solving the material balances, energy balance, and/or phase equilibria of process equipment. These problems will help you to get a better understanding of how HYSYS does it calculations. The sixth problem will be related to the laboratory experiment that your team will plan, conduct, analyze, and report.

Using problem-based learning and the problem-solving methodology that were described earlier, your project team members will work cooperatively to solve these six problems under the guidance of your project supervisor during the six, two-hour work sessions. Your team will formally document the solutions to these problems and write a project memorandum that summarizes your team's major results and conclusions for specific problems. This formal project documentation is submitted to your project supervisor on the third Monday after the Friday assignment.

While using the five tenants of cooperative learning, your team members will rotate their roles to complete the bi-weekly project. The roles are coordinator, assembler, observer, and monitor. The coordinator helps the team to identify and understand its goals and keeps everyone on task during the work sessions. The assembler prepares the bi-weekly project report packet and makes sure it is turned in on time. The observer double-checks the problem solutions before they are submitted and conducts the group processing activity. The monitor checks that everyone understands the problem solutions and the strategies used to get them. All four team members actively participate in drafting the team memorandum and problem solutions. For a five-member team, a troubleshooter asks the "What If" questions and encourages the discussion of opposing ideas. For a four-member team, the coordinator also takes on the role of the troubleshooter. Your project supervisor will provide your team with guidance as you perform your team roles to complete the bi-weekly project assignment.

In the Process Engineering Department of BEEF, Inc, our teams do not have leaders. Teams need leadership and not leaders. Stein and Hurd [2000] address this issue as follows:

> "A popular myth is that a group [team in our context] has to have a leader. This myth is perpetuated by a failure to distinguish between a leader and leadership. It is true that a group has to have leadership, but this need not be identified with a single person. In fact, attributing leadership to a single person is generally dysfunctional, particularly in regard to synergy. The leader becomes the focal point of the group. … Group members may defer to the leader too much. It is tempting to let the leader decide important issues."

Your team requires not a leader but leadership; that is, actions that keep the team focused and move the team closer to completing its bi-weekly projects. In their team roles, the coordinator, assembler, observer, monitor, and troubleshooter each has a professional responsibility to practice the leadership needed to keep the team productive on a project assignment. This shared leadership is important because it fosters team synergy, the feeling that the whole is much more than the sum of its parts. Your project supervisor will provide an exercise for your team to learn about the importance of leadership.

- **Develop effective interpersonal skills.**

Some conflicts of ideas and resulting frustration are to be expected at varying points throughout a team project. In fact, the complete absence of disagreement is not a good sign for effective teamwork and problem solving. It signals that little meaningful idea integration or decision making is occurring, and/or that people are not openly communicating their feelings. If approached and managed constructively, conflict can lead to good and creative choices. On the other hand, poorly managed conflict can lead down a destructive path, resulting in anger, hurt feelings, and poor team performance.

Team performance is strongly dependent on the behavior of the individual team members. By mastering their behaviors in communication, decision making, collaboration, and self-management, team members can manage conflict constructively and truly establish themselves as a cohesive unit. The following five paragraphs on these four key behaviors and their associated roles is taken direct from *The Team Developer: An Assessment and Skill Building Program*, a student guidebook, by McGourty and De Meuse [2001, pp. 15-19].

**Communication**. Good communication involves helping to create and sustain a team environment in which all team members feel free to speak and listen attentively. Listening carefully and actively can improve understanding and thus reduce conflict. Listening more and speaking less is good advice in any team effort. The following two fundamental roles are important in this behavior:

- *Active Listener*: A team member who is very attentive to what others are saying and takes an active role to ensure that what is said is fully understood. An "active listener" provides constructive feedback to other members based on a full understanding of what is heard.
- *Influencer*: An individual who conveys his or her viewpoints in a manner that wins support from fellow team members. This person presents issues in a confident manner and uses facts to get points across to the listener(s).

**Decision Making**. Decision making is done best *by* the team, not *for* the team. It involves a clear understanding of the problem or task, gathering and weighing alternatives, achieving consensus whenever possible, and communicating that decision in a timely, acceptable manner. The follow three fundamental roles are important in this behavior:

- *Analyzer*: An individual who thinks logically and reviews each situation from several viewpoints. An "analyzer" encourages fellow team members to explore and discuss all alternative solutions before making a final decision.
- *Innovator*: A team member who always generates new ideas and encourages others to do the same. He or she suggests new ways of looking at problems and challenges the way things normally are done.
- *Fact Seeker*: A person who encourages fellow team members to use facts as the basis for decisions. He or she seeks information from all sources including those "outside" the team.

**Collaboration**. In many ways, collaboration is the essence of teamwork. It involves working with others in a positive, cooperative, and constructive manner. Collaboration requires that you demonstrate a commitment to the team's overall purpose and to supporting other team members. It requires that team members share responsibility for group functioning and productivity. The following two fundamental roles are important in this behavior:

- *Conflict Manager*: A team member who consistently acknowledges issues that the team must confront and resolve. An effective "conflict manager" works to resolve differences of opinion and negotiates solutions that all team members can accept.
- *Team Builder*: An individual who encourages all members to participate in team activities. He or she values and reinforces the contributions of all members. The "team builder" cooperates with others and willingly shares information.

**Self-Management**. The focus on communication, decision making, and collaboration increasingly moves one towards the behavioral category of "self-management" in the team process. *Management* here is not the exclusive domain of a single individual; it is a behavior expected of every team member. A self-manager within a team will collaborate with others in seeking a team solution or new direction. The effective self-manager communicates clearly and effectively, keeping the team on task. The following three fundamental roles are important in this behavior:

- *Goal Director*: An individual who helps the team identify its goals and ensures that goals are understood by all members. This person encourages the use of action plans and timetables to help meet team goals.
- *Process Manager*: A person who ensures that the team stays on focus and uses meeting time in an efficient manner. The "process manager" suggest ways for the team to proceed when needed.

- *Consensus Builder*: A team member who solicits input from all members and encourages them to express their views candidly. The "consensus builder" frequently polls people regarding their current position on an issue and summarizes the team's position.

Each of the above four behaviors and 10 roles is critical to a team's success. As team members acquire the requisite skills needed to perform these roles, a team's performance will improve. However, it takes time for individuals to learn and develop these skills. As a team member, you need to receive feedback on how well you are performing. You and your team members will use *Team 360* software to receive this needed feedback. This software provides a formal, non-threatening system for an individual member to obtain feedback from other team members regarding his/her performance on the four key behaviors, as well as to what extent he/she is performing the ten essential team roles. This feedback will enable each member to develop individual team skills, as well as help the team to perform more effectively overall.

- **Conduct self-assessment of the team's performance.**

As indicated by the fifth tenant of cooperative learning, regular self-assessment of how the team is functioning will provide you and your team with valuable information on enhancing your performance as well as your team's performance. As indicated above, you will use *Team 360* software to conduct these assessment activities.

A team survey in *Team 360* will contain a number of statements, generated by the instructor, that relate to the four behavioral categories: (a) communication, (b) decision making, (c) collaboration, and (d) self-management. Team members use a rating scale to anonymously rate themselves and all of their fellow team members on various team behaviors addressed in the statements. Based upon those ratings, each team member receives a confidential feedback report. The report summarizes how each person sees himself or herself, as well as how their team members collectively perceive them.

Based on the feedback you receive from your teammates, you are encouraged to prepare a carefully developed plan (i.e., an action plan) to enhance your team skills. Besides McGourty and De Meuse's student guidebook [2001], the Pennsylvania State University web-based resource "Puzzled About Teams" can provide you with insights to help you formulate an action plan. Since our provisional engineers are motivated and conscientious, they will benefit from using this system to improve their team skills. Your project supervisor will provide you with directions on the use of *Team 360*.

## Professionalism

In a professional organization like BEEF, Inc., engineers need constructive feedback from their supervisors and teammates about their abilities as problem solvers, memo writers, and team players. This feedback in the form of performance evaluations helps them to learn and improve their professional craft. Your project supervisor and a teaching assistant in the Process Engineering Department will evaluate your team's bi-weekly projects and provide you with feedback on your performance. Your team will also complete three, one-week projects that will be evaluated by the teaching assistant. This section of the handbook addresses the importance of your technical competency, explains how your team's performance is determine on projects, and outlines how your individual performance is determined for your contribution to the team's efforts.

- **Develop a conscientious attitude.**

As citizens in our society, engineers must observe the conventional ethics of "obey the laws of the land" and "observe the golden rule," that is, "do unto others as you would have them do unto you." However, engineers must further observe professional or engineering ethics that protect the public interest, because engineers develop processes and systems that can affect the public welfare. Failures or improper designs in any process or system can have possibly devastating impact on an individual or group of individuals. As aptly stated by Florman in his book, *The Civilized Engineer* [1987, pp.103-104], "One can only conclude that the great need in engineering ethics is an increased stress on competence. ... Other words come to mind: dedication, energy, self-discipline, caution, alertness, awareness—and most of all, as I have suggested, conscientiousness. The greatest threats to moral engineering are carelessness, sloppiness, laziness, and lack of concentration. An engineer may start out honest and high-minded but become immoral by falling prey to one or more of these sins. On the other hand, an engineer who starts out by being conscientious must end up by being honest, since competent engineering, excellent engineering, is in its very nature the pursuit of truth. A conscientious engineer, by definition, cannot falsify test reports or intentionally overlook questionable data, cannot in any way evade the facts."

The effect of incompetence is best illustrated by an example, as reported by Florman [1987, pp. 102-103]. In a 1977 research study at the Swiss Federal Institute of Technology, Miroslav Matousak analyzed 800 cases of structural failure in which 504 people were killed, 592 people injured, and many millions of dollars in damage incurred. The incompetence of engineers in these failures is summarized in Table 3. The first four causes, which are 79% of the total, are attributed to individual incompetence. A critical review of one's work by peers could eliminate most of these causes. The next four causes could be reduced significantly by additional supervisory control. The "other" category is the unethical behavior in the conventional sense, that is, greed or intent to deceive.

**Table 3. Failures of Incompetent Engineers**

| Cause† | Percent |
|---|---|
| Insufficient knowledge | 36 |
| Underestimation of influence | 16 |
| Ignorance, carelessness, negligence | 14 |
| Forgetfulness, error | 13 |
| Relying upon others without sufficient control | 9 |
| Objectively unknown situation | 7 |
| Unprecise definition of responsibilities | 1 |
| Choice of bad quality | 1 |
| Other | 3 |
| | 100 |

†Table extracted from Florman, S. C. *The Civilized Engineer*. St. Martin's Press, New York, NY, 1987, p. 103.

The purpose of engineering ethics is to protect the public interest. As a provisional engineer, you must develop a conscientious attitude and avoid the sins of incompetence. You must work hard, pay attention to detail, and take pride in your work. Furthermore, you must not "pass the buck" but accept your professional responsibilities.

- **Assess the team's project performance.**

For each project, your team is to work cooperatively using the principles of problem-based learning and the problem-solving methodology to solve the six assigned technical problems. In the two-hour work sessions, your project supervisor will provide guidance and ask your team to do many cooperative activities designed to facilitate your team's work. These activities will incorporate positive interdependence, individual accountability, face-to-face promotive interaction, teamwork skills, and team self-assessment. How well your team has performed to complete the project is based on the quality of your team's informal memo report that contains your team's project memo and formal problem solutions. Your team's memo report will be assessed and evaluated by a teaching assistant. Appendix E provides the company guidelines and standards that will be used by the teaching assistant to determine the quality of your team's performance for a project assignment. As a provisional engineer, you have a professional responsibility to learn and apply the company guidelines and standards.

In Appendix E, the pink cover sheet, that is place on top of a team's memo report, is basically an assessment and evaluation form. Your team's project quality is determined by the following formula:

$$\text{Team's Project Quality} = (\text{ performance factor }) \times (\text{ solution average }),$$

and its value is on a scale of 0 to 100, where 100 is the best quality. This project quality is the product of your team's performance factor and solution average.

The **performance factor** assesses how well did your team's project memo and problem solutions meet the company guidelines and standards. Its value is on a scale of 0.00 to 1.00, where one is the best performance. Basically, the performance factor answers the question of "Is your team doing a professional job?"

The **solution average** assesses the correctness of your problem solutions. Each problem's statement, conceptual model, mathematical model, mathematical algorithm, numerical solution, and heuristic observation are assessed. A maximum of 100 total points exists for a problem solution. After all six problems have been assessed, the total solution points are average to give a value on a scale of 0 to 100. Basically, the solution average answers the question of "How correct are your team's problem solutions?"

Two examples are now presented to illustrate how the "Team's Project Quality" is determined. Team 3 worked on Project 2 and appeared to have read the company guidelines and standards. Their project memo received a performance factor of 0.40, while their project solutions received a 0.59. The solution correctness for their six problems was 85, 90, 100, 80, 85, and 93 points, giving a solution average of 89. Team 3's project quality is calculated as follows:

$$\text{Team 3's Project Quality} = (0.99) \times (89) = 88.$$

Team 7 worked also on Project 2 and appeared **not** to have read the company guidelines and standards. Their project memo received a performance factor of 0.32, while their project solutions received a 0.45. The solution correctness for their six problems was 87, 90, 83, 86, 91 and 95 points, giving a solution average of 89. Team 7's project quality is calculated as follows:

$$\text{Team 7's Project Quality} = (0.77) \times (89) = 69.$$

Because of the multiplicative effect of the performance factor, your project team must maintain a **high standard of professionalism** while doing a team project; that is, each member of your team needs to learn and apply the company guidelines and standards and have his/her work review by other team members.

- **Assess a team member's individual performance.**

Over the 14-week continuing education course, a team member's individual performance in the team projects will be assessed four times: a) based on the first two-week project before the first exam (Cycle 1), b) based on the next two, two-week projects before the second exam (Cycle 2), c) based on the next two, two-week projects before the final exam (Cycle 3), and d) based on the lab oral presentation on the last Monday of the semester plus the three, one-week projects (Cycle 4). For each assessment, your work quality is determined by the following formula:

Member's Work Quality = ( professionalism factor ) x ( project average ),

and its value is on a scale of 0 to 100, where 100 is the best quality, but you can get a score higher than 100 depending upon the value of your professionalism factor. Your work quality is the product of your professionalism factor and project average.

The **project average** is determined by adding the "Team's Project Quality" values in that cycle and dividing by the number of team projects. Its value is on a scale of 0 to 100, where 100 is the best quality. Basically, the project average answers the question of "How well did the team do on projects in that cycle?"

The **professionalism factor** assesses how well you did as a team member when working on the projects in a cycle. Basically, the professionalism factor answers the question of "Are you doing professional work?" This factor is composed of two parts, as indicated by the following formula:

Professionalism Factor = ( journal rating ) x ( peer rating ),

and its value is on a scale of 0.00 to 1.16, where 1.16 is the best quality work. The **peer rating** assesses how your team members perceive that you are doing in the team projects. Its value is on a scale of 0.00 to 1.05, where 1.05 is the best rating.

The **journal rating** is a measure of how well you have been keeping your own technical journal and completing independently-documented (ID) tutorials and quizzes in it. During a cycle, your project supervisor and/or the teaching assistant will periodically review, evaluate, and sign your journal. The evaluation scale that they will use is shown in Table 4.

**Table 4: Technical Journal Work**

| Quality | Rating | Organization | Independently-Documented |
|---|---|---|---|
| superb | 1.10 | | ID Quizzes and Tutorials done. |
| | 1.05 | Organized, well maintained. | ID Tutorials done. |
| good | 1.00 | | |
| | 0.98 | | ID Quizzes and Tutorials done. |
| poor | 0.94 | Organized, loosely maintained. | ID Tutorials done. |
| | 0.90 | | |
| unacceptable | 0.80 | Not organized or maintained. | |

Your technical journal is evaluated at two levels—organization and independent work. For example, if it is organized and well maintained, and you have completed only the ID tutorials, then your journal rating would be 1.05. Organization means the guidelines in Appendix B are being followed. Maintenance means entries are being made and the table of contents is being updated. Associated with each project will be a set of independently-documented (ID) tutorials and quizzes. You are expected to complete all

ID tutorials and at least three ID quizzes to qualify for the indicated journal rating. You are encouraged to consult with your teammates while doing the ID tutorials and quizzes. However, you must independently document your completion of these ID items and place them in your technical journal. To do otherwise would be plagiarism.

Normally, your journal rating will adjust your peer rating up or down by 10 percent. If your journal is not organized or maintained, your journal rating will adjust your peer rating down by 20 percent, even if you have completed the ID items.

Near the end of a cycle, your project supervisor will ask your team members to confidentially evaluate how well they and each of their teammates fulfilled their team responsibilities, using the following prescribed list of nine terms:

- **Excellent**: Consistently went above and beyond, tutored teammates, carried more than his/her fair share of the load.
- **Very Good**: Consistently did what he/she was supposed to do, very well prepared and cooperative.
- **Satisfactory**: Usually did what he/she was supposed to do, acceptably prepared and cooperative.
- **Ordinary**: Often did what he/she was supposed to do, minimally prepared and cooperative.
- **Marginal**: Sometimes failed to show up or complete assignments, rarely prepared.
- **Deficient**: Often failed to show up or complete assignments, rarely prepared.
- **Unsatisfactory**: Consistently failed to show up or complete assignments, unprepared.
- **Superficial**: Practically no participation.
- **No Show**: No participation at all.

Before doing this evaluation, your project supervisor will caution you that you are evaluating **only responsibility of performance** and not academic ability or percentage contribution to the projects. After all team members complete their evaluations, your project supervisor and/or the teaching assistant will compile these evaluations to determine a peer rating for your individual contribution to the team projects in that cycle.

At the end of the continuing education course, your four "Work Quality" values will be averaged, in order to determine your overall individual contribution to all of the team projects.

## Summary

As a new provisional engineer in the Process Engineering Department of BEEF, Inc., you are a problem solver, a memo writer, and a team player. Your four-member project team conducts an analysis study, in order to recommend the process requirements and operating conditions for a process design to manufacture styrene monomer from methanol and toluene for one of our clients. Your project team reports its technical solution to your project supervisor in the form of an informal memorandum report. This chapter of the handbook has outlined your engineering team project, summarized your technical activities, presented your communication activities, and defined your teamwork activities. It has concluded with your professional responsibilities and how they are assessed.

# Conclusions

As a consultant company, BEEF, Inc. solves chemical processing problems and implements their solutions for our governmental and commercial clients. In the Process Engineering Department, project teams of provisional engineers must effectively solve the process requirements for chemical processing problems and report their solutions to our company and our clients. However, these engineers are new employees, who have limited experience as technical problem solvers, report writers, and team players. This handbook helps our provisional engineers learn how to do the company's business. Specifically, it defines the organizational structure of our company, describes how it functions, and outlines the technical, communication, and teamwork activities of engineers in our Process Engineering Department.

Once our new provisional engineers read this handbook, they can draw the following conclusions about the development of an engineering project in BEEF, Inc.:

1. Our corporate organization supports a decision-making methodology, called the engineering development process, to solve the complex processing problems of our clients.

   The four stages in that methodology are process development, systems development, systems implementation, and systems evaluation. The solution to a client's chemically-related problem is a technical process and its supporting physical system.

2. In the first stage of this methodology, four provisional engineers in the Process Engineering Department must organize a project team, determine the technical process requirements, and report the solution for a specific process flowsheet, under the guidance of a project supervisor.

3. As problem solvers, our new provisional engineers acquire a technical knowledge base using problem-based learning and apply the problem-solving methodology of understand the problem, model the phenomena, devise a plan, carry out the plan, review the problem solution, and report the problem solution.

   Our provisional teams apply this methodology to determine the process requirements and "best" operating conditions to manufacture styrene monomer from methanol and toluene for one of our clients. They also develop various technical and professional skills while learning how to solve a complex chemical processing problem.

4. As report writers, our new provisional engineers learn how to prepare an informal memorandum report and document their problem solutions to meet company standards.

   They learn that the writing process is composed of pre-writing (i.e., planning), drafting, and revising. They also develop various computer skills in electronic communication, informational retrieval, word processing, drawing, graphing, and computer-aided analysis.

5. As team players, our new provisional engineers practice their interpersonal skills using the five tenants of cooperative learning, in order to develop better analytical, creative, and critical thinking skills and to obtain a deeper understanding of the technical material.

   As a provisional team, its members learn about preferred styles of learning, the dynamics of teamwork, a team contract, different team roles, and self-assessment of team performance.

Because most engineering problems require complex solutions, our new engineers learn that a purposeful plan is needed to handle the complexity. This handbook describes plans to do your technical and communication activities in a professional manner.

# Recommendations

As indicated in this handbook, problem solving, report writing, and teamwork are the primary activities of engineers in BEEF, Inc. As a new provisional engineer, you need to develop your abilities as a problem solver, report writer, and team player. To begin the learning process, this handbook recommends that you do the following:

1. Attend the two-hour cooperative learning sessions in our continuing education program.
2. Apply the principles of problem-based learning and the problem-solving methodology.
3. Consult your project supervisor for information and advice.
4. Learn on your own by reading the recommended literature material.
5. Keep your technical journal by recording daily entries.
6. Organize your project team for its technical, writing, and teamwork tasks.
7. Make significant contributions to your project team and accept feedback graciously.
8. Develop your technical skills in electronic information retrieval, computer word processing, computer drawing, computer graphing, and computer-aided process analysis.
9. Produce professional-looking informal memorandum reports.

BEEF, Inc. hired you as a new employee, because you possess the talent to become a process engineer. What you must decide is "Does the degree of my desire match that of my talent?" You must work hard, pay attention to detail, take pride in your work, and observe professional ethics, in order to become an effective engineer.

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Project Catalyst was designed to address the systemic change needed in the engineering classroom by having faculty collaborate in teams to re-envision their roles in the learning process with the ultimate goal of:

- learning and integrating instructional design techniques into the classroom,
- transforming the classroom into a cooperative learning environment, and
- efficiently and effectively incorporating the use of information technology.

Each of these change agents has been shown to be effective in a wide range of pedagogical studies. By combining these change agents with faculty teamwork, this Catalyst project developed a transferable model to produce the systemic reforms needed to graduate engineering students who not only possess technical competency but significant creativity, imagination, and lifelong learning skills.

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| | |
|---|---|
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# Appendix A. Units Conversion

*Introduction*

As a chemical engineer, you need to master the intellectual skill of converting units between the meter-kilogram-second (**mks**), foot-pound-second (**fps**), and centimeter-gram-second (**cgs**) systems of units. It is assumed that you know how to do units conversion. This appendix presents a general procedure that you can review. This procedure can be applied to simple as well as complex conversion problems. The following four examples illustrate units conversion:

1. Convert 1500 g to $lb_m$ :

$$m = 1500\text{ g}\left\langle \frac{1\text{ lb}_m}{453.592\text{ g}} \right\rangle$$
$$= 3.30694\text{ lb}_m \quad = \quad 3.3\text{ lb}_m$$
$$\cong \frac{2}{5}\times\frac{10^{+3}}{10^{+2}} \quad \cong \quad 4.0\text{ lb}_m \qquad \text{a mental check}$$

2. Convert 32.54 ft/min to m/s:

$$u = 32.54\ \frac{\text{ft}}{\text{min}}\left\langle \frac{1\text{ m}}{3.2808\text{ ft}}\cdot\frac{1\text{ min}}{60\text{ s}} \right\rangle$$
$$= 0.165305\,\frac{\text{m}}{\text{s}} \quad = \quad 0.1653\,\frac{\text{m}}{\text{s}}$$
$$\cong \frac{3}{3\cdot 6}\times\frac{10^{+1}}{10^{+1}} \quad \cong \quad 0.1667\,\frac{\text{m}}{\text{s}} \qquad \text{a mental check}$$

3. Convert 3 weeks to milliseconds:

$$t = 3\text{ wk}\left\langle \frac{7\text{ d}}{1\text{ wk}}\cdot\frac{24\text{ h}}{1\text{ d}}\cdot\frac{60\text{ min}}{1\text{ h}}\cdot\frac{60\text{ s}}{1\text{ min}}\cdot\frac{1\text{ ms}}{10^{-3}\text{ s}} \right\rangle$$
$$= 1.8144\times10^{+9}\text{ ms}$$
$$\cong 3\cdot7\cdot2\cdot6\cdot6\times\frac{10^{+1+1+1}}{10^{-3}} \quad \cong \quad 1.5\times10^{+9}\text{ ms} \qquad \text{a mental check}$$

4. Convert expression for Reynolds Number (Re) to unitless:

$$Re = \left(2.067\text{ in}\cdot\frac{0.048\text{ ft}}{\text{s}}\cdot\frac{0.805\text{ g}}{\text{cm}^3}\cdot\frac{\text{m s}}{4.3\times10^{-4}\text{ kg}}\right)\left\langle \frac{1\text{ kg}}{10^{+3}\text{ g}}\cdot\frac{1\text{ ft}}{12\text{ in}}\cdot\frac{3.2808\text{ ft}}{1\text{ m}}\cdot\frac{28\,317\text{ cm}^3}{1\text{ ft}^3} \right\rangle$$
$$= 1437.99 \quad = \quad 1400$$
$$\cong \frac{2\cdot5\cdot8\cdot3\cdot3}{4\cdot1}\times\frac{10^{-2-1+4}}{10^{-4+3+1}} \quad \cong \quad 1.8\times10^{+3} \qquad \text{a mental check}$$

These four problems exemplify the knowledge required to do units conversion, calculate the answer, account for precision, and approximate the answer to check the calculated result. For the conversion process, you have a starting point (a "Given") and an ending point (a "Find") as illustrated for the above four examples in the example units problems below. Your goal is to create a dimensional equation that goes from the "Given" to the "Find" using the **units conversion algorithm** outlined in the remainder of this appendix.

# Appendix A. Units Conversion

*Example Units Problems*

**Starting Point**

| Given |
| --- |
| symbol, name |
| value(s) and units |

| Find |
| --- |
| as |
| new units |

**Some Examples**

| Given |
| --- |
| m, mass |
| 1500 g |

| Find |
| --- |
| as |
| $lb_m$ |

| Given |
| --- |
| u, velocity |
| 32.54 ft/min |

| Find |
| --- |
| as |
| m/s |

| Given |
| --- |
| t, time |
| 3 wk |

| Find |
| --- |
| as |
| ms |

| Given |
| --- |
| Re, Reynolds Number |
| $\dfrac{2.067\text{ in}\cdot\dfrac{0.048\text{ ft}}{\text{s}}\cdot\dfrac{0.805\text{ g}}{\text{cm}^3}}{4.3\times10^{-4}\ \dfrac{\text{kg}}{\text{m s}}}$ |

| Find |
| --- |
| as |
| unitless |

**Ending Point**

A dimensional equation: ( the Given ) < series of conversion factors > = answer

# Appendix A. Units Conversion

*Units Conversion Algorithm*

1. Begin the dimensional equation. Write the "Given" as a product of factors as follows:

$$\frac{\#\ \text{num\_unit}}{\text{dem\_unit}} \cdot \frac{\#\ \text{num\_unit}}{\text{dem\_unit}} \cdot \ \cdots \ \cdot \frac{\text{num\_unit}}{\#\ \text{dem\_unit}} \cdot \frac{\text{num\_unit}}{\#\ \text{dem\_unit}} \cdot \ \cdots$$

2. Select a unit in the "Given" that belongs to a specific unit class, such as length, time, or mass. Call it the current state.

3. **If** the "Find" is not unitless **then**

   identify a unit in the "Find" with the same unit class as the current state.

   **else**

   identify a unit in the "Given" with the same unit class as the current state.

   **endif**.

   Call this identify unit the goal state.

4. Select an appropriate equivalence (≡) that relates the "current state" unit to the "goal state" unit. Use the web site www.onlineconversion.com to find various unit equivalences. For example,

Current State: kg
Goal State: oz

| Equivalences | Selection |
|---|---|
| 1 kg ≡ 1000 g<br>1 kg ≡ 2.20462 $b_m$<br>1 kg ≡ 35.27396 oz | 1 kg ≡ 35.27396 oz |

Current State: $lb_m$
Goal State: g

| Equivalences | Selection |
|---|---|
| 1 kg ≡ 1000 g<br>1 kg ≡ 2.20462 $lb_m$<br>1 kg ≡ 35.27396 oz | 2.20462 $lb_m$ ≡ 1000 g |

5. Generate a conversion factor from the equivalence relationship as follows:

Equivalence: current ≡ goal    Conversion factor: $\left\langle \frac{\text{goal}}{\text{current}} \right\rangle$

For example, $\left\langle \frac{35.27396\ \text{oz}}{1\ \text{kg}} \right\rangle$ or $\left\langle \frac{1000\ \text{g}}{2.20462\ \text{lb}_m} \right\rangle$

6. Place the conversion factor as the next product term in the dimensional equation, but invert it only if the "current state" unit appears in the denominator of the dimensional equation.

# Appendix A.  Units Conversion

For example, $$1500\ \text{lb}_\text{m} \left\langle \frac{1000\ \text{g}}{2.20462\ \text{lb}_\text{m}} \right\rangle$$

For example, $$\frac{1}{1500\ \text{lb}_\text{m}} \left\langle \frac{2.20462\ \text{lb}_\text{m}}{1000\ \text{g}} \right\rangle$$

7. Raise the conversion factor to a power, if necessary.

For example, $$\left\langle \frac{1^3\ \text{m}^3}{3.2808^3\ \text{ft}^3} \right\rangle$$

8. Place a SI prefix conversion factor as the next product term, if necessary.

For example, $$1500\ \text{kg} \left\langle \frac{1\ \text{lb}_\text{m}}{453.592\ \text{g}} \cdot \frac{10^3\ \text{g}}{\text{kg}} \right\rangle$$

9. Cancel those units in the numerators and denominators that match.

10. Continue Steps 2 to 9 until the remaining units in the dimensional equation are the "Find" units.

11. Do the calculation using a calculator and record the answer using 6 significant digits.

For example, $$\begin{aligned} \text{m} &= 1500\ \text{kg} \left\langle \frac{1\ \text{lb}_\text{m}}{453.592\ \text{g}} \cdot \frac{10^3\ \text{g}}{\text{kg}} \right\rangle \\ &= 3306.94\ \text{lb}_\text{m} \end{aligned}$$

12. Account for precision and report the final answer.

For example, $$\begin{aligned} \text{m} &= 1500\ \text{kg} \left\langle \frac{1\ \text{lb}_\text{m}}{453.592\ \text{g}} \cdot \frac{10^3\ \text{g}}{\text{kg}} \right\rangle \\ &= 3306.94\ \text{lb}_\text{m} \quad = \quad 3300\ \text{lb}_\text{m} \end{aligned}$$

13. Approximate the answer using scientific notation, as a mental check on the calculated result.

For example, $$\frac{1.5}{4.5} \times \frac{10^{+3+3}}{10^{+2}} \quad \cong \quad 3333\ \text{lb}_\text{m}$$

# Appendix B. Technical Journal

Project documentation is the keeping of a complete and detailed engineering record, a practice followed by many professional engineers. It allows you to keep precise and accurate records of what you are doing. Because no one can remember everything precisely, a written record at the time something happens is the only way to insure accuracy of the event. Furthermore, this written record serves to inform you, your other team members, as well as other personnel in the company. Professional engineers have an ethical responsibility to keep precise and clear records of their technical and rhetorical work.

The Process Engineering Department of BEEF, Inc. has some basic standards on keeping a technical journal. These standards serve as a basic framework. You should modify them, wherever appropriate, in order to meet your technical and rhetorical responsibilities. Please consult with your project supervisor whenever you what to make a major modification to the standards. Remember that your technical journal will become a permanent document in the company's archives.

Your technical journal is to be kept in a three-ring binder with tab dividers. The following list of sections is suggested for the table of contents (TOC) in your technical journal. Remember it is a suggestion, so you can freely add to or subtract from this list of sections.

- TOC
- Notes — Co-ops
- Notes — Lab
- Notes — Problems
- .
- .
- .
- Notes — Review
- Handouts
- Projects
- Tests
- Literature
- etc.

In the TOC section, write each of the section headings at the top of a new page. Provide separate page headings for the "Notes" categories, such as "Notes — Co-ops", "Notes — Lab", "Notes — Problems", etc. Arrange all of these "table of contents" pages in whatever order you want. Leave a few blank pages at the end for any new section headings.

Each section must have a labeled tab divider; except for the "Notes" sections. They have only one tab divider named “Notes”. Behind the "Notes" tab, record all of your daily work. Behind the "Handouts" tab, place materials that you receive from your project supervisor and other individuals. Behind the "Projects" and "Tests" tab, place the final products for these items. Behind the "Literature" section, place xerox copies of articles, printed copies of web pages, etc.

In the "Notes" section, number the pages consecutively in the upper right corner of a page. Use your "Notes" section every day taking each page in order. For each category entry in this section, label that entry with its category, topic, and date; for example, "Co-op, Material Balances, Tue., 2/6/18. After completing each entry, go to the appropriate "Page" category in the table of contents and list the topic with a brief description and page number for future reference.

# Appendix B. Technical Journal

When you place items in the "Handouts", "Projects", "Tests", or "Literature" section, write an item number in the upper right corner on the first page of that item (e.g., H4 for Handouts). Then, go to the appropriate section in the table of contents, and write the item number and a short item description for future reference.

As a new provisional engineer at BEEF, Inc., you are to observe the following guidelines while keeping your technical journal:

- Provide some identification for your technical journal by placing a journal title, your name, address, phone number, and email address somewhere in the front of the three-ring binder.

- Establish a complete table of contents at the front of your notebook to enable rapid location of the information that you record or place in the journal.

- Provide written entries in the "Notes" section that are legible, in ink or pencil, and complete enough to be understood by another colleague. (If you look at an entry a week later and cannot understand it, the entry fails this rule.)

- Do not leave major blank spaces between written entries in the "Notes" section. If you begin a new page, draw a large X or Z through the blank section of the previous page.

- Treat your "Notes" section as a workbook, a useful tool to assist you in thinking and solving your problems, drafting your memos, and recording your team's cooperative exercises. Since it is not a work of art, you may cross out mistakes, draw sketches as ideas come, and work towards accuracy rather than beauty.

- Enter all drafts of problem solutions in the "Notes" section. Do not use scrap paper and then copy entries into the technical journal. Place electronic drafts of memos or parts of memos in this section too.

- Do not erase or obliterate entries or sub-parts of entries in the "Notes" section. In case of changes or improvements to an original entry, make a new entry under the current day while referring back to the old entry. For example, if a draft problem solution or part of it is found to be erroneous, cross it out and enter the correction under the current day's entries and refer back to the old entry. At the crossed-out old entry, add a note that refers to the page of the new entry.

- Record important information in the "Literature" section when you are doing a literature search, such as bibliographical information, abstracts, and summaries of works found in the library. Place material you photocopy during your literature search into the "Literature" section.

- Place your signature at the bottom of every page in the "Notes" section. In case a sketch of an idea seems worthy of some further consideration, have this witnessed by two other persons. A description of the idea should accompany the sketch.

To keep an effective technical journal, you **must develop a regular habit** of recording and placing information in it and updating its table of contents. Faithfully keeping your journal will allow you to accomplish, efficiently, your technical and rhetorical tasks as a problem solver, memo writer, and team player in the Process Engineering Department of BEEF, Inc.

# Appendix B.  Technical Journal

Your technical journal is your own responsibility.  Gerald R. Levin in *Becoming a Self-Directed Learner* [1990, pp. 24-28] provides further guidelines for keeping a personal journal.  As a professional engineer, you must develop the habit of keeping precise and accurate records of what you are doing, both technically and rhetorically.  Although this writing is personal, remember it becomes part of the legal record of a project and might end up as evidence in litigation.  Your project supervisor and/or the teaching assistant **will periodically review, evaluate, and sign** your technical journal.

# Appendix C. Bibliography Information

The bibliography provides your readers with references to your information sources. It is placed at the end of a memorandum or problem solution. The purpose of a reference "is twofold: to give your audience a place to go for further information about the topic and to avoid plagiarism. Both are important, but the first is merely a kindness. The second is an ethical and legal imperative" [Woolston, et al., 1988, p. 171]. The key to avoiding plagiarism (i.e., claiming someone else's work as your own) is to document your sources of information.

In your technical material, your team documents its sources by citing references in the written text and by providing a bibliography of those references. You will use the author-date system to cite references in memoranda and problem solutions. In this system, when you reference a source in the text, you cite it by listing the author, year of publication, and page number(s) in parentheses or brackets. This citing technique was used in the above paragraph. Please cite your references using the following guidelines:

- surround the reference citation with brackets or parentheses.
- type the author(s), date, and page using 10-point font.
- use authors' last names only. For two authors, spell both last names. For three or more authors, use the first author's last name and the Latin abbreviation "et al.", and do not forget the period after the "al".
- omit the author name(s) from the citation if they appear in the text.
- use the Latin abbreviation "ibid." for the author(s) in the next citation of a paragraph, when those author(s) were used in the last citation of that paragraph.
- <u>optionally</u>, include the abbreviation "p." ("pp.") with the page number(s).

When using the author-date citation, you **do not use footnoting** in the pages of your technical material to document your sources of information. These sources are placed in a section labeled "Bibliography" or “References” at the end of your memorandum or problem solution.

Your project team will compile a bibliography using the conventions outlined by Woolston, et al. [1988, pp. 172-173]. In the bibliography, all of your sources, which are cited in a memo or problem solution, are listed alphabetically by the first author's last name, with a full reference. For a book, you provide the author(s), title, edition, publisher, city, state, and date. For a journal article, you provide the author(s), title, journal title, volume and number of the journal, the date of the journal, and the pages on which the article appears. To document sources other than books and journals, you can consult the Bertrand Library web site that devotes several pages to the subject of citation guides. The following two examples for an article and a book might appear in a bibliography:

Felder, R. M. and L. K. Silverman. "Learning and Teaching Styles in Engineering Education." *Engineering Education*, Vol. 78, No. 7, April 1988, pp. 674-681.

Florman, S. C. *The Civilized Engineer*. St. Martin's Press, New York, NY, 1987.

Further examples of sources can be found in the "Bibliography" section of this handbook for provisional engineers.

In compiling your bibliography, you must be consistent, clear, and provide all the essential information. Accuracy is **paramount**, because the readers of your report may want to consult the original sources of your information. You must collect the essential bibliographical information on a source when you are looking at it. Do not rely on your memory; record the essential information in your technical journal.

# Appendix D. The Rough Draft

The writing process is composed of three major stages—pre-writing or organizing the information, writing the rough draft, and revising the rough draft. This appendix focuses on the development and revision of the rough draft. The material in this appendix has been condensed from the following two literature sources:

Mathes, J. C. and D. W. Stevenson. *Designing Technical Reports: Writing for Audiences in Organizations*, Second Edition. Macmillian Publishing Company, New York, NY, 1991.

Woolston, D. C., P. A. Robinson, and G. Kutzbach. *Effective Writing Strategies for Engineers and Scientists*. Lewis Publishers, Inc. Chelsea, MI, 1990.

In the text below, the pertinent pages from these textbooks are indicated within brackets; for example, [WRK, pp. 52-53]. The code "WRK" represents the initials of the authors' last names. Please consult these literature sources for details and examples. They are available at the Bertrand Library.

## Rough Draft Development

The development of a rough draft involves getting words on paper efficiently and incorporating tables, figures, and equations into the technical report. Before you do revisions, you must write something. As stated by Woolston, Robinson, and Kutzbach [WRK, p. 53], "you must say something before you worry about whether you have said it well; and to worry about saying something and to worry about saying it well are too much to worry about at once." The following procedure [WRK, pp. 52-53] helps you to write your first drafts of report or memo sections and then revise them:

1. Start by expanding the easiest part of a section's outline.
2. Write as quickly as possible using a computer word processor.
3. After you finish a section, let it sit overnight.
4. After this cooling-off period, revise the section.
5. Give the drafted section to one or more colleagues for review.
6. After a second cooling-off period, revise the section again.

Remember that "unless you have an extraordinary gift" to write correctly the first time, "you would do best by following the six steps listed above" [WRK, p. 53].

## Report Format

Your project team of four provisional engineers must prepare an informal technical memorandum report for each assigned bi-weekly project and each weekly project. While drafting a report, your team must address the issues of typography, format cues, and report package. "Ineffective format can inhibit readers, but effective use of typography, white space, headings and subheadings, numbering and bulleting, and highlighting techniques can increase your readers' speed, comprehension, and retention of your message. Moreover, these same techniques can improve the subjective impression that your document inevitably creates in the minds of your readers merely because of its physical appearance" [Mathes and Stevenson, 1991, p. 400]. Report formatting is an important issue; it should not be treated lightly. The word processor, Microsoft Word on a computer, easily allows you to produce technical reports that are formatted properly. Mathes and Stevenson [1991, Ch. 12, p. 379] discuss "formatting the document." Their recommendations are summarized below. Chapter 12 in their textbook provides the justifications for these formatting recommendations.

# Appendix D. The Rough Draft

While using a word processor, you have to make decisions about typefont, character size, margins, etc. In preparing your project report, you **must apply** the typographical standards given in the following table:

| Category | Standard |
|---|---|
| Typefont | Times New Roman |
| Character size | 11- or 12-point |
| Typestyle | Plain, but use italic, bold, and underline for emphasis |
| Text justification | Left-justified text; squared off on left margin but "ragged" on right margin |
| Line length | 6.5 inches |
| Line spacing | Single space |
| Margins | One inch at top, bottom, left, and right. |

With single-spaced text, you will use a block indentation and a line of white space between paragraphs. This handbook for provisional engineers follows the typographical standards in the above table.

Format cues increase readers' speed and comprehension. They include white space, headings and subheadings, numbering and bulleting, highlighting techniques, and color. The recommendations are as follows:

- Use white space to show hierarchy.
- Use informative headings and subheadings.
- Use numbering or bulleting to signal coordinate and subordinate relationships.
- Use highlighting techniques such as italic, boldfaced, and underlined type.
- Use color, if your technology of printing permits it.

In numbering and bulleting, "numbers indicate order and they imply comprehensive treatment; bullets do not indicate order and their use implies illustrative treatment" [Mathes and Stevenson, 1991, p. 394]. Again, this handbook follows these recommendations for format cues.

The report package is the physical arrangement of the items that constitutes your team's informal memorandum report. These items are a standard cover sheet, your team's project memorandum, the project assignment memo, and each problem solution. You are to staple a multi-page memorandum. Also, you are to staple each problem solution, separately. The report package is to be held together by a spring click. Your project supervisor will provide your team with a standard cover sheet for each project assignment.

# Appendix D.  The Rough Draft

## Tables, Figures, and Equations

While drafting your sections of a technical report or memorandum using Word, you will need to incorporate tables, figures, and/or equations into those sections.  Figures can be either drawings or graphs.  Microsoft Word provides commands to create tables, drawings, and equations.  You can use the Microsoft Excel or Matlab program on a Windows or Macintosh computer to create graphs and then copy them into the Word program.

Woolston, Robinson, and Kutzbach provide guidelines for creating effective tables and figures [WRK, pp. 75-100].  Follow these guidelines when drafting your technical report sections.  The guidelines for constructing tables [WRK, p. 79] are as follows:

- Place columns to be compared next to each other.
- Make headings and data reflect an organizational principle, such as priority, descending order, and alphabetical order.
- Label each column and row.
- Include units of measure in the headings.
- Align decimals in a column.
- Put table number and title at the **top**; its number is an Arabic numeral.
- Use footnotes for more extensive explanations of data or headings.

The general guidelines for constructing line graphs in technical reports [WRK, p. 80] are as follows:

- Limit the number of lines on a graph to three or four.
- Show experimental data points with symbols.
- Distinguish different lines by some design.
- Include zero on the axis lines, whenever possible.
- Label each axis with quantity and units.
- Place a figure legend within the graph, when needed.
- Orient graph with the holes or binding at its left or top.
- Put figure number and title at the **bottom**; its number is an Arabic numeral.

Woolston, et al. provide additional guidelines and examples for logarithmic graphs, bar graphs, and pie graphs [WRK, pp. 80-86].  They also provide guidelines for pictographs; that is, flow charts and drawings [WRK, p. 87-88].  Furthermore, they discuss how to write titles for tables and figures, how to design visuals, and how to integrate visuals into the text [WRK, p. 88-99].  An additional source of information on the preparation of tables and figures is *Designing Technical Reports:  Writing for Audiences in Organizations*, Second Edition, by Mathes and Stevenson [1991, pp. 337-378].

For your readers to get the most out of your visuals (i.e., tables, graphs, and drawings), you **must** integrate them **verbally** into the text itself.  The visual will better supplement the text if you refer to it by table or figure number as soon as you begin describing it rather than after you are done with the description.  Also, you must provide a complete explanation of the visual in the text.  You would inconvenience your readers if you send them back and forth between visual and text.  Finally, you must place the figure as near as possible to its **first reference** in the text, preferably on the same page or the next page [WRK, p. 98-99].

When referencing tables and figures in the text, **do not** use parentheses; for example, "... data (Table 3) are ..."  or  "... the organizational structure (Figure 6) is ...".  In an English sentence, parentheses represent a parenthetical expression—one that can be dropped from the sentence and not effect its meaning.  Because tables and figures are an integral part of the text, make their reference an important part of the sentence. For example, "... data in Table 3 are ...", "... the organizational structure in Figure 6 is ...", or "... as given in Figure 8 ...". Note that the words **Table** and **Figure** are not abbreviated, and their first letter is capitalized.

Equations are to be used in the main body of your technical report or memo only if they are essential to the report's or memo's purpose and audience. In most technical reports or memos, equations are appropriate only in appendices [WRK, p. 163-164]. If you are convinced that equations are necessary in your report or memo sections, follow these guidelines to include them in the text:

- Use the **Insert/Object/Microsoft Equation** command of Word to write an equation.
- Write an equation by centering it horizontally on its own line. For a set of equations, also align them vertically with respect to their equal signs.
- Place its number in square brackets or parentheses flush with the right margin.
- Place flush with the left margin words like **where**, **whence**, **therefore**, **but**, and **substituting**, which appear between or following equations.
- Define all variables below an equation or set of equations.
- Use the symbol font to type Greek letters or special signs.

When an equation is referred to in the text, use its number prefixed with the abbreviation "Eq."; for example, "... as shown in Eq. 4." or " ... as derived in Eqs. 5 to 8." These guidelines are illustrated in the following passage from a report:

- **The weight of an object at a specific location on Earth.**

  It is proportional to the product of its mass and the acceleration of gravity at that location. This fact is an example of Newton's second law of motion, and it is expressed mathematically as

$$W = m \cdot g \qquad (4)$$

| | | | |
|---|---|---|---|
| where | W | is | the force exerted on an object by Earth's gravitational attraction at a location, $lb_f$; |
| | m | is | the mass of the object, $lb_m$; |
| | g | is | the acceleration of gravity at a location, $ft/s^2$. |

In Eq. 4, the conversion factor of $1\ lb_f \equiv 32.174\ lb_m\ ft/s^2$ is used to relate "mass·acceleration" and force units. Symbol "≡" means equivalent.

Although the above guidelines are for writing equations in the main body of a report or memo, they also apply when you write equations in appendices.

# Appendix D.  The Rough Draft

## Rough Draft Revision

The purpose of revision is to achieve clarity and conciseness in your drafted sections of a report. "Revising a draft is much more than checking spelling and adding a few commas here and there" [WRK, p. 72].  In the revision process, you want to avoid pretentious words, remove redundant expressions, minimize passive voice, eliminate expletives, show what is important, make clear references, avoid personal pronouns, and follow writing standards [WRK, pp. 54-72].  Do not worry about any of these revision problems while you are writing first drafts; but worry about all of them in turn as you revise.

- **Avoid pretentious words.** {WRK, pp. 54-56}

Sometimes writers choose words to impress rather than inform or to disguise rather than reveal. They suffer from an intellectual ego, wanting to show their intelligence instead of meeting the needs of their audience.  They choose unusual, even obscure words to express familiar concepts.  For example, they might choose the word **diaphoresis** instead of **sweat** or **emesis** instead of **vomit**.  In technical writing, good ideas and clear recommendations inform readers; big words and pretentious phrases irritate them.  Eliminate pretentious words from your drafts.

- **Remove redundant expressions** {WRK, pp. 57-58}

Empty words and phrases do not clarify your writing.  They are redundant and slow the reader down.  Some examples and their corrections are given as follows:

| Example | Correction |
|---|---|
| caused hostile antagonism | caused antagonism |
| to eradicate completely | to eradicate |
| from foreign imports | from imports |
| as a result of the fact that | because |
| to take into consideration | to consider |
| to give assistance to | to assist |

The extra words add no emphasis but suggest that you are not thinking carefully.  Eliminate redundant words and phrases from your drafts.

- **Minimize passive voice.** {WRK, pp. 58-60}

In active voice, a verb conveys the action on its subject.  In passive voice, the subject of a verb is being acted upon by something or someone.  For example, in the two following sentences:

The cat ate the rat.
The rat was eaten by the cat.

the subject of the first sentence is **cat**.  The cat is actively doing the eating.  The subject of the second sentence is **rat**.  It is not doing anything.

These two sentences convey the same meaning, yet they differ in their effect on a reader.  In the first sentence, the action goes in the same direction the reader scans.  In the second sentence, the action works backward, from the end back toward the beginning. A reader detects a difference in emphasis as well. In the first sentence the emphasis is on the **cat**, while in the second sentence it is on the **rat**.

As a rule, use active voice in your technical writing, because it offers a more natural, informative, concise, and compelling form of writing. However, the passive voice verb is sometimes preferable, particularly when you want to emphasize what is being acted upon by something or someone. For example, "The Interstate Highway System will be completed in 1992," a passive voice sentence, works well because what is being completed is much more important than who is doing the completing. Eliminate passive voice verbs from your drafts, whenever appropriate. Replace them with active voice verbs by rewriting the sentences.

- **Eliminate expletives.** {WRK, pp. 60-62}

The most common expletive constructions are **it is** and **there are**. They are found at the beginning of a sentence or a clause. Eliminate expletives from your rough drafts, because they make a literally meaningless word the subject of a sentence. In the examples below,

| Original | Revision |
|---|---|
| There are three deer that live in those woods. | Three deer live in those woods. |
| It is imperative that new employees file a data card with the company. | New employees must file a data card with the company. |

the sentences are revised by replacing **it is** and **there are** with real "subjects.' Most technical writers who use many passive voice verbs also overuse expletives. Eliminate the expletives **it is** and **there are** from your drafts.

- **Show what is important.** {WRK, pp. 62-63}

In technical writing, you can improve control of readers' expectations by writing better sentences—sentences that show what is important and what is less important, through the use of subordination and coordination of clauses. For example, in the following sentence,

> Since it operated at a $150,000 deficit last year, the Training Department is investigating ways to cut instructional costs.

subordination is used. The sentence has two clauses. The first which begins with **since** is called a subordinate clause. The second clause (after the comma) is called an independent clause. The subordinate clause is less important; it is subordinate to another clause. The independent clause could stand by itself as a sentence. In the above example, the sentence structure tells the reader that the investigating is the important fact, the one the reader expects to read more about in the rest of the written passage.

The opposite of subordination is coordination. In a sentence with coordination, two independent clauses are treated with equal importance. These clauses are connected with a coordinate conjunction such as **but, and**, and **or**. When one of these words joins two independent clauses, a reader will treat the two statements as equals. In technical writing, **good writers use subordination frequently**. They use coordination infrequently. Improve the clarity of your drafts by incorporating sentences that use subordination.

- **Make clear references.** {WRK, pp. 63-65}

In your technical writing, you must avoid vague pronouns and misplaced modifiers. First, pronouns have to point clearly to the word or words for which they stand. Second, words or phrases that describe (modify) something in a sentence must be positioned so that no reader can misread what is being described. Several examples of unclear references are given in the following two tables:

| Vague Pronoun | Revision |
|---|---|
| The task force failed to complete its study of the mine accident. **This** was the subject of a scathing editorial in the union newsletter. | The task force failed to complete its study of the mine accident. This failure was the subject of a scathing editorial in the union newsletter. |
| Putting marigolds next to cucumbers will keep the rabbits away from **them**. | Putting marigolds next to cucumbers will keep rabbits from eating the cucumbers. |

| Misplaced Modifier | Revision |
|---|---|
| Upon completion of the installation, the contractor shall leave the premises **in an orderly condition.** | Upon completion of the installation, the contractor must ensure that the premises are in an orderly condition. |
| **Hoping for a better crop**, the field was irrigated frequently. | Hoping for a better crop, the farmer irrigated the field more frequently. |

Of these examples, the vague pronoun **this** appears often in technical writing. In the example above, the reader will question what singular noun does **this** stand for. The revision is simple; place a noun after the vague pronoun **this**. Look for and correct the vague pronoun **this** in your drafts.

- **Avoid Personal Pronouns.**

In your technical writing of **formal** reports, you must avoid the use of personal pronouns. However, their use in informal reports and memoranda is acceptable. In a formal report the **only** references to persons should occur on the title page. The elimination of personal pronouns is accomplished by replacing the pronoun with the direct object. For example, instead of saying “We designed the extraction tower on the basis of ...,” a more acceptable form would be “The extraction tower was designed on the basis of ...” or “The basis for the extraction-tower design was ... .” Finally, the pronoun “one” is sometimes used in technical writing. In formal writing, it should be avoided or, at most, employed only occasionally. Look for and eliminate personal pronouns in your drafts.

- **Follow writing standards.** {WRK, pp. 65-66}

Adhering to the standards of English helps you to communicate with your readers. Writing carelessly gives an unfortunate impression of sloppy work habits. Some guidelines you should follow during the revision process are as follows:

- Never end a sentence with a preposition.
- Never start a sentence with **and**, **or**, or **but**.
- Never write a sentence fragment, one without a subject or verb.
- Do not split infinitives (e.g., to **easily** read).
- Subjects and their verbs must agree in number.
- Pronouns and their antecedents must agree in number.

In addition, some of the most common grammar and punctuation errors found in technical writing are described in Appendix 1 of Woolston, et al. [WRK, pp. 153-159]. Also, Appendix 2 [WRK, pp. 161-163] defines conventions governing abbreviations in technical writing. Eliminate incorrect grammar, punctuation, and abbreviations from your drafts.

## Summary

The development and revision of the rough draft is an integral part of the technical writing process. This appendix outlined a procedure for quickly writing the first draft of the sections in a technical report or informal memorandum, using Microsoft Word. It also gave guidelines for the report or memo format and the creation of tables, figures, and equations. Finally, it presented an eight-step revision process to achieve clarity and conciseness in your drafted sections of a technical report or memorandum.

# Appendix E. A Project Assessment

## CHEG 200 Project Report Memo

# BEEF, Inc.

Memorandum

**Date:** January 15, 2018

**To:** Student Evaluator, Project Assistant
Process Engineering Department

**From:** Project Supervisors
Process Engineering Department

**Copy:** CHEG 200 Provisional Engineers
Process Engineering Department

**Subject:** **CHEG 200 Project Report**

As you are aware, a project supervisor in our Process Engineering Department assigns bi-weekly, as well as some weekly, projects to four- or five-member teams of provisional engineers, who are participating in our company's 14-week Internship Program. A project assignment is made usually on a Friday, and the teams must submit their informal project reports on the Monday following the end of a bi-weekly or weekly project. You are asked to assess and evaluate the team reports and then return them to their ENGR 100 mailboxes no later than the Monday of the following week. This memo provides directions on how to do the assessment and evaluation of a team's project performance.

A bi-weekly project assignment contains six problems. One problem addresses the semester simulation project of determining the process requirements and "best" operating conditions to manufacture styrene monomer from methanol and toluene using the HYSYS process simulator. Four analysis problems focus on manually solving the material balances, energy balance, and/or phase equilibria of process equipment. These four problems are intended to help the provisional engineers get a better understanding of how HYSYS does it calculations. The sixth problem is related to a bi-weekly laboratory experiment conduct in the Unit Operation Laboratory (Dana 033). The problems for the simulation project are taken from *Chemical Process Simulation and the Aspen HYSYS Software*, by Hanyak. Most of the four analysis problems are taken from *Elementary Principles of Chemical Processes*, by Felder, Rousseau, and Bullard. The lab experiments require a team to solve a problem for one of our clients, Hawbawg Chemical Company. A one-week project assignment contains two to three problems, one of which involves the use of the HYSYS simulator.

As participants in our Internship Program, the provisional engineers are provided the company document on the *Development of an Engineering Project: A Handbook for Provisional Engineers*, authored by Michael Hanyak. This handbook presents how project teams are to work cooperatively to solve the assigned problems using problem-based learning and a problem-solving methodology, under the guidance of their project supervisors during the two-hour co-op sessions in a project assignment.

A project team must formally document their solutions to **<u>all</u>** assigned problems and submit them as an informal memorandum report. This report package contains a pink cover sheet, the team's project memorandum, the project assignment memo issued by the project supervisor, and the team's problem solutions.  The basic report structure is as follows:

- Cover Sheet
- Team's Project Memo  { two to three pages }
  - Header Information
  - Purpose statement (for each problem)
  - Solution Method and Major Results (for each problem)
  - Major Conclusions (for each problem)
  - Questions and Closure
  - Bibliography, if needed
- Project Assignment Memo
- Team's Problem Solutions

The standard cover sheet is an assessment and evaluation form, a copy of which is attached to this memo with an explanation page.  The team's project memorandum basically summarizes their major results and conclusions for two specifically-identified problems.  In this memo, a team is to refer explicitly to the attachments that give the reader more detailed information.  The attachments are the project assignment memo issued by the project supervisor and the team's formal solutions to all of the assigned problems in the project.  When the problem is a laboratory experiment, the problem solution is a copy the completed laboratory checklist form provided by the teaching laboratory assistant.  This form is an assessment of the team's documentation in their laboratory notebook for that experiment.   For a bi-weekly project only, a team's timesheet concludes the attachments to the team's project memorandum.

The team's project memo is to be about two to three pages in length for a bi-weekly or one-week project assignment.  Its header information is the date, to, from, and subject.  Only those team members **who have participated in the preparation** of the informal memorandum report are to provide their names and sign their initials above those names.  The first paragraph of the project memo describes the purpose of the memo by presenting the organizational context, the technical investigation, and the communication purpose.  For each indicated problem in the project assignment memo, a team presents the solution method used and summarizes the major results.  Tables, figures, and, only when necessary, equations are to be used in this summarization.  Next, a team presents the major conclusions that are supported by the attached problem solution.  After the specifically-indicated problem solutions have been summarized, a team closed the memo by possibly asking questions of the project supervisor for further clarification on the project assignment.  The last statement in the memo may be an offer for further contact.  It should also indicate the total time spent by the team only on a bi-weekly project and reference the team's attached timesheet.  Finally, a bibliography for any literature cited in the memo text needs to be provided.

Our company has standards on the preparation of a project memo and its attached problem solutions.  Three attachments to this memo are provided to assist you in your assessment and evaluation work.  The **Project Evaluation Policy** and **Problem Solution Format** attachments describe how to assess the performance factor list and problem solution columns on the pink cover sheet.  The **Problem**

# Appendix E.  A Project Assessment

**Solution Documentation** attachment provides guidelines for teams to follow when they are formally preparing their problem solutions.  You are to assess if a team is using the guidelines.  The final attachment is an **Example Memorandum** that illustrates the standard memo format that our company requires.

The Process Engineering Department's work policy is that a team's project memo report **will not be accepted** for assessment and evaluation after its due date.  Exceptions only exist when two or more team members are absent due to illness, family death, off-campus job interview, etc., during the time when the project is to be done.  For these exceptions, the team must write a memorandum to their project supervisor and provide a copy to you, indicating who will be absent, why, and for how long.  This memo must also indicate when they will submit their project memo report.  All team members must sign their initials on this memorandum.  For late reports, you are to evaluate **only those** that are accompanied with the team's exception memorandum that the project supervisor has signed.  You are to return the exception memorandum and the team's memo report to the project supervisor after you have completed the assessment and evaluation.

Finally, please review the attached material and then contact me to arrange a meeting to discuss your assessment and evaluation work.  Please note that our provisional teams will be completing the first project assignment soon, and they will be submitting their first memo reports on the first Monday in the semester.

# Appendix E.  A Project Assessment

## CHEG 200 Project Report Memo

## Chemical Engineering Department
## Bucknell University
**Lewisburg, PA  17837**

**To:** Drs. Timothy Raymond and Katsuyuki Wakabayashi **Date:** ____________

**From:** Team _____; Coordinator: ________________ Assembler: ________________

Observer: ________________ Monitor: ________________

**Subject:** **CHEG 200 Project ______ Cover Sheet** Troubleshooter: ________________

### Performance Factor

| Project Memorandum: | | factor |
|---|---|---|
| 1. Organization, Appearance, Neatness | (0.10) | ______ |
| 2. Purpose Statement | (0.10) | ______ |
| 3. Solution Method and Major Results | (0.10) | ______ |
| 4. Major Conclusions and Timesheet | (0.10) | ______ |
| **Problem Solutions:** | | |
| 1. Organization, Appearance, Neatness | (0.10) | ______ |
| 2. Completeness, Each Solution Stapled | (0.10) | ______ |
| 3. Engineering Paper, Margins, Headings | (0.10) | ______ |
| 4. Proper Graphs and/or Tables | (0.10) | ______ |
| 5. Numbers, Units, Conversion Factors | (0.10) | ______ |
| 6. Block-In Answers, Precision | (0.10) | ______ |
| | Total = | ______ |

### Solution Correctness of Project Problems

| | **Problem:** (points) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
|---|---|---|---|---|---|---|---|---|
| Problem Statement | (5) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Conceptual Model | (20) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Mathematical Model | (30) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Mathematical Algorithm | (15) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Numerical Solution | (20) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Heuristic Observations | (10) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Total = | (100) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

Team's Project Quality = ( performance factor ) x ( solution average )

Team's Project Quality = __________ x __________ = __________

# Appendix E.  A Project Assessment

## Assessment Activities on the Cover Sheet

How well a team has performed to complete their bi-weekly or one-week project is based on the quality of the team's informal memo report, which contains the team's project memo, the project assignment memo, and the team's formal problem solutions.  The team's memo report is assessed and evaluated by a teaching assistant.  Appendix E provides the company guidelines and standards that are to be used by the teaching assistant to determine the quality of a team's performance for a project assignment.

The pink cover sheet, which is place on top of a team's memo report, is basically an assessment and evaluation form.  On this cover sheet, the **team must complete** the date, team number, members' roles, subject, and the "Problem:" numbers like H1, A1, A2, A3, A4, and L1.   The team's project quality is determined by the following formula:

Team's Project Quality   =   ( performance factor )  x   ( solution average ),

and its value is on a scale of 0 to 100, where 100 is the best quality.  This project quality is the product of the team's performance factor and solution average.

The **performance factor** assesses how well did a team's project memo and problem solutions meet the company guidelines and standards.  Its value is on a scale of 0.00 to 1.00, where one is the best performance.  Basically, the performance factor answers the question of "Is a project team doing a professional job?"

The **solution average** assesses the correctness of a team's problem solutions.  Each problem's statement, conceptual model, mathematical model, mathematical algorithm, numerical solution, and heuristic observation are assessed.  A maximum of 100 total points exists for a problem solution.  After all six problems have been assessed, the total solution points are average to give a value on a scale of 0 to 100.  Basically, the solution average answers the question of "How correct are the team's problem solutions?"

Two examples are now presented to illustrate how the "Team's Project Quality" is determined. Team 3 worked on Project 2 and appeared to have read the company guidelines and standards.  Their project memo received a performance factor of 0.40, while their project solutions received a 0.59.  The solution correctness for their six problems was 85, 90, 100, 80, 85, and 93 points, giving a solution average of 89.  Team 3's project quality is calculated as follows:

Team 3's Project Quality   =   ( 0.99 )  x   ( 89 )   =   88.

Team 7 worked also on Project 2 and appeared **not** to have read the company guidelines and standards. Their project memo received a performance factor of 0.32, while their project solutions received a 0.45. The solution correctness for their six problems was 87, 90, 83, 86, 91, and 95 points, giving a solution average of 89.  Team 7's project quality is calculated as follows:

Team 7's Project Quality   =   ( 0.77 )  x   ( 89 )   =   69.

Because of the multiplicative effect of the performance factor, a project team must maintain a **high standard of professionalism** while doing a team project; that is, each member of a team needs to learn and apply the company guidelines and standards and have his/her work review by other team members.

# Appendix E. A Project Assessment

## Project Evaluation Policy

A. For each bi-weekly project, six problems will be assigned. For each one-week project, usually two to three problems will be assigned. All problems must be formally documented. The problems were assigned in a memorandum to the project team from their project supervisor.

Each team **must** supply a pink cover sheet on top of their informal project report, which consists of the team's project memo, the assignment memorandum, and each stapled problem solution. For a bi-weekly project only, a team’s timesheet must also be attached as the last item in the packet. This packet of information must be held together with a spring clip.

In the pink cover sheet, the team must fill in the **date**, **team number**, **names** of the role players, **project number**, and **problem numbers** in the "Project Problem" area, like H1, A1, A2, A3, A4, and L1. The pink cover sheets are available next to the ENGR 100 mailboxes on the second floor of the Dana Engineering Building.

B. Project memorandum performance factor (Is the team doing a professional job?)

1. **Organization** (0.04), **Appearance** (0.03), **Neatness** (0.03)

   If these are average or better, then give indicated value.
   That is, the team members are meeting their responsibilities in these three areas.

   For organization, is the memo header information complete? Is a closure statement provided? Is a bibliography provided when literature is cited or should be cited in the memo text? Is the project assignment memo present? Deduct 0.01 for each item that is missing or incomplete.

   If sloppy or not responsible, give 0.00.

2. **Purpose Statement**

   Is an organizational context for the project identified? Is the project technical investigation described? Is the communication purpose of the project memo provided?

   If present and the quality is decent, give 0.03 for organizational context, 0.04 for technical investigation, and 0.03 for communication purpose. If not, give 0.00 for that item.

3. **Solution Method and Major Results**

   Give 0.10 if these two items are provided and decent for all problems. If one of them is missing or not decent for a problem, consider the presentation for that problem incomplete. Count the number of complete presentation, and determine the factor as follows:

   > Six problems assigned but only two were required for presentation in the team’s project memo. Of the two presentations only one was considered complete, thus the factor is 1/2 (0.10) = 0.05 (rounded up).

4. **Major Conclusions and Timesheet**

   Give 0.04 if major conclusions are provided and decent for all problems. If they are missing or not decent for a problem, consider their presentation for that problem incomplete. Count the number of complete presentation, and determine factor as follows:

   > Six problems assigned but only two were required for presentation in the team's project memo. Of the two presentations only one was considered complete, thus the factor is 1/2 (0.04) = 0.02 (rounded up).

   Give 0.06 for the team's timesheet if it is attached to the project memo and it has been responsibly completed. If it is not, give a zero for this part.

C. Problem Solutions performance factor (Is the team doing a professional job?)

1. **Organization** (0.04), **Appearance** (0.03), **Neatness** (0.03)

   If these are average or better, then give indicated value.
   That is, the team is meeting its responsibilities in these three areas.

   For organization, has the **Problem Solution Format**, which is described later in this appendix, been followed completely in all problems? This is an all or nothing deal.

   If sloppy or not responsible, give 0.00.

2. **Completeness** (0.09) **and Each Solution Stapled** (0.01)

   Completeness as applied to each problem. If all problems are completed as described by the **Problem Solution Format** section of this appendix, give 0.09.

   However, if at least one item is missing from the solution of a problem such as conceptual model or mathematical model, consider the problem solution incomplete. Count up number of complete problems, and determine factor as follows:

   > Six problems assigned, two are complete,
   > factor is 2/6 (0.09) = 0.03 (rounded up).

   Each solution stapled: count as 0.01, otherwise zero if one or more are not stapled.

3. **Engineering Paper, Margins, Headings**

   For each solution page on engineering paper, computer printout, or xerox-copied material, are the instructions given by Items 2 and 3 in the **Problem Solution Documentation** section of this appendix being followed for these three items?

   > Give 0.04 for engineering paper,
   > 0.03 for margins,
   > 0.03 for headings.

# Appendix E. A Project Assessment

This is an all or nothing deal. For example, zero credit is given for any improper margins or any missing headings.

4. **Proper Graphs and/or Tables**

For each <u>graph item</u> given below, give a 0.005 if it was done in all graphs in all problems. If graphs were not needed in any assigned problems, give 0.05.

1) Use appropriate graph paper (back of engineering paper is **not OK**).
2) Done in pencil or ink or by a computer program.
3) Graph is inside grid pattern on rectilinear graph paper only.
4) Axis labeling (major divisions, has origin, symbol and units for X and Y axes).
5) Title: dependent variable vs. independent variable.
6) Have equation on graph for a straight line.
7) A data point is indicated by a symbol such as a circle, box, or diamond, line not through symbol, different symbols for different curves, and symbol legend for more than one curve.
8) Initials and date.
9) For calibration curve, include location, make, and serial number of measuring device.
10) Graph placed properly in stapled problem solution. That is, graph is oriented with its holes or binding at its left or top.

Count up the number of above <u>graph items</u> that were done properly and multiple by 0.005 to determine the **graph factor**.

For each <u>table item</u> given below, give a 0.01 if it was done in all tables in all problems. If tables were not needed in any assigned problems, give 0.05.

1) Columns that are being compared are placed next to each other.
2) Headings and data reflect an organizational principle, such as priority, descending order, or alphabetical order.
3) Columns and rows are labeled properly and when necessary with units.
4) Decimal points are aligned in columns with numbers.
5) Table content looks balanced with proper spacing and alignment.

Count up the number of above table items that were done properly and multiple by 0.01 to determine the **table factor**.

Combine the <u>graph factor</u> and <u>table factor</u>;
for example, combined factor is 0.03 + 0.03 = 0.06.

5. **Numbers, Units, Conversion Factors**

Numbers: For each problem, are the instructions given by Items 5 and 6 in the **Problem Solution Documentation** section of this appendix being followed for expressing numbers?

Units: Is the student including units for each problem?

Conversion factors: Is the student showing conversion factors for each problem?

If at least one of these three items is missing or wrong in a problem, consider the problem incorrect.  Count number of correct problems, and determine factor as follows:

> Six problems assigned, three are correct,
> factor is 3/6 (0.10) = 0.05 (rounded up).

6. **Block-In Answers, Precision**

For each problem, are the instructions given by Item 6 in the **Problem Solution Documentation** section of this appendix being followed for these items?

If at least one of these two items is missing or wrong in a problem, consider the problem incorrect.  Count number of correct problems, and determine factor as follows:

> Six problems assigned, five are correct,
> factor is 5/6 (0.10) = 0.09 (rounded up).

# Appendix E. A Project Assessment

## Problem Solution Format

**(5 pts) A. Problem Statement**

| | |
|---|---|
| 1. Legibly print or xerox: (5 pts) | Give 0 pts if missing, 3 pts if incomplete, 5 pts if correct. |

**(20 pts) B. Conceptual Model**

| | |
|---|---|
| 1. Diagram: (10 pts) | Give 0 pts if missing, 5 pts if incomplete, 10 pts if correct. |
| 2. Assumptions: (5 pts) | Give 0 pts if missing, 3 pts if incomplete, 5 pts if correct.<br><br>In some problems, the assumptions may appear under the conceptual model, when they are brief. |
| 3. Givens and Finds: (5 pts) | Give 0 pts if missing, 3 pts if incomplete, 5 pts if correct) |

**(30 pts) C. Mathematical Model** (a problem may contain several sub-models)

| | |
|---|---|
| 1. Equations: (20 pts) | Give 0 pts if no model, 10 or 15 pts if incorrect, 20 pts if correct. |
| 2. Degrees of freedom: (10 pts) | Give 0 pts if missing, 5 pts if incorrect, and 10 pts if correct. |

**(15 pts) D. Mathematical Algorithm** (a problem may contain several sub-algorithms)

| | |
|---|---|
| 1. Functional definition: (2 pts) | Give 0 pts if none, 1 pts if incorrect set of independent variables, 2 pts if correct.<br><br>A math algorithm should begin with the following functional notation:<br><br>[dependent vars] = func [independent vars]<br><br>An incorrect set of independent variables is where the number of independent variables does not equal the degrees of freedom (DOF). |
| 2. Steps in algorithm: (8 pts) | Give 0 pts if no algorithm, 4 pts if incorrect, 8 pts if correct. |

3. Functional References: ( 5 pts) — Give 0 pts if all missing, 2 pt if incomplete, 5 pts if correct.

   For each functional equation, either the literature sources (authors, edition, page) or the page location in the problem solution for each functional description must be cited.

**(20 pts) E. Numerical Solution** (a problem may contain several sub-solutions)

1. Basis and givens: ( 10 pts) — Give 0 pts if not done, 5 pts if incorrect in any way, 10 pts if correct.

2. Numeric results: ( 10 pts) — Give 0 pts if not done, 5 pts if incorrect in any way, 10 pts if correct.

   The numeric results must contain units and show precision for the boxed answers.

**(10 pts) F. Heuristic Observations**

1. Numerical solution: ( 2 pts) — Give 0 pts if missing, 1 pt if incorrect, 2 pts if correct or not applicable.

2. Math algorithm: ( 3 pts) — Give 0 pts if missing, 1 pt if incorrect, 3 pts if correct or not applicable.

3. Math model: ( 3 pts) — Give 0 pts if missing, 1 pt if incorrect, 3 pts if correct or not applicable.

4. Conceptual model: ( 2 pts) — Give 0 pts if missing, 1 pt if incorrect, 2 pts if correct or not applicable.

Example problems that use the above "Problem Solution Format" are given in Chapter 5, 6, and 7 of the *Companion in Chemical Engineering: An Instructional Supplement* by Michael Hanyak. Also, Chapter 4 in this same source outlines a problem-solving methodology to solve problems that use material and energy balances and phase equilibrium relationships. The above "Problem Solution Format" is based on this problem-solving methodology.

Experimental laboratory and HYSYS simulation problems have a different problem solution format than the one described above. Their solution formats are presented next.

# Appendix E. A Project Assessment

### *HYSYS Problems in Blue Manual*

Each HYSYS problem in a project assignment is evaluated according to the instructions in the table below.

| Documented Parts | Points | Required Materials |
|---|---|---|
| Problem Statement | 5 | Problem from Project Memo Assignment |
| Conceptual Model | 20 | Appendix references to Blue Manual |
| Mathematical Model | 30 | Appendix references to Blue Manual |
| Mathematical Algorithm | 15 | Appendix references to Blue Manual |
| Numerical Solution | 20 | Excel tables and graphs, if applicable |
| Heuristic Observations | 10 | Word answers to the team questions |

Use the guidelines on the previous two pages to evaluate missing, incomplete/incorrect, or correct for the documented solution to a HYSYS problem. Multiple HYSYS problems in a project assignment are to count as one project problem.

The "Problem Statement" can be accessed through the project memo assignment, which is available in the Moodle site for the CHEG 200 course as a pdf file. A team is to access this ".pdf" file and then copy/paste the problem statement for inclusion in their documented solution to a HYSYS problem. The "Blue Manual" is *Chemical Process Simulation and the Aspen HYSYS Software* by Hanyak. The "Appendix references" are the appropriate process unit or units in the Blue Manual. The second, third, and fourth items are to be only references to the appropriate appendices (such as "See Appendix C for a pump in the Blue Manual, pp. C-1 to C-8."). The last two items in the above table address the team part of each assigned HYSYS problem in the Blue Manual. If applicable, the "Numerical Solution" is Excel tables and graphs. The "Heuristic Observations" are team answers to questions in a Word document. Web links in the Blue Manual provide access to the Excel and Word templates for completion by the team.

### *Experimental Laboratory Problem*

A lab problem is evaluated according to the instructions in the table below. It counts as one project problem.

| Documented Parts | Points | Lab Notebook Materials |
|---|---|---|
| Problem Statement | 5 | Purpose or Objective |
| Conceptual Model | 20 | Major Equipment and Instruments |
| Mathematical Model | 30 | Math Model, Safety, Procedure |
| Mathematical Algorithm | 15 | Experimental Data |
| Numerical Solution | 20 | Analysis using Excel Spreadsheet |
| Heuristic Observations | 10 | Observations and Record Keeping |

A team is given an experimental assignment that contains a purpose, equipment, math model, safety, procedure, experiment, and analysis. The supplied mathematical model is not necessarily correct, and it may be incomplete. All documentation for the experiment is to be kept in the team's lab notebook. The laboratory assistant will monitor the team's lab notebook using a checklist form, which is available in the Moodle for the CHEG 200 course. A project team is to print this checklist form, fill-in its top three or four lines, and provide it to the laboratory assistant during the first Monday of a project. The laboratory assistant will evaluate a team's progress using this checklist form. At the completion of an experiment, this checklist form will be provided to the teaching assistant, who will transfer the lab section grades to the pink cover sheet.

# Appendix E.  A Project Assessment

## Problem Solution Documentation

Solving an assigned problem is a two-step process; that is, solving a draft version followed by the formal documentation of the problem solution.  First, your team will solve the problem informally in draft form.  This draft represents your progress towards the problem solution.  It need not be done in a formal manner, but it must be readable and contain those major items defined in the **Problem Solution Format** section of this appendix.  When you become proficient with the problem-solving methodology, you will be able to combine this draft version step with the formal documentation step.

Once your team is satisfied with the draft solution, you then prepare the formal solution, which will be submitted for evaluation.  Your team will be expected to do a professional job.  The following seven guidelines on problem solution documentation must be followed:

1. The presentation of your work must be organized, clear and concise, and neat and legible.  Manually print your words, numbers, and punctuation marks using pencil or ink, unless you are using computer-generated output.

2. Engineering paper must be used, but it can be combined with computer printouts and xerox-copied materials.  Use only the un-ruled side of an engineering sheet, with the holes to the left.  Keep all work inside of the margin lines on engineering paper.

3. Fill in the heading on each solution sheet (engineering paper as well as all other sheets) and number the pages, starting with one for each problem in the project assignment.  For example,

   | Team 4<br>your name | Problem P1.A2 | 7/29/43<br>2 of 4 |
   |---|---|---|
   | | | |

   If you are not a member of a team, then use the course label like “CHEG 200” in place of the team number.

4. Draw any graphs on appropriate graph paper or use an appropriate computer program.  On graph paper, keep graph inside of margin lines (this includes the labeling of the axes), whenever possible.

5. Use the following convention regarding values and their units, as recommended by the America Institute of Chemical Engineers (AIChE).

   Place a zero before the decimal point in numbers between l and -l.  For example, 0.3478 or -0.5982.  Write zero as 0.0.

   Express very large or very small numbers in scientific notation.  For example, $2.73 \times 10^{-5}$.

   Commas should not be used to separate groups of digits.  For example,  6387.92  or  83.6794.

   For a compound unit that is a quotient, use a slash to form the symbol.  For example,  km/h.

   When writing the symbol for a compound unit that is a product use either a "product dot" (a period raised to a centered position) or a space between the symbols.  For example,  N·m or N m.

Use parentheses to avoid ambiguity in any combination of units. For example, $m/s^{-2}$ or $(m/s)/s$, not $m/s/s$.

6. Use the following "convenient" convention regarding significant figures and precision in a numerical solution when using a pocket calculator or a computer program:

   - write each calculated result using six significant digits,
   - ignore trailing zeros after the decimal point and drop the decimal point when all digits are zeros.

   Example applications of the above convention for a ten-digit calculator are given in Table E-1:

   **Table E-1. Ten- to Six-digit Conversion Convention Examples**

| Result for 10-digit Calculator | 6-digit convention |
|---|---|
| -732.3419834 | -732.342 |
| 0.2347836534 | 0.234 784 |
| -0.3568000000 | -0.3568 |
| 63457.34392 | 63457.3 or $6.34573 \times 10^4$ |
| -2.345678236-05 | $-2.34568 \times 10^{-5}$ |
| 3.489032169+06 | $3.48903 \times 10^6$ |

   This above convention **does not** account for precision when determining calculated results. However, when reporting the final answers, the results should be given to as many significant figures as are contained in the least accurate number of the given values in the problem statement.

   Usually, a problem statement should provide values with a clear indication of their precision. If this indication is not clear because no decimal point appears in a value, then assume that the number has infinite precision.

   To account for precision, you will first solve the whole problem using the above "convenient" convention. For the "Finds" variables only, you will record the precise answer and then **box-in** that precise answer. For example,

$$W = \left(124.8\,lb_m\right)\left(32.052\,\frac{ft}{s^2}\right)\left\langle\frac{lb_f}{32.174\,\frac{lb_m ft}{s^2}}\right\rangle = 124.327\,lb_f = \boxed{124\,lb_f}$$

   for three significant figures of precision.

7. When your problem solution involves only two or three equations, you may combine the mathematical model, mathematical algorithm, and numerical solution for an equation, as follows:

$$\begin{pmatrix}\text{calculated}\\ \text{variable}\end{pmatrix} = \text{expression} = \begin{pmatrix}\text{substituted values}\\ \text{with units and conversion}\end{pmatrix} = \text{answer}$$

For example,

$$W = m \cdot g = \left(124.8\,lb_m\right)\left(32.174\frac{ft}{s^2}\right)\left\langle \frac{lb_f}{32.174\frac{lb_m ft}{s^2}} \right\rangle$$

$$W = 124.8\ lb_f$$

The pamphlet "*SI for AIChE*" published by the American Institute of Chemical Engineering (AIChE) provides additional information on units, symbols, prefixes, usage format, and units conversion. It also contains examples that demonstrate calculations in conversion from common engineering units to SI units. A copy of the pamphlet is available in the "Course Information" section of the Blackboard CHEG 200 course. Some of the above seven guidelines were extracted from this pamphlet.

# Appendix E.  A Project Assessment

## Example Memorandum

# BEEF, Inc.
Memorandum

**Date:** May 30, 2009

**To:** Drs. Michael E. Hanyak and Timothy M. Raymond, Project Supervisors
Process Engineering Department

**From:** Dolores O. Good, Clair A. Thor, Rick A. Troop, and Chris O. Wheat
Project Team 9, Provisional Engineers
Process Engineering Department

**Subject:** Project 6 Report

Header Information

Per your memo of 12 May 2009,

Organizational Context

our team has completed the solutions to a HYSYS problem, two analysis problems, and an experimental problem in your Project 6 assignment.

Technical Investigation

Four attachments are included to support our problem summary solutions given below.  The original memo assignment is also attached for your convenience.

Communication Purpose

In Problem P6.H1, a chemical reactor that converts propylene and benzene to cumene was simulated in the Aspen HYSYS system using the Peng-Robinson-Stryjeck-Vera (**PRSV**) fluid package, per the directions in Hanyak's blue HYSYS manual. Starting with a base solution for the steady-state continuous process, four parameters were changed in the process flow diagram to investigate what effect scaling has on the material and energy balances.  All flow rate variables in any material balances can be scaled, and the compositions are not effected by the scaling.  The flow rate, heat duty, and shaft work variables in the energy balance can be scaled provided the temperature, pressure, and composition of each process stream remain constant.

For Each Problem have a Problem Statement, Solution Method, Major Results, and Conclusions

# Appendix E. A Project Assessment

| | |
|---|---|
| Project 6 Report<br>5/30/09, Page 2 | Header Information |
| In Problem P6.A1, the reactor heating or cooling requirement was determined for the production of ethanol from ethylene and water with a side reaction that produces diethyl ether. The pressure was assumed constant at 3 atm, and a basis of 1 kg-mole/h for the feed was used. For a 4% molar conversion of ethylene and an ethanol molar yield of 0.15, a mathematical model was created based on mole and energy balances to solve this problem. As calculated by E-Z Solve, the heating requirement was 2.96 kJ/mol, and it compares favorably with a HYSYS-determined value of 2.93 kJ/mol. In conclusion, the reactor needs to be heated, as opposed to being cooled, when ethanol and diethyl ether are being produced from ethylene and water. | Second Problem |
| etc. | Other Problems |
| If you have any questions about the above solutions, please contact any member of our team. | Closure |
| **References:**<br><br>Hanyak, Michael. *Chemical Process Simulation and the Aspen HYSYS Software*, Version 2006, Blue Manual. Chemical Engineering Department, Bucknell University, Lewisburg, PA, 2007.<br><br>Good, Dolores, Clair Thor, Rick Troop, and Chris Wheat. *Team 9 CHEG 200 Laboratory Notebook*. Process Engineering Department, BEEF, Inc., Lewisburg, PA. 2009. | |
| attachments<br>cat/dog/rat/cow | Footer Information |

## Observations:

- "attachements" means attachments follow; however, they are not provided here for this example.
- "cat" means the initials of who wrote the memo. When other team members contributed material to the memo and its attachments, their initials are added also (e.g., dog/rat/cow).
- A BEEF memo template as a Microsoft Word file is available under the "**Course Materials**" section of the Moodle site for the **CHEG 200** course.

# Appendix E.  A Project Assessment

# BEEF, Inc.
## Memorandum

**Date:** May 30, 2009

**To:** Drs. Michael E. Hanyak and Timothy M. Raymond, Project Supervisors
Process Engineering Department

**From:** Dolores O. Good, Clair A. Thor, Rick A. Troop, and Chris O. Wheat
Project Team 9, Provisional Engineers
Process Engineering Department

**Subject:** Project 6 Report

Per your memo of 12 May 2009, our team has completed the solutions to a HYSYS problem, two analysis problems, and an experimental problem in your Project 6 assignment.  Four attachments are included to support our problem summary solutions given below.  The original memo assignment is also attached for your convenience.

In Problem P6.H1, a chemical reactor that converts propylene and benzene to cumene was simulated in the Aspen HYSYS system using the Peng-Robinson-Stryjeck-Vera (**PRSV**) fluid package, per the directions in Hanyak's blue HYSYS manual.  Starting with a base solution for the steady-state continuous process, four parameters were changed in the process flow diagram to investigate what effect scaling has on the material and energy balances.  All flow rate variables in any material balances can be scaled, and the compositions are not effected by the scaling.  The flow rate, heat duty, and shaft work variables in the energy balance can be scaled provided the temperature, pressure, and composition of each process stream remain constant.

In Problem P6.A1, the reactor heating or cooling requirement was determined for the production of ethanol from ethylene and water with a side reaction that produces diethyl ether.  The pressure was assumed constant at 3 atm, and a basis of 1 kg-mole/h for the feed was used.  For a 4% molar conversion of ethylene and an ethanol molar yield of 0.15, a mathematical model was created based on mole and energy balances to solve this problem.  As calculated by E-Z Solve, the heating requirement was 2.96 kJ/mol, and it compares favorably with a HYSYS-determined value of 2.93 kJ/mol.  In conclusion, the reactor needs to be heated, as opposed to being cooled, when ethanol and diethyl ether are being produced from ethylene and water.

In Problem P6.A2, the adiabatic flame temperature of a furnace burning natural gas with 20% excess air was determined.  Assumptions of continuous, steady state, adiabatic, complete combustion,

Project 6 Report
Page 2

negligible potential and kinetic energy effects, no shaft work, and ideal gas behavior were used to develop a mathematical model based on mole and energy balances. As calculated by E-Z Solve, an adiabatic flame temperature was determined to be 800°F, and this value compares favorably with 950°F approximated by using constant heat capacities. In conclusion, increasing the percent excess air decreases the flame temperature because the additional air dissipates the energy within the system.

In Problem P6.L1, a laboratory experiment was conducted to verify the total and component mass balances when continuously mixing a water stream and an isoproponal stream to form a mixture stream of the two chemical compounds. The temperature, pressure, flow rate, and composition of each stream were measured in the laboratory and recorded in our team laboratory notebook. Assuming steady-state operation, a mathematical model was programmed into Excel to determine the relative imbalances [(in flow – out flow) / in flow] for the three material balances. The total mass balance had a 2.34% imbalance, and the two component mass imbalances were -2.22% and 1.23% for isoproponal and water, respectively. Although these results are within experimental error, the isopropanol imbalance implies that more of it flowed out than flowed in. A natural tendency for a leaky mixing operation is to have less flow out than in.

If you have any questions about the above solutions, please contact any member of our team.

**References:**

Hanyak, Michael. *Chemical Process Simulation and the Aspen HYSYS Software*, Version 2006, Blue Manual. Chemical Engineering Department, Bucknell University, Lewisburg, PA, 2007.

Good, Dolores, Clair Thor, Rick Troop, and Chris Wheat. *Team 9 CHEG 200 Laboratory Notebook*. Process Engineering Department, BEEF, Inc., Lewisburg, PA. 2009.

attachments
cat/dog/rat/cow