Chapter 22

Written Reports and Oral Presentations

22.0 OBJECTIVES

At the completion of its design work, whether it be for a process or a product, the design team is required to prepare a detailed report, documenting the details of the design and how it was produced, projecting its profitability, and making a recommendation as to whether or not management should make an investment in the process or the product. Management will also need a marketing report, which may, but probably will not, be part of the design report. While marketing may seem foreign to chemical engineering, far more often than not, marketing mistakes, rather than technical mistakes, are responsible for the failure of a new process or product.

A *process design report* identifies the key assumptions in the design and their potential impact on the performance of the process and its anticipated profitability. This is particularly important for designs completed by undergraduate students at universities, where facilities and time are rarely available for laboratory work or pilot-plant testing.

It is these uncertainties, especially when data are lacking, that engineers encounter throughout their careers. Even when laboratories and pilot plants are available, engineering judgments are needed to determine when the investment of money and time is justified to organize an experimental program. In this respect, engineers are asked regularly to estimate the profitability of processes about which they have too little information. For these reasons, design teams usually expend considerable effort in trying to eliminate as much of the uncertainty as possible (by locating data in the literature, conducting process simulations, etc.). Invariably, however, uncertainties remain, and it is important that the design report identifies the uncertainties and, when it recommends that a process be constructed, makes recommendations as to how the uncertainties should be resolved.

A *product design report* documents all of the steps leading up to the design of the product. This includes a discussion of the need for a new product, a summary of all the possible ways generated by the design team to satisfy the need, the rationale behind the selection of the best ideas and ultimately the one selected, and the design of the new product. In industry, the report might also include the development of the manufacturing process as well as the performance of a prototype of the design. In universities, undergraduate students may not have the time to produce a prototype of the product and determine its performance. On the other hand, a product design developed by a student design team in a previous year could be given to a new design team in the current year for the development and assessment of a prototype.

The design team should view its design report as an opportunity to showcase its most creative engineering efforts for management. Wherever possible, a process design should

highlight the engineering work that it believes will lead to greater economies than are achievable using alternative or conventional technologies. A product design should emphasize the superiority of the new product over available products with similar functions.

For most student design teams, the design report is the first extensive report of their professional careers. It is the culmination of a major engineering effort and, when done well, is deserving of considerable attention by other students, faculty, industrial consultants, and perspective employers. In this respect, the professional reputation of the design team depends, in part, on how well the design problem has been analyzed, how ingeniously the process has been laid out or the product developed, and how thoroughly the engineering calculations and design work have been done. The efforts of a design team are judged almost entirely by the quality of the engineering report provided to their supervisor, which describes the work that has been accomplished. Of particular importance to management is the strength of and justification for the recommendations made in the report. Almost always, the report will be accompanied by an oral presentation by the leader of the design team and perhaps some team members, where questions can be asked by management.

There is perhaps a tendency to view the preparation of the design report and the oral presentation to management as activities reserved for the completion of a design project. Although, indeed, the level of activity in writing builds steadily toward the end, especially as the design becomes more promising, an objective of this chapter is to present the many reasons for documenting the results gradually, as the design project proceeds. In fact, a close look at Figure 1.2, and the discussions throughout the book, especially in Sections 1.1, 1.2, and 3.5, shows that up-to-date documentation is very important to the success of a design team, especially as the composition of the team changes.

After studying this chapter, the reader should

1. Understand the template that prescribes the sections in most design reports, and have a good appreciation of the materials to be included in each section.
2. Be prepared to coordinate the preparation of the design report with the other members of the design team, beginning early in the design process, and to recognize the important milestones, that is, those portions of the report that are best prepared before work begins on the next step in the design process.
3. Understand the role and format of a typical oral presentation, including the alternative media for the presentation, and related topics such as the need for rehearsals and the desirability of a written handout.

22.1 CONTENTS OF THE WRITTEN REPORT

This section begins with a template of items to be included in most design reports and is followed by a discussion of several techniques found to be helpful in their preparation, as well as recommendations for the page format to permit the design report to be bound for distribution.

Opening Sections of the Report

This listing is presented in outline form to identify, at a glance, the sections that are normally included in the sequence shown. The first four items are common to both process design and product design reports.

1. ***Letter of Transmittal.*** This letter, on professional letterhead, is normally directed to the supervisor who requested that the design work be done. It should be signed by all members of the design team.
2. ***Title Page.*** In addition to the title, in uppercase, the authors and their affiliations are listed, as well as the publication date. The title should be short, but very descriptive.

3. ***Table of Contents.*** All sections in the report should be listed, including the page numbers on which they begin. Hence, all pages in the report, *without exception*, must be numbered. This applies to text pages, for which the word processor will probably have provided the page numbers, as well as tables, figures, and appendixes, whose pages may have to be numbered manually. Note that unnumbered pages are not readily found by the reader, who may resent the time wasted thumbing through the report to find pages that are missing or not numbered.
4. ***Abstract.*** The abstract is a brief description, in one or two paragraphs, of the design report, its key conclusions, special features, and assumptions. These include projections of any applicable economic measures of goodness (e.g., the return on investment and the net present value) and recommendations to management.

Remaining Sections of a Process Design Report

5. ***Introduction.*** The introduction contains some or all of the following sections.
   - **a.** A description of the product to be manufactured, including its chemical formula, and a discussion of the role of this product in the industry and its significance in national and international trade.
   - **b.** A survey of the methods used in manufacturing this product, including the process being described in this report, giving the raw materials, the principal chemical reactions, byproducts, and intermediates.
   - **c.** An explanation of the choice of the production method. This often involves a description of partially synthesized flowsheets and the reasons why these flowsheets were rejected in favor of the design selected.
   - **d.** A discussion of the choice of the production level and plant location.
   - **e.** A discussion of the reasons for entering the market at this time.
   - **f.** An overview of the environmental issues encountered, including the toxicity of the chemicals, and the potential safety problems.
6. ***Process Flow Diagram and Material Balances.*** This is the detailed process flow diagram discussed in Section 3.5 and shown for a vinyl chloride process in Figure 3.19. All of the streams are numbered clearly and all of the process units are labeled. At some point on the arc for each stream, the temperature and pressure should appear, or the information should be tabulated (e.g., see Table 3.5). Note that, as mentioned in Section 3.5, many software packages are available to simplify the preparation of flow diagrams, most notably those associated with the process simulators.

   In addition, the drawing should contain a *material balance block*, similar to the one shown for the the vinyl chloride process in Table 3.5, that is, a table showing for each numbered stream:

   - **a.** Total flow rate
   - **b.** Flow rate of each chemical species
   - **c.** Temperature
   - **d.** Pressure

   and other properties of importance (density, enthalpy, etc.). It is desirable that the flow diagram and the material balance block appear on a single sheet for continuous reference, preferably $8\frac{1}{2}$ by 11 in., so that it can be bound easily with the remainder of the report. Most commonly, this combination is prepared by computer, often using Microsoft VISIO, although a hand-drawn flow diagram is normally acceptable. If the flow diagram is hand drawn, it should be of a larger size, perhaps 20 in. by 30 in. Such flow diagrams should be drawn on paper in ink, or pencilled on vellum or other erasable, translucent media, so that a reproduction (such as an Ozalid or similar black-

on-white print) may be prepared, and folded and included in the pocket on the inside back cover of the report. The symbols on the drawing should follow a standard list, such as those provided in Figure 3.20 and by Peters et al. (2003), Sandler and Luckiewicz (1993), and Ulrich (1984). All entries should be made with straightedges and templates.

7. ***Process Description.*** This section provides an explanation of the flow diagram. It best begins, however, with reference to a block flow diagram, similar to that in Figure 3.18, which shows just the process steps that involve chemical reactions and the separation of chemical mixtures. Then, a more detailed description is presented that refers to all steps in the process that are shown in the process flow diagram (e.g., Figure 3.19). The detailed description describes the function of each equipment item and discusses the reasons for each particular choice. Note that the details of each major equipment item are presented below in Section 9, on unit descriptions. To aid the reader, however, the discussion of each item in Section 7 should be accompanied by a reference to the page number in Section 9. As in the introduction, when this flow diagram has been selected from among alternatives, it is appropriate to present the alternative flow diagrams and process descriptions, and to describe the reasons for the final choice.
8. ***Energy Balance and Utility Requirements.*** In describing most chemical processes, it is desirable to have a section that discusses the energy requirements of the process, and the measures adopted to improve the plant economics by energy and mass conservation, usually through the application of the methods described in Chapter 9 on second-law analysis, Chapter 10 on heat and power integration, and Chapter 11 on mass integration. In this section, all of the heating, cooling, power, and other utility and mass-separating-agent demands should be identified (with numerical values provided), and the methods of satisfying these demands shown. A list should be provided of each demand (e.g., 500,000 Btu/hr to heat stream 5 from 80 to 200°F) and the vehicle for its satisfaction (e.g., 500,000 Btu/hr from stream 15 as it is cooled from 250 to 100°F). When power generated by a turbine is used to drive a compressor and pumps, these integrations should be listed as well. Methods used to minimize the need for solvents and other mass-separating agents, as well as to minimize wastes, should be described.
9. ***Equipment List and Unit Descriptions.*** In this section, every process unit in the flow diagram is described in terms of its specifications and the design methodologies (e.g., the methods for estimating the heat transfer coefficients, the graphical design of a distillation tower by means of the McCabe–Thiele method, and the recommendations of industrial consultants) and the data employed (e.g., to characterize the reaction kinetics and vapor–liquid equilibria). The important approximations should be discussed, as well as any difficulties encountered in performing the design calculations (e.g., in converging equilibrium-stage calculations with a simulator). In addition, the materials of construction should be indicated, together with the reasons for their selection.

   Each process unit described in Section 9 should refer to the page number in the appendix on which the design calculations appear or are described. Note that the latter calculations are usually printed neatly, and when done by computer, the printed output is carefully annotated. In addition, the description for each process unit should refer to a corresponding specification sheet, discussed below, which is assembled with the other specification sheets in Section 10. Finally, the descriptions should refer to the installed and operating costs for the process unit in cost summaries, discussed below.

   The identification of each process unit (e.g., Unit No. E-154, the condenser on an ethanol still) should be very clear, so that the concerned reader is able, without confusion, not only to relate each unit description to the corresponding specification sheet,

its costs in the cost summaries, and its design calculations in the appendix, but also to locate that additional information readily and to check it when necessary.

The process units described in Section 9 should include (a) storage facilities for the feed, product, byproduct, and intermediate chemicals, (b) spare equipment items (pumps, adsorption towers, etc.) required to avoid shutdowns in the event of operating difficulties, and equipment for startup, which is often not needed during normal operation.

The descriptions are accompanied by an equipment list, which includes the unit number, unit type, brief function, material of construction, size, and operating conditions of temperature and pressure.

10. ***Specification Sheets.*** Specification sheets are required to guide purchasing agents in locating vendors of desired equipment and to enable vendors to prepare bids. These sheets provide the design specifications for each of the process units in the process flow diagram, as referred to in the unit descriptions. A typical example is shown in Figure 22.1.

DISTILLATION COLUMN

Identification: **Item** *Distillation Column*
Item No. T-*700*
No. required 1

Date: *9 April 1997*
By: *SFG*

Function: Separate Benzoic Acid and Benzaldehyde from VCH, Styrene, and other organics.

Operation: Continuous

Materials handled:	*Feed*	*Feed 2*	*Liquid Dist.*	*Bottoms*	*Vapor Dist.*
Quantity (lb/hr):	161,527		153,022	6947	1558
Composition:					
Butadiene	4 PPB		2 PPB	trace	236 PPB
VCH	0.059		0.061	2 PPM	0.109
Styrene	0.861		0.899	0.087	0.630
Butene	10 PPB		5 PPB	trace	604 PPB
Cis-Butene	29 PPB		16 PPB	trace	2 PPM
Trans-Butene	9 PPB		5 PPB	trace	545 PPB
n-butane	3 PPB		1 PPB	trace	171 PPB
Isobutylene	7 PPB		3 PPB	trace	454 PPB
Isobutane	trace		trace	trace	9 PPB
Ethyl Benzene	0.039		0.041	96 PPM	0.041
Benzoic Acid	0.011		trace	0.244	trace
Benzaldehyde	0.028		31 PPM	0.647	10 PPM
H_2O	0.004		0.002	trace	0.205
N_2	139 PPM		2 PPM	trace	0.014
CO_2	6 PPB		1 PPB	trace	559 PPB
O_2	150 PPB		5 PPB	trace	15 PPM
Tar	902 PPM		trace	0.021	trace
Stabilizer					
Temperature (°F):	70.0		126.3	255.9	126.3

Design Data: Number of trays: 23
Pressure: 3.2 psig
Functional height: 70.5 ft
Material of construction: Carbon-steel
Recommended inside diameter: 21.0 ft
Tray efficiency: 0.70
Feed stage: 13
Feed 2 stage:
Side stream stage: 1
Molar reflux ratio: 10
Tray spacing: 3.0 ft
Skirt height: 14.5 ft

Utilities: Cooling water at 1.09 MM lb/hr and 370.52 M lb/hr 100 # stream
Controls:
Tolerances:
Comments and drawings: See Process Flow Sheet, 7 and Appendix F, 222-4.

Figure 22.1 Typical specification sheet for a process unit.

11. ***Equipment Cost Summary.*** In this section a table is prepared, containing the estimated purchase price of every equipment unit in the process flow diagram, identified according to the unit number and unit type on the process flow diagram and in the equipment list. The sources of the prices should be identified (graphical or tabulated cost data, a quotation from a specific manufacturer, etc.).
12. ***Fixed-Capital Investment Summary.*** In this section, the fixed-capital investment is related to the purchase cost of the equipment items. If desired, the equipment list and the list of equipment purchase costs can be combined. The methods for estimating the fixed capital investment, beginning with the purchase costs, should be clearly stated. If a factored cost estimate is used, the overall factor or individual equipment factors should be noted.
13. ***Other Important Considerations.*** In most design reports, the following considerations may deserve separate sections. Often, they are sufficiently important to warrant coverage apart from any discussion in the other parts of the report. These include those aspects of the design that address

    a. Environmental problems and methods used to eliminate them.
    b. Safety and health concerns, including a HAZOP (hazard and operability) study and a HAZAN (hazard analysis).
    c. Process controllability and instrumentation, including a piping and instrumentation diagram (P&ID).
    d. Startup, including additional equipment and costs.
    e. Plant layout.

    To the extent that these matters influence the choice of particular or additional items of equipment, as well as operating strategies, at least some discussion should be included in Sections 5–12. This section is intended to allow for a more thorough discussion of these subjects than might be appropriate elsewhere, and to enable the design team to draw attention to their importance in developing the design.
14. ***Operating Cost and Economic Analysis.*** This section begins with a presentation of the annual costs of operating the proposed plant, that is, the cost sheet, as discussed in Section 17.2 and shown in Table 17.1. In addition to the total production cost on the cost sheet, it should provide an estimate of the cost per unit weight of the product (e.g., $ per lb, kg, ton, or tonne). Note that when cash flows are computed for different production rates from year to year, a separate cost sheet is required for each unique production rate. Note also that, in addition to appearing on the cost sheet, the utilities for each equipment unit and their costs should be summarized in a separate table.

    Next, the working capital is presented, with a discussion of how it was estimated. Then the total capital investment is presented.

    This section concludes with a presentation of the calculations to obtain several of the profitability measures. Normally, this includes one or more of the approximate measures, such as return on investment (ROI) and venture profit (VP), and one or more of the rigorous methods that involve cash flows, such as net present value (NPV) and investor's return on investment (IRR). The latter is also referred to as the discounted cash flow rate of return (DCFRR). In all cases, it is important to indicate clearly the depreciation schedule and, for the rigorous methods, to provide a table that shows the calculation of the annual cash flows, as shown in Example 17.29, as well as plots of cash flow of the type shown in the same example. Finally, the design team should present its judgment of the profitability of the proposed plant.
15. ***Conclusions and Recommendations.*** The principal conclusions of the design study should be presented, together with a clear statement of the recommendations, accompanied by justifications, for management. At this point, before the remaining sections of the report are discussed, it is important to emphasize that an engineering supervisor

may find it necessary to check the calculations of the engineers in the design team. For this purpose, Sections 9–12, and 14, as well as the associated sections of the appendix, are very important. References to the specific pages in each of these sections for every equipment item are equally important. Neither the supervisor responsible for the work of the design team, nor the faculty member who grades the design report, will regard with favor references to various sections of the report, including the appendix, that are absent or difficult to locate. The same is true of an industrial supervisor who causes such a report to be created.

16. ***Acknowledgments.*** Most design teams obtain considerable assistance and advice from industrial consultants, equipment vendors, librarians, fellow students, faculty, and the like. This section provides an opportunity to acknowledge their contributions with an expression of appreciation and thanks.
17. ***Bibliography.*** All works referred to in the design report, including the appendix, should be listed in this section. It is recommended that the references appear in the form shown in the Reference sections near the end of each chapter in this textbook.
18. ***Appendix.*** The following items are typically included in the appendix, whose pages should be numbered sequentially with the body of the report.

    a. The design procedures and detailed calculations for all of the equipment items in Section 9 must be included here. These are normally *not* typed, but must be sufficiently neat to be easily read and understood. Photocopies of legible calculation sheets, even bearing erasures, are adequate.

    b. Computer programs developed for the design should be listed with sufficient documentation to enable the principal sections to be identified. This can normally be accomplished through the use of comment statements at the beginning of each section, including definitions of the key variables.

    c. Relevant portions of the computer output (the variables on each stage of a distillation column, a graph showing the variables as a function of the stage number, etc.) should be included here. It is important that the output be sufficiently well annotated to permit the reader to read it intelligently. In some cases, hand-written annotations are helpful and adequate.

    d. Pertinent printed material (e.g., materials provided by equipment vendors that describe their products) should be included here.

At the risk of stating the obvious, it cannot be emphasized too strongly that the appendix is not a repository in which large quantities of computer printout, pertinent or not, are included to increase the weight and thickness of the report. Unless the information in the appendix can readily be located by appropriate references in Sections 5–14, a responsible supervisor may doubt the results that appear in the foregoing sections. This can only affect adversely the evaluation of the report and the quality of the proposed design.

Remaining Sections of a Product Design Report

No one outline can apply to all product design reports. However, the following list may provide a starting point.

5. ***Introduction.*** The introduction can be very short, just long enough to inform the reader about the nature of the product and the customer needs that it will satisfy. The remaining sections will present the necessary background and approach that was used to develop the product.
6. ***Existing Similar Products.*** This section is based on discussions among members of the design team, bolstered by interviews with major customers and consumers of the existing products that are similar to the new product being presented in the report. This section should answer the questions:

a. What are the main functions of the existing products?
b. What product improvements would be welcomed and what has hindered the improvements?
c. How and where are the existing products marketed?
d. Are new markets possible if the nature of the product could be improved?
e. What patents protect the existing products or possible future products?

7. ***Product Specifications.*** This section lists the specifications for the new product and delineates the differences between the new product and the existing products.
8. ***Generation of Concepts.*** This section presents a list of all the ideas and concepts for the new product, as generated by the design team. It is preferable that the list be organized into several categories. Then the categories are compared in an attempt to select the best one or two categories for further consideration.
9. ***Selection of the Best Concept(s).*** This section follows from the previous section in an attempt to narrow the list of concepts to just a few, giving reasons why some concepts are dropped and others retained. Usually one, or at the most three, concepts will be selected for further evaluation. The selection is best based on supporting calculations, presented in an appendix, to prove the workability of the concept(s). This section should answer the question of possible patent protection for the new concept(s).
10. ***Architectural Design of the Product(s).*** This section presents the design of the new product(s), complete with dimensioned sketches and reference to design calculations presented in an appendix.
11. ***Prototype.*** This section presents the development of a working model of the product(s), testing procedures, and an assessment of the superiority of the product(s) over current competitors.
12. ***Manufacture.*** This section presents proposed methods for manufacturing the product(s), ensuring that product specifications are met.
13. ***Human Factors.*** This section discusses any potential adverse effects of the new product(s) on humans or the environment.
14. ***Marketing and Cost Estimates.*** This section discusses the potential market for the new product(s) and presents estimates of the selling price.

The remaining sections are essentially identical to Sections 15–18 of the process design report.

Preparation of the Written Report

Coordination of the Design Team

As mentioned in the introduction to this chapter, it is important for a design team to document its work throughout the design process. In this regard, each member is normally assigned responsibilities for a portion of the design work, as well as for its documentation. In industry, the assignments are usually coordinated by the head of the design team, who is normally appointed by the project supervisor. At a university, it is also recommended that a member of a student design team be appointed the team leader. The team leader schedules meetings to review progress of the team, to plan its next steps, make assignments, and set due dates. The faculty advisor is often very helpful in advising the team as it reviews its progress and plans its next steps.

Project Notebook

When carrying out a design, the design team normally maintains a project notebook, most likely a loose-leaf binder, in which important sources of information are placed. These include articles from the literature, data from the laboratory or the literature, design calcula-

tions, and computer programs and printed outputs. This repository of information is updated regularly and is particularly helpful during the meetings of the design team, especially when visitors, such as the team's faculty advisor and industrial consultants, are present.

Milestones

Since no two design projects follow exactly the same sequence of steps, it is not possible to suggest a timetable with specific milestones to be met by all design teams. Rather, in this subsection, it should suffice to identify the milestones, with emphasis on the steps to be accomplished and the portions of the design report that can be written. It is up to the team leader to prepare the timetable so that the final completion date can be met. The following steps pertain to a process design report. Similar steps, not given here, can be formulated for a product design report.

a. ***Assessment of the primitive design problem and literature search.*** These are the first steps in carrying out the design. As the specific problems are created and the preliminary database develops, the design notebook is augmented. This is an excellent time to write a draft of the Introduction (Section 5), which discusses many of these findings.

b. ***Complete the block flow diagram and the detailed process flow diagram showing the material balances.*** Most design teams spend considerable time in the process creation steps, identifying alternative process flow diagrams and creating the synthesis tree, as discussed in Section 3.4. While these steps, and the application of the algorithmic methods for process synthesis (which are usually carried out in parallel), are very important in leading to the most profitable processes, it is crucial not to spend too much time generating alternatives. Fairly early in the design process, the team should begin to focus its attention on the base-case design, as discussed in Section 3.5. This involves the preparation of a detailed process flow diagram (see Figure 3.19) and the completion of the material balances. As this is completed, the design team should prepare a draft of Sections 6 and 7 of the report. Should the base-case design be modified, the section is revised accordingly to show how the modifications improve upon the original design.

c. ***Complete the heat integration.*** In many cases, an attempt to achieve a high degree of heat and power integration is not undertaken until after mass integration is complete and the reactor(s) and separation equipment have been designed. After heat and power integration is complete and the heat exchangers, pumps, and compressors are installed in the base-case design, it is recommended that Section 8, on the energy balance, be completed.

d. ***Complete the detailed equipment design.*** After this step is completed, Sections 9 and 10, on the unit descriptions and the specification sheets, should be written. Note that it helps to complete hand calculations neatly so that they can be inserted into the appendix without any additional work. Furthermore, it is recommended that the important sections of the computer outputs be removed and annotated when necessary for insertion into the appendix.

e. ***Complete the fixed-capital investment and the profitability analysis.*** After these steps are completed, Sections 11, 12, and 14 should be written.

For the novice design team, it is hoped that the preceding pointers will help to simplify both the preparation of the design report and the design process. Although many merely follow common sense, they are included to help the design team set milestones to achieve throughout the design process.

lected to receive their awards at the Annual Meeting of the AIChE, usually in November, and to make oral presentations at the associated Student Chapter Meeting.

22.4 SUMMARY

In this chapter, readers have been presented with a template and associated milestones that must be completed, for guidance in the preparation of the written design report. No exercises are included because the template is intended to be used by design teams when writing their written reports.

Furthermore, readers have learned how to organize an oral design presentation. In this connection, they have become familiar with the alternative media for the presentation, with the reasons for rehearsing the presentation and the methods used to evaluate presentations.

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