Chapter 26

Written Reports and Oral Presentations

26.0 OBJECTIVES

At the completion of its design work, the design team is required to prepare a detailed report. If the design is in the final stages of consideration, the report should document 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 product and/or the process. Also, a design report identifies the key assumptions in the design and their potential impact on the performance and profitability of the product and/or process. 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, or for the construction and testing of a product prototype.

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 products and 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 identify the uncertainties and, when it recommends that a product be launched and/or a process be constructed, make recommendations as to how the uncertainties should be resolved.

A design report documents all of the steps leading up to the design of the product and/or process. This includes a discussion of the need for the new product and/or process, a summary of all the possible ways the design team generated 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 and/or process. In industry, the report might also include the development of a pilot plant as well as the performance of a product prototype and the manufacturing tests. However, 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 for management its most creative engineering efforts. Wherever possible, a design report should highlight the engineering work that the team believes will lead to greater economies than are achievable using alternative or conventional technologies—emphasizing the soundness of its ideas, but the need for data to prove their validity. 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 from other students, faculty, industrial consultants, and prospective 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 product has been developed and/or the process laid out, 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 its supervisor that 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 design team, 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, for the gate reviews in Figures PI.1, PII.1, and PIII.1, as discussed in Section 1.3 and Chapter 2 and in the case studies throughout the book, 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.

26.1 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.

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 six items are common to reports involving product and process designs.

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.
5. ***Introduction and Project Charter.*** This presents the origin of the design project and focuses on the project charter created when the design team began its work. The latter should include the specific goals, a project scope, and the deliverables and time line followed.
6. ***Innovation Map.*** This section of the report could be titled "Technology-Readiness Assessment." An innovation map should be presented showing the new technologies (materials, process/manufacturing, and product technologies) upon which the new product is based. A brief history of the technologies is helpful when discussing the innovation map, which should show how the voice of the customer for the new product is linked to the new technologies. Questions to be answered include whether all technologies are ready or can be used with minor variations.
7. ***Concept Stage***

Sections for Each Design

(a) **Market and Competitive Analyses.** These describe the market(s) for the new product and identify the principal competitors. When available, the production levels and annual sales of existing products are provided. Also, sales projections for the new product are included.

(b) **Customer Requirements.** The voice of the customer is presented in the form of customer requirements. While student design groups have limited access to customers, expressions of need should be stated based upon information from trade journals, advertisements, Web searches, and industrial consultants to design courses at universities. The customer requirements should be classified as fitness-to-standard (FTS) or new-unique-difficult (NUD).

Sections that Emphasize Product Design

These sections are prepared when the design team has focused on designing new chemical products, especially when designing *industrial* and *configured consumer* products. They document the steps followed in the *concept* stage of the SGPDP in Section 2.4. For examples, see the product designs for the halogen light bulbs (Section 17.2), LCD glass substrates (Section 15.2), washable crayons (Section 15.3), water-dispersible β-carotene (Section 13.4), and high-throughput screening of kinase inhibitors (Section 17.4). For many *basic* chemical products, where the chemical structure is well-known, these sections are skipped because the emphasis of the design team is on process design.

(c) Critical-to-Quality (CTQ) Variables—Product Requirements. This section should begin by identifying the CTQ variables, which are normally the NUD variables. Then, the translation of the customer requirements (CTQ variables) into technical requirements should be discussed. Their relationships should be presented in the rectangular section of the House of Quality (HOQ). The triangular interaction matrix, showing the synergistic technical requirements, should be added to the HOQ.

(d) Product Concepts. The alternative product concepts should be presented, preferably using the Pugh matrix. The advantages and disadvantages of each product concept should be discussed relative to a reference concept (normally the best existing product).

(e) Superior Product Concept. The superior concept should be presented, with justification for its selection.

(f) Competitive (Patent) Analysis. Having identified the superior concept for the new product, normally the competitive analysis is revisited. In this discussion, the results of more specific market analysis are presented. Also, the results of a more specific patent search are discussed in a so-called IP assessment.

(g) 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

1. Environmental problems and methods used to eliminate them.
2. Safety and health concerns, including a HAZOP (hazard and operability) study and a HAZAN (hazard analysis), as discussed in Section 1.5.

This subsection 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 product design.

(h) Business Case—Profitability Analysis. For most product designs, an approximate profitability analysis is carried out in the *concept* stage—to be refined with more accurate calculations in the later stages of the SGPDP. Normally, at least, an approximate profitability analysis is presented when documenting the *concept* stage.

This subsection provides estimates of the cost sheet(s) of annual costs, as discussed in Section 23.2 and shown in Table 23.1. 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.

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

This subsection concludes with a presentation of the calculations used to obtain several of the profitability measures. Normally, this includes one or more of the approximate measures, such as the return on investment (ROI) and the venture profit (VP), and one or more of the rigorous methods that involve cash flows, such as the net present value (NPV) and the 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 23.29. Finally, the design team should present its judgment of the profitability of the proposed plant. Where possible, the results of sensitivity analyses and optimizations are presented.

Sections that Emphasize Process Design

These sections discuss the alternatives considered during preliminary process synthesis, plus the assembly of the database and bench-scale laboratory work. Note that for product designs, where manufacturing processes are normally not synthesized in the *concept* stage of the SGPDP, these sections are skipped. For *basic* chemicals, on the other hand, where the chemical structure is normally well known, the emphasis in the *concept stage* is on process design. Examples include the manufacture of vinyl chloride and, even, tissue plasminogen activator (tPA), as discussed in Section 4.4.

(c) Preliminary Process Synthesis. The alternative process flowsheets should be presented, and possibly the synthesis tree, with a discussion of the most promising flowsheets.

(d) Assembly of Database. The principal thermophysical and transport property data should be presented, together with chemical kinetics data and toxicity data, with prices for the principal chemicals.

(e) Bench-Scale Laboratory Work. When laboratory data are available, they should be presented. Otherwise, the need for a laboratory program should be discussed.

8. *Feasibility, Development, Manufacturing, and Product-Introduction Stages*

Sections that Emphasize Product Design. When items under Section 7 are *not* carried out in the *concept* stage, such as the creation of a prototype product or pilot-plant testing (which would normally be performed in a later stage such as the *feasibility* stage), these sections should be devoted to a discussion of the missing items and the stage in which they will be carried out. Also, as the business case (profitability analysis) is refined, a section should be included to present the more complete analysis.

Sections that Emphasize Process Design. The following items should be documented. Normally, they will be carried out in the *feasibility* and *development* stages.

(a) Process Flow Diagram and Material Balances. This is the detailed process flow diagram discussed in Section 4.5 and shown for a vinyl-chloride process in Figure 4.19. 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 4.6). Note that, as mentioned in Section 4.5, 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 vinyl-chloride process in Table 4.6, that is, a table showing for each numbered stream:

1. Total flow rate
2. Flow rate of each chemical species
3. Temperature
4. 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, using the latest software, such as Microsoft VISIO. The symbols on the drawing should follow a standard list, such as those provided in Figure 4.20 and by Peters et al. (2003), Sandler and Luckiewicz (1993), and Ulrich and Vasudevan (2004).

(b) 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 4.18, 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 4.19). 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 Subsection (d), on unit descriptions. To aid the reader, however, the discussion of each item in Subsection (b) should be accompanied by a reference to the page number in Subsection (d). 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.

(c) 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 heat and power integration (including second-law analysis), and Chapter 10 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.

(d) 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 rigorous design of a distillation tower by means of a simulation program, 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 Subsection (d) should refer to the page number in the appendix on which the design calculations appear or are described. Note that the latter calculations are either handprinted neatly or done by computer. In addition, the description of each process unit should refer to a corresponding specification sheet, discussed below, that is assembled with the other specification sheets in Subsection (e). Finally, the descriptions should refer to the estimated 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 estimated 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 Subsection (d) should include: (1) storage facilities for the feed, product, byproduct, and intermediate chemicals, (2) spare equipment items (pumps, adsorption towers, etc.) required to avoid shutdowns in the event of operating difficulties, and (3) 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.

(e) 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 26.1.

It is recommended that students at universities, before preparing specification sheets, have more experienced individuals (e.g., faculty and industrial consultants) review the specifications to identify, hopefully, impractical specifications and significant inconsistencies.

(f) Equipment Cost Summary. In this subsection a table is prepared that contains 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.).

(g) Fixed-Capital Investment Summary. In this subsection, the fixed-capital investment is related to the estimated 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.

(h) Other Important Considerations. In most design reports, the following considerations may deserve separate subsections. 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

1. Environmental problems and methods used to eliminate them.
2. Safety and health concerns, including a HAZOP (hazard and operability) study and a HAZAN (hazard analysis), as discussed in the supplement to Chapter 1.
3. Process controllability and instrumentation, including a piping and instrumentation diagram (P&ID).
4. Startup, including additional equipment and costs.
5. Plant layout when critical.

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 Section 7 and in Section 8 (a–g). 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.

(i) Operating Cost and Economic Analysis. This is the same subsection that appeared earlier for the documentation of product designs (Subsection 7h, Business Case–Profitability Analysis). For process designs, it is normally completed and documented in the *development* stage of the SGPDP.

This subsection begins with a presentation of the estimated annual costs of operating the proposed plant, that is, the cost sheet, as discussed in

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:
Sidestream 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 26.1 Typical specification sheet for a process unit.

Section 23.2 and shown in Table 23.1. 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 subsection concludes with a presentation of the calculations used to obtain several of the profitability measures. Normally, this includes one or more of the approximate measures, such as the return on investment (ROI) and the venture profit (VP), and one or more of the rigorous methods that involve cash flows, such as the net present value (NPV) and the 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 23.29. Finally, the design team should present its judgment of the profitability of the proposed plant. Where possible, the results of sensitivity analyses and optimizations are presented.

9. ***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, when documenting process designs, Subsections (d–g) and (i) in Section 8, 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.

10. ***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.
11. ***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.
12. ***Appendix.*** The following items are typically included in the appendix, whose pages should be numbered sequentially with the body of the report.
    - **(a)** For each process design, the design procedures and detailed calculations for all of the equipment items in Section 8(d) 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 or lined-out corrections, 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 at 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, handwritten 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 printouts, 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 5–8, a responsible supervisor may doubt the results that appear in the foregoing sections. This can only adversely affect the evaluation of the report and the quality of the proposed design.

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, 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 calculations, 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 pertain to process designs. Similar steps, not given here, can be formulated for product designs.

(a) ***Complete the block flow diagram and 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 4.4. 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 4.5. This involves the preparation of a detailed process flow diagram (see Figure 4.19) and the completion of the material balances. While this is completed, the design team should prepare a draft of Subsections (a) and (b) of Section 8 for each process design in the report. Should the base-case design be modified, the section is revised accordingly to show how the modifications improve upon the original design.

(b) ***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 Subsection (c) of Section 8, on the energy balance, be completed for each process design in the report.

(c) ***Complete the detailed equipment design.*** After this step is completed, Subsections (d) and (e) of Section 8, on the unit descriptions and the specification sheets, should be written for each process design in the report. 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.

(d) ***Complete the fixed-capital investment and the profitability analysis.*** After these steps are completed, Subsections (f, g, and i) of Section 8 should be written for each process design.

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 pointers merely follow common sense, they are included to help the design team set milestones to achieve throughout the design process.

Word Processing and Desktop Publishing

The advent of the word processor has had a major impact on the preparation of the design report. Because sections of text can be cut and pasted with ease, it is possible to write drafts of many sections, as discussed previously. As the base-case design is modified, new sections can be composed and added easily to the previously prepared sections, which can usually be included with minor modifications. For technical writing. Word, WordPerfect, PageMaker, and LaTeX are the most commonly used word processors. Except for highly mathematical manuscripts, the former two word processors are preferred.

Many design reports have on the order of 100 pages that include the sections discussed earlier. Since there are many cross-references between the sections, it can be very helpful to add headers to the pages that identify the section numbers and titles. Furthermore, in addition to the table of contents, an index can be very helpful when the reader is searching for coverage of a specific topic.

Editing

No matter how careful an author is, it is difficult to compose concise text without redundant terms and the use of words that add little, if any, meaning. Most novice designers and writers examine their manuscripts carefully for spelling errors with the help of the spelling checkers in their word processors. They also seek to confirm that their statements are technically correct. However, many are inexperienced in the art of editing.

To obtain a more tightly structured document, it is recommended that the design team read its text carefully with the objectives of improving the grammatical constructions (eliminating split infinitives, avoiding the use of long strings of adjectives, etc), avoiding the usage of redundant terms, and eliminating terms that add no meaning to the sentence. This step is important even for the most experienced writers, who can take advantage of recent versions of word processors that include grammar checkers. Checks are made and suggestions sometimes given for:

1. Incomplete sentences.
2. Use of passive voice when active voice would give more punch.
3. Improper use of *who*, *whom*, *which*, and *that*.
4. Capitalization.
5. Hyphenation.
6. Punctuation.
7. Subject and verb agreement.
8. Possessives and plurals.
9. Sentence structure.
10. Wordiness.

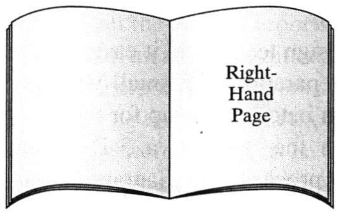
It must be noted, however, that grammar checkers are not always correct and suggested corrections should, therefore, not always be accepted.

Page Format

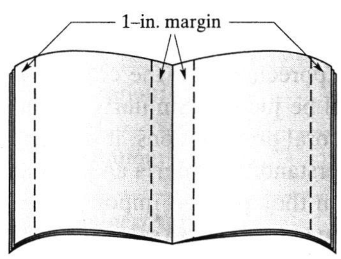
At many companies and universities, the design reports are bound for storage in technical libraries and repositories. When this is the case, to save space on the bookshelves and simplify the usage of the reports, the following guidelines are recommended for the preparation of a manuscript for binding.

(a) The pages of the report, including the appendix, should be numbered at the bottom center of each page.

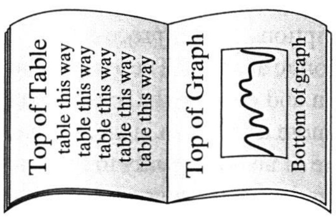
(b) The pages of the report should be printed back-on-back (two-sided), with the odd page numbers appearing on the right-hand page, as shown below.



(c) All pages, including the appendix, should have left and right margins that are at least 1 in. wide, as shown below.



(d) Sheets that appear sideways (broadside) should be mounted so that their tops face the left margin, as shown below. Remember that, for sideways sheets, the top and bottom (which become the left and right side of the page when rotated, must have 1-in. margins.



(e) Black ink should be used for the printed calculations, to ensure that the pages will photocopy adequately.

(f) When a large flow diagram is prepared by hand, as discussed in Section 8(a), it cannot be bound into the report, which is printed on $8\frac{1}{2}$-in.-by-11-in. pages. Such a flow diagram should be folded for insertion into a cover pocket, which is pasted onto the inside back cover of the report after the binding is completed.

(g) The complete manuscript should be submitted in a file folder for binding.

Sample Design Reports

Samples of design reports are available in the libraries and repositories of technical reports maintained by companies and universities. In a few cases, they are available from Interlibrary Loan, for example, the design reports prepared by students at the University of Pennsylvania since 1993. Note that titles of the problem statements that led to these reports are reproduced in Appendix II of this textbook, with full problem statements included in the file Supplement_to_Appendix_II .pdf in the PDF File folder, which can be downloaded from the Wiley Web site associated with this text book.

www.wiley.com/college/seider

26.2 ORAL DESIGN PRESENTATION

It is probably most common for the oral design report in industry to be presented to the immediate supervisor of a design team, together with managers who are responsible for deciding upon the prudence of investing funds in the proposed design. Similar presentations to a somewhat different audience (including industrial consultants, faculty, and fellow students) are prepared at universities, usually to provide the students with an experience similar to what they are likely to encounter in industry. It should be noted, however, that only occasionally do young engineers have the opportunity to attend a meeting where their work and ideas are presented to the decision makers among their employers, especially to make the presentation in person.

Typical Presentation

A typical oral design presentation by a team comprised of three students at a university is scheduled for 30 min with an additional 10 min for questions and discussion. This provides sufficient time to

1. Introduce the design problem and project charter.
2. Provide an overview of the technologies involved and the customer needs; that is, introduce the innovation map.
3. For a product design, present the superior concept(s), emphasizing their strengths. For a process design, discuss the sections of the proposed process (emphasizing the strengths of the design).
4. Present the results of the economic analysis.
5. Discuss other considerations.
6. Summarize the design and make recommendations.

Normally, each student speaks for 10 min, although it is not uncommon to split the presentation into as many as six or seven segments, with each member of the design team covering those portions of the design with which he or she is most familiar.

Media for the Presentation

Overhead Projector

Until recently, the overhead projector was the most actively used vehicle for displaying the key concepts, graphs, figures, and tables that accompany a design presentation. In some cases, two overhead projectors permitted the presenters to describe concepts that benefited from the simultaneous display of two complementary figures. Although most engineers have extensive experience in the use of these projectors, it continues to be helpful to remind presenters of the importance of using sufficiently large fonts and maintaining appropriate borders to enable the entire transparency to be displayed clearly and simultaneously.

Computer Projection Software

Rapidly gaining favor with speakers in recent years, with the availability of LCD pads and computer projection devices, are computerized projection facilities. To prepare and display the images, several software packages have been developed, including PowerPoint. This software is capable of displaying animated sequences, halftones, and videos. In most cases, the quality is significantly improved relative to the use of overhead projectors. Students using this technique of presentation should be warned to carefully check out the system just prior to the presentation. Otherwise, failure of the computer system to project the presentation could result in severe criticism of the speaker(s).

Preparation of Exhibits

To avoid duplicate work effort, it is recommended that design teams prepare all of the figures and tables for their written reports in such a way that they are displayed properly by an overhead projector or computer projection software. This requires that the figures and tables be prepared with sufficiently large fonts and the information placed less compactly than when an oral presentation is not required.

Rehearsing the Presentation

One of the most difficult tasks a design team encounters is the organization of a 30-min presentation to summarize the most salient features of an extensive written report. It is especially challenging because the members of the team have usually been so involved in the details of the design calculations that they find it difficult to summarize the really important results without overemphasizing the details. For this reason, and to help the team see the forest through the trees, it is important for them to rehearse the presentation in the presence of a colleague or teacher. In the best situation, this person will have attended many design presentations in the past, and will be well positioned to recommend that certain topics be expanded upon while others be deemphasized or eliminated entirely.

In one format for the rehearsal, the team makes a complete presentation without any interruptions, with the critic sitting toward the back of the room, to check that the exhibits can be seen and that the speakers can be heard easily. In addition, the critic takes notes and records the time that each speaker begins his or her presentation. Then, when the presentation is completed, the critic reviews the timing and offers some general comments. Often the design team makes a brief pass through its exhibits to enable the critic to offer more specific criticisms. The critic often has a major impact on the organization of the report and, more specifically, in helping the design team to achieve a well-balanced presentation.

Written Handout

In some situations, design teams find it easier to make their points through the preparation of a small written handout. Often, this includes an innovation map for the new technologies associated with the product, a 3-D sketch of the product, or a detailed process flow diagram, similar to that shown in Figure 4.19.

Evaluation of the Oral Presentation

When preparing an oral design presentation, it helps the speakers to have an appreciation of the criteria by which their presentation will be judged. Similarly, when serving on a team to evaluate oral presentations, it is important for the evaluators to understand the criteria and to apply them fairly, especially when they play an important role in the preparation of a course grade and the selection of an award winner.

One possible list of items to be evaluated is shown in Figure 26.2. Included for the product designs are the quality of the product charter and the innovation map, the description of the customer and technical requirements, the quality of the superior concept, and the discussion of the economic analysis; and, for the process designs, the quality of the process description, the descriptions of the process units, and the discussion of the economic analysis. These are at the heart of the design presentation and deserve the most attention. The next item, novelty, is more difficult to judge, as some design problems provide more of an opportunity to be creative than others. This is recognized by most judges, who attempt to rate the creativity of the design work in the context of the design problem and the opportunities it provides to develop novel solutions. The next items address the organization of the presentation and its execution. Then, the quality of the exhibits and visual aids is evaluated. Finally, the overall presentation is rated, which includes a recommendation for a grade when the design report is the work of a student design team.

Videotapes and DVDs

Increasingly, oral design presentations are recorded on videotape or DVD to provide a record of the presentations, as well as to enable each design team to critique its own presentation with a view toward improving the next one. In most cases, a portable camcorder, mounted on a tripod, is adequate to capture the bulk of the presentation.

26.3 AWARD COMPETITION

At many universities, an award is presented to the design team that prepares a design judged to be the most outstanding. Normally, the criteria are a combination of those discussed for both the written and oral design reports. However, since the written reports become available using Interlibrary Loan, and the best reports are often submitted for regional competitions in which the judges select from among reports that originate from other universities, it is common to place more emphasis on the written reports.

Usually, a small awards committee, comprised of academic and industrial members, is appointed to make the judgment. It begins by reading the reports of those design teams whose oral presentations were judged to be among the best.

At many universities, the design award is presented to the design team at the commencement exercises, either for the Chemical Engineering Department, the Engineering School, or the entire university. It often involves a small stipend and a certificate or plaque.

Finally, it is important to mention the annual National Student Design Competition prepared by AIChE members from industry and academia for the AIChE Student Chapters. The design contest is timed to be completed by the end of the spring semester, after which the awardees are selected 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.

Name of Presenter(s):
Title of Presentation:
Date of Presentation:
Name of Examiner/Appraiser:

Content	**Noteworthy**	**Acceptable**	**Needs Improving**
Product Design			
Project charter			
Innovation map			
Customer requirements			
Superior concept			
Economics			
Totals			
Process Design			
Process description			
Unit descriptions			
Economics			
Novelty of design			
Totals			

Figure 26.2 Oral design presentation evaluation form. (*Continued*)

Presentation—Organization	Noteworthy	Acceptable	Needs Improving
Core message			
Clear objectives			
Overall structure			
Visible logic			
Totals			

Presentation—Execution	Noteworthy	Acceptable	Needs Improving
Confident, enthusiastic, forceful, convincing			
Controlled pace/natural finish			
Voice quality (clear, calm, understandable)			
Frequent eye contact			
Totals			

Visual Aids	Noteworthy	Acceptable	Needs Improving
Interesting, relevant			
Easy to read			
Totals			

Figure 26.2 *(Continued)*

26.4 SUMMARY

In this chapter, readers have been presented with a template, associated milestones that must be completed, and 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 way, they have become familiar with the alternative media for the presentation, along with the reasons for rehearsing the presentation and the methods used to evaluate presentations.

REFERENCES

1. Peters, M.S., K.D. Timmerhaus, and R. West, *Plant Design and Economics for Chemical Engineers*, 5th ed., McGraw-Hill, New York (2003).

2. Sandler, H.J., and E.T. Luckiewicz, *Practical Process Engineering*, XIMIX, Philadelphia, Pennsylvania (1993).

3. Ulrich, G.D., and P.T. Vasudevan, *Chemical Engineering Process Design and Economics: A Practical Guide*, 2nd ed., Process (Ulrich) Publishing, www.ulrichvasudesign.com (2004).

PRODUCT AND PROCESS DESIGN PRINCIPLES

Synthesis, Analysis, and Evaluation

Third Edition

Warren D. Seider

Department of Chemical and Biomolecular Engineering
University of Pennsylvania

J.D. Seader

Department of Chemical Engineering
University of Utah

Daniel R. Lewin

Department of Chemical Engineering
Technion—Israel Institute of Technology

Soemantri Widagdo

3M Company
Display and Graphics Business Laboratory

WILEY

John Wiley & Sons, Inc.

Publisher: Donald Fowley
Executive Editor: Jennifer Welter
Production Manager: Dorothy Sinclair
Marketing Manager: Christopher Ruel
Production Editor: Sandra Dumas
Design Director: Jeof Vita
Media Editor: Lauren Sapira
Editorial Assistant: Mark Owens
Production Management Services: Elm Street Publishing Services
Electronic Composition: Thomson Digital

This book was typset in Times New Roman by Thomson Digital and printed & bound by Courier (Westford). The cover was printed by Courier (Westford).

The paper in this book was manufactured by a mill whose forest management programs include sustained yield harvesting of its timberlands. Sustained yield harvesting principles ensure that the number of trees cut each year does not exceed the amount of new growth.

This book is printed on acid-free paper. ♾

ISBN 13: 978-0470-04895-5

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1