AACE INTERNATIONAL RECOMMENDED PRACTICE

16R-90

CONDUCTING TECHNICAL AND ECONOMIC EVALUATIONS - AS APPLIED FOR THE PROCESS AND UTILITY INDUSTRIES

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AACE® International Recommended Practice No. 16R-90

CONDUCTING TECHNICAL AND ECONOMIC EVALUATIONS – AS APPLIED FOR THE PROCESS AND UTILITY INDUSTRIES

TCM Framework: 3.2 – Asset Planning
3.3 – Investment Decision Making

Rev. April 1, 1991

Note: As AACE International Recommended Practices evolve over time, please refer to www.aacei.org for the latest revisions.

This recommended practice is the culmination of several years of effort by a special AACE ad hoc committee. The document has been reviewed by all concerned technical committees in AACE and was formally accepted by the AACE Board of Directors as a recommended practice in September 1990.

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CONDUCTING TECHNICAL AND ECONOMIC EVALUATIONS – AS APPLIED FOR THE PROCESS AND UTILITY INDUSTRIES

TCM Framework: 3.2 – Asset Planning
3.3 – Asset Performance Assessment

April 1, 1991

1. INTRODUCTION(*)

The American Association of Cost Engineers (AACE) has had a long-standing interest in developing standards and recommended practices. The Recommended Practice described herein is for executing techno-economic evaluations of process oriented engineering projects. Most, if not all, cost engineers are involved in process-oriented techno-economic studies in the course of their work. Some concentrate in estimating only plant investment; others are involved in specific areas of cost estimating or only in financial analysis; still others, in overall economics. Adherence to a consistent set of process evaluation guidelines would improve the quality of these studies and would lower the cost to prepare them (improve productivity).

There are several ways of conducting technical and economic evaluations in the process industries and within these ways there are many variations. This recommended practice was developed to reduce the variations to a manageable level.

2. CRITERIA

The AACE Recommended Practices and Standards (RPS) Committee and other standards-making organizations have stated that standards should, at the minimum, meet the dual criteria of verifiability and comparability.

*The Practice was developed by an AACE ad hoc committee set up for this purpose. Members of this ad hoc committee were as follows:

Fred R. Douglas, Chairman (Texaco, Inc.)
Daryl Brown (Battelle Pacific Northwest Laboratories)
Raymond A. Cobb (Northeast Utilities)
Thomas J. George (Morgantown Energy Technology Center)
John W. Hackney (Mobil Oil deceased)
Kenneth K. Humphreys (AACE Executive Director)
Paul Wellman (Ashland Oil retired)

Other contributors are:

Morgantown Energy Technology Center, METC Fuels Cell Branch, which originally spearheaded this effort.

Electric Power Research Institute (EPRI)

American National Standards Institute (ANSI), who provided information necessary to achieve consensus and who established that there was a genuine technical community interest in the Practice.

The Recommended Practice described herein was developed to meet these criteria in the following manner:

- Verifiability - The technical and economic evaluation should be conducted and reported such that all aspects of the study may be independently verified with reasonable effort.

- Comparability - The evaluation should be conducted and reported in ways that assure that changes in assumptions are readily and consistently evaluated. Also maximized is the ease of comparing any or all aspects of the subject study with any other study conducted under the aegis of the recommended practice.

In addition to the goals of verifiability and comparability, the Practice should facilitate evaluations that are accurate and correct. Thus another criteria for this Practice is:

- Accuracy - The evaluation should be conducted in a manner that yields technically and economically correct results within the levels of uncertainty corresponding to the level of detail required.

This recommended practice is not intended to replace existing procedures but rather to provide guidelines such that the above criteria may be met. Different industries (and different companies within these industries) conduct technical and economic studies in different ways. This recommended practice is largely oriented to the chemical process industries although most of the methods outlined may be adapted to other industries.

This recommended practice was largely written for budget-type estimates defined by AACE as having a +30% to -15% accuracy. It is primarily intended for those companies seeking preliminary quotations from contractors such that all are on the same basis and may be readily compared. Others could find the practice useful to conduct their own preliminary evaluations in a consistent manner. Still others could find the practice useful within their own company and for publishing or other external purposes (such as for sales discussions).

AACE feels that the collaboration of individuals on this project who represent the private sector, government and not-for-profit institutions have made an impressive contribution to the development of this Practice.

3. SCOPE

3.1 This practice establishes a consistent procedure for conducting budget-type technical and economic evaluations for use by the process industries such that ease of comparability and verification are of paramount importance.

3.2 Mass and energy balances, composition and properties of all streams, equipment specifications, and performance criteria are all developed and reported according to a recommended format.

3.3 Direct costs of plant sections are developed and reported according to recommended procedures and formats.

3.4 Other costs, such as foundations, structures, insulation, instruments, etc. are established by recommended factors for each type of process or type of equipment.

3.5 Field indirects, engineering, overhead and administrative costs are determined by factors herein recommended.

3.6 Operating costs are developed based on estimates of raw material, utility and operating labor requirements. Other elements of operating costs such as maintenance and overhead are based on factors recommended herein.

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3.7 A financial analysis is conducted based upon prescribed procedures.

3.8 A sensitivity study may be conducted to determine the effects of changes in key variables and assumptions.

3.9 A recommended reporting format is provided to be sure that all information required for verifiability and comparability is included. Also included are listings of deviations from this established practice.

4. APPLICABLE DOCUMENTS AND REFERENCES

4.1 AACE, **Cost Engineers' Notebook.**

4.2 AACE Metropolitan New York Section, **AACE Transactions**, "The Module Estimating Technique as an Aid in Developing Plant Capital Costs," 1962.

4.3 Brown, D. R. et al, **An Assessment Methodology for Thermal Energy Storage Evaluation**, Prepared for U.S. Department of Energy by Battelle Memorial Institute, Pacific Northwest Laboratory, November, 1987.

4.4 Electric Power Research Institute (EPRI), **TAG™ - Technical Assessment Guide, Vol.** 1, Electricity Supply - 1989; Vol. 2, Electricity End-Use - Part 1, 1987, Parts 2 & 3, 1988; Vol. 3, Fundamentals and Methods, Supply - 1987; Vol. 4, Fundamentals and End-Use - 1987, EPRI P-4463-SR, Palo Alto, CA.

4.5 Guthrie, K. M., **Process Plant Estimating Evaluation and Control**, Craftsman Book Company of America, Solana Beach, CA, 1974.

4.6 Humphreys, K. K. and P. Wellman, **Basic Cost Engineering, 2nd ed.**, Marcel Dekker, Inc., New York, 1987.

4.7 Peters, M. S. and K. D. Timmerhaus, **Plant Design and Economics for Chemical Engineers**, 3rd ed, McGraw-Hill Book Co., New York 1980.

4.8 Weinheimer, W. R., **Cost Engineers' Notebook**, "Percent Your Indirect Field Costs," Revision 1 dated November 1984

4.9 Wessell, H. E., "New Graph Correlates Operating Labor Data for Chemical Processes," **Chemical Engineering**, July 1952, p. 209.

5. DEFINITIONS

5.1 For the purpose of this document the following terms are defined, (Other terms used are defined in AACE Recommended Practice No. 10S-90, "Cost Engineering Terminology").

5.1.1 ADR (Asset Depreciation Range) Class Life. Approximate ranges of useful equipment life established by the Internal Revenue Service for tax purposes.

5.1.2 Depreciable Life. The legal capital cost recovery period established by the Modified Accelerated Cost Recovery System (MACRS). MACRS and its predecessor technique ACRS, Accelerated Cost Recovery System, are depreciation techniques mandated by U.S. tax law.

5.1.3 Measure of Merit. An economic measurement (e.g., present value, interest rate of return) used to determine the economic viability of a project. Syn. Figure of Merit

5.1.4 Inflation. A rise in the general price level, usually expressed as a percentage rate. "Inflation" is usually used to describe the general change in prices for all goods and services. "Escalation" usually refers to specific items.

5.1.5 Internal Rate of Return. The compound rate of interest that, when used to discount study period costs and benefits of a project, will make the two equal, i.e., the discount rate that results in a net present value of zero.

5.1.6 Levelized (Annualized) Production Cost. A unit cost equal to the annualized cost of production divided by the annual production rate. The annualized cost, recurring every year for the life of a project, has a present value equivalent to the present value of all project costs. When the discount rate used is the after-tax weighted cost of capital, the levelized production cost is similar to the revenue requirements used by the utility companies, and the cost of capital is considered part of the cost of production.

5.1.7 Net Present Value. The sum of all project cash flows, both negative and positive, discounted to the present time.

5.1.8 Nominal (Current) Dollars. Dollars of purchasing power in which actual prices are stated, including inflation or deflation. In the absence of inflation or deflation, current dollars equal constant dollars.

5.1.9 Overnight Cost. A measurement of capital investment that excludes any interest expense or escalation of costs that may occur during the construction period, as if the project had literally been built overnight.

5.1.10 Payoff Period, Discounted. The length of time required for the cumulative present value of after-tax cash flows of a project to become positive.

5.1.11 Price Year. The reference year for a cost estimate or cash flow. For example, a capital cost estimate might be based on 1990 dollars or some other year's dollars.

5.1.12 Profitability Ratio. The net present value of a project divided by the present value of the initial capital investment.

5.1.13 Real (Constant) Dollars. Dollars of uniform purchasing power exclusive of general inflation or deflation. Constant dollars are tied to a reference year.

6. SUMMARY OF RECOMMENDED PRACTICE

The following sections are organized as follows:

- Significance, use and limitations of this Recommended Practice
- General description of the step-by-step procedures in using the Practice
- Objectives, alternatives, constraints and assumptions
- Data and other requirements
- Detailed description of computations necessary to conduct the step-by-step procedures
- Summary of applications and limitations of methods
- Summary of report procedure
- Appendices containing tables and charts to be used in the procedures

7. SIGNIFICANCE, USE AND LIMITATIONS

7.1 The significance of this Recommended Practice is that it provides a comprehensive yet consistent procedure for taking into account all the technical information needed to develop a budget-type estimate as well as all the relevant costs necessary to evaluate the economic performance of a process being evaluated.

7.2 The method is intended to compare readily and in a consistent manner the economics of competing processes as well as the economic viability of individual processes. The consistency of the method, providing verifiability and comparability, makes it particularly useful for publishing results or for other external purposes such as for sales discussions. The method may also be used in analyzing possible cost reductions in existing plants, for incremental studies, to design and cost individual components of projects or for optimizing purposes. In short, the method has applications wherever conceptual, preliminary or budget-type techno-economic studies are required. The method is not intended for definitive-type estimates, although some parts of the practice may be adapted for this use (particularly the financial analysis model).

7.3 The practice is not intended to replace existing design and cost procedures but rather to provide guidelines such that the criteria of verifiability and comparability in the transmission of results to others may be readily met. The words, "This study was performed using the AACE Recommended Practice" should provide instant information as to exactly what was done and exactly how it was done.

8. PROCEDURES (See Section 12 for detailed description)

8.1 Identify Objectives, Alternatives and Assumptions Necessary to Conduct the Study. The first step in the procedure is to establish the specific objectives of the study, identify alternative ways of accomplishing these objectives and bring out any constraints that limit the resultant analysis.

8.2 Develop the Design. A process plant size is first established based on market considerations. Flow sheets showing the major equipment required with detailed material and energy balances around each equipment item are developed. Standard engineering practice as outlined in such texts as Peters & Timmerhaus (ref. 4.7) are followed using a common set of recommended design premises.

8.3 Develop Equipment Specifications. Major equipment components are sized according to the requirements of the process flow sheet and material and energy balances. Major equipment items are specified sufficiently to conduct budget-type costing. For example, in a budget-type estimate for a heat exchanger, only the surface area, required type of exchanger and materials of construction are needed to develop the cost. Such details as the tube pitch and length of tubes are helpful but are not necessary for a budget estimate of the cost.

8.4 Establish Total Capital Requirement. Plant costs are built up by first establishing the cost of each equipment item delivered to the plant site. Material and labor costs to set and install equipment are next estimated using recommended factors. Total plant costs are established by adding field indirects, engineering costs, overhead and administration based on recommended factors. Finally, total capital requirement is established by adding in such costs as pre-production or start-up costs, inventory capital, initial chemicals and catalyst charges and land.

8.5 Estimate Plant Operating Cost. Operating labor, utility and chemical requirements are first estimated from the design data and from these total operating costs are established by means of recommended factors.

8.6 Conduct Financial Analysis. Detailed cash flows (year-by-year) are first established based on recommended procedures. One or more of a set of measures-of-merit techniques are selected generally involving discounted cash flow in order to determine economic viability.

8.7 Conduct Sensitivity Study. A set of key variables and assumptions are selected and the effects of changes in these on the previous results are determined.

8.8 Prepare Report. All the findings and the basis for them are documented by a set of recommended tables. Discussions of the results are included in the report. All deviations from the recommended practice are documented and reasons for the changes from those recommended are discussed.

The above steps are described in more detail in Section 12.

9. OBJECTIVES, ALTERNATIVES AND CONSTRAINTS OF THE RECOMMENDED PRACTICE

The objective of this Technical and Economic Practice is to provide a consistent and reliable guide to performing budget-type estimates such that communication of results to others is readily achieved with clear and unequivocal understanding of what was and what was not included in the study. The criteria of verifiability and comparability are the goals to be met.

The method is primarily aimed at generating budget-type estimates as defined by AACE having accuracy limits of +30% to -15%. The method is also adaptable to order-of-magnitude estimates. The method is aimed at the process industries and those doing business with them, but here again, other industries may find it useful.

The method does not detail rigid engineering design techniques. These are more than adequately covered in plant design texts and other sources. Major equipment components are only specified sufficiently to conduct budget-type estimates. Certain factors (or ranges of factors) in the costing procedure are specified for the purpose of consistency. Recommended procedures for year-by-year cash flows and financial analyses are provided. Here again, deviations are allowed as long as they are specified.

Finally, individual sections of the practice, such as the operating cost routine or the financial analysis procedure, may be followed as long as it is made clear as to what is being done.

10. ASSUMPTIONS AND DEVIATIONS FROM RECOMMENDED PRACTICE

The primary assumption in using the recommended practice is that the process has been developed enough so that sufficient detail is available to conduct the study for a budget-type estimate that will result in an accuracy range of +30% to -15%. Reliable data for developing mass and energy balances around major equipment items should be available. A sensitivity study, described below, is to be conducted on those items for which insufficient data (including costs) are available or for which questionable assumptions are made. The reliability of the data, as well as other factors, may necessitate deviating from the recommended practice. Deviations from the recommended practice must be well documented in the report.

11. DATA REQUIREMENTS

Some of the data needed in the specific calculations have been discussed and will also be covered in the following sections. Briefly, these are summarized as follows:

11.1 Plant Design. Material balance, energy balance, stream composition and quality, flow sheets showing plant configuration.

11.2 Equipment Specifications. Design of individual equipment to the extent necessary for costing; materials of construction required; number of equipment items necessary; sparing philosophy used; utility requirements; etc.

11.3 Total Capital Requirements. Factors to be applied if not using recommended ones; cost curves and data (including utility investment costs); construction labor rates.

11.4 Operating Costs. Factors required if not using recommended ones; operating labor requirements; annual utility and chemical requirements; raw material and byproduct unit costs and quantity requirements.

11.5 Financial Analysis. Factors required if not using recommended practice factors; timing of cash flows; cost of capital; discount factors; inflation rates for operating labor; investment capital; power rates, chemical and catalyst rates.

12. COMPUTATION PROCEDURES

12.1 Identify the Objectives, Alternatives and Assumptions. It is first necessary to establish the specific objectives for the technical economic study. For example, two or more design changes may be evaluated to determine which has the best economic potential in the overall scheme. Thus, a contractor could optimize the design to produce the desired end result and thus be competitive with other contractors when opening discussions with a client. The client might be evaluating two or more processes from different contractors to determine which, if any, are worthy of further consideration. If all the studies are done in a consistent manner as outlined in this practice, then comparisons are possible.

It is also necessary to establish basic assumptions in applying the practice to the objective desired. The comprehensiveness of the study will depend on the degree of complexity of the problem, the intended purpose of the evaluation, the cost and resources available to perform the evaluation, and the impact, both monetary and non-monetary, contingent on the investment decision. Each of these may require different assumptions and different detail within the budget-type estimate.

Assumptions made with respect to engineering design and bare equipment costs should be carefully considered. An error in establishing bare equipment costs can be magnified three to five times by the time the final results are estimated.

Deviations from the recommended practice should be carefully documented and explained. Keep in mind that one of the main objectives of the practice is one of communicating to others exactly what is and what is not included in the study so that verification and comparability of results are readily obtained.

12.2 Develop the Design. This section includes a description of the necessary information to define properly the process under consideration. This section also defines the recommended design premises to be used in the study.

12.2.1 Process Definition -- Budget estimates require a detailed process flow diagram and stream summaries incorporating the following data:

a. Raw material feed rates and composition of all streams.
b. Temperature and pressure of all streams.
c. Residence or reaction time for all reactors.
d. All streams should be shown, including intermediate, recycle and main.

Mass and energy balances should be conducted according to normally acceptable engineering practices and using the design premises outlined below. It is not necessary to document the complete design unit but basic performance design criteria on which conclusions rest should be documented. In most cases, all that would be necessary are the flow diagrams outlined above, the equipment list (described below) and deviations from the design premises (described below).

Before developing the process flow diagrams, a plant size should be established based on marketing conditions, expected share of market, economies of scale and other factors. In comparing alternatives, plant size (output) should be kept constant except in those cases where plant size is being evaluated in a sensitivity study.

12.2.2 Define Plant Sections and Sub-sections -- As the process is being developed, care should be taken to establish logical plant section names and the groups of equipment to be contained within those sections. Even within the same organization, slight variations in practice can complicate future study-to-study comparisons (e.g., does heat exchange equipment go in its own section, in the section that produces the waste heat, or in the section that benefits from the heat exchanger product?). If executed with care, plant section definition will aid the ease of comparing studies, as for example, the situation when the studies are executed by different entities for a single sponsor.

12.3 Develop Equipment Specifications. Major equipment items are sized according to the requirements of the process flow-sheets and material and energy balances. The items are specified sufficiently to conduct budget-type costing. Major equipment items in a process plant include heat exchangers, columns, reactors and other vessels, pumps, compressors, process furnaces, direct-fired heaters, miscellaneous equipment, specialized equipment, etc. A list of all major equipment items with design parameters specified should be included as part of the report. Examples of the degree of documentation that should be included are shown in Table 1. Appendix A provides a listing of optimum design and costing specifications for many types of equipment.

Table 1. Example of a Detailed Equipment List Showing Parameters Necessary for Cost Estimation

Amine contactor (4 required) Size: Top, 9' ID X 29'6" high; bottom, 12' ID X 35'6" high Operating pressure: 200 psig Operating temperature: 150°F *Amine regenerator* (2 required) Size: 19' ID X 84' high Operating pressure: 50 psig Operating temperature: 260°F *Caustic precontactor* (2 req'd) Size: 2' ID X 24' high Operating pressure: 180 psig Operating temperature: 120°F *Caustic contactor* (2 required) Size: 4'6" ID X 61' high Operating pressure: 180 psig Operating temperature: 120°F	*Amine knockout drum* (2 required) Size: 12' ID X 16'6" high Operating pressure: 180 psig Operating temperature: 120°F *Amine flash drum* (2 required) Size: 10' ID X 30' high Operating pressure: 60 psig Operating temperature: 150°F *Regenerator reflux drum* (2 req) Size: 9' ID X 11' high Operating pressure: 50 psig Operating temperature: 100°F *Amine sump* (2 required) Size: 8' ID X 8' high Operating pressure: atmospheric Operating temperature: 160°F	*Sand filters* (4 required) Size: 9' ID X 15' high Operating pressure: 50 psig Operating temperature: 185°F *Carbon filters* (4 required) Size: 9' ID X 15' high Operating pressure: 50 psig Operating temperature: 185°F *Lean amine pumps* (3 required, including 1 spare) Type: centrifugal Capacity: 1,[illegible]75 gpm Drive: motor Hp: [illegible] *Amine filter pump* (2 required) Type: centrifugal Capacity: 620 gpm Drive: motor Hp: 25 *Semi-lean amine pump* (5 required, including 1 spare) Type: centrifugal Capacity: 2.640 gpm Drive: motor Hp: 900

12.3.1 Design Philosophy and Equipment Sparing -- Conventional commercially available equipment should be selected wherever possible. Deviations and special design equipment should be documented.

Sparing should be done to provide 90% availability exclusive of planned maintenance unless prior experience or system engineering studies have indicated that another level of sparing is appropriate for the process being studied.

12.4 Establish Total Capital Requirement

12.4.1 Introduction -- Total Capital Requirements are built up by first establishing the cost of purchased delivered equipment items and then applying factors for: handling and setting; commodity material and labor costs; field indirects; engineering; overhead and administration; contingencies.

Finally, factors for start-up costs, working capital, prepaid royalties, initial catalyst and chemical charges, and land are applied to give the total capital requirement. The components are summarized in Table B-1 in Appendix B. Details are provided in the following sections.

