the equipment can be used, based on the manufacturer's data, as well as projected laboratory growth and long-term goals. There are other factors tailored to specific pieces of equipment that cannot be generalized, such as the general maintenance requirements versus a lease-plan maintenance agreement, projected frequency of upgrading of the software system, and the depreciated value of the equipment after a certain period.

CONCLUDING REMARKS

Any long-term laboratory development project should be based on a methodical and systematic plan to ensure its proper development. Many factors have been described in this paper, but not all of them are applicable to all cases. Different laboratories may require vastly different approaches at the planning stage. The intent of the paper has been to provide some general guidelines for the planning and management of instructional laboratories. Several of the guidelines are applicable to almost all cases. They are

- Establishment of an advisory committee to review the objectives and plans and to make recommendations regarding the future needs of the facility.
- Establishment of a channel for direct input from industrial colleagues and alumni.
- Long-term projections of the laboratory needs with regard to the number and types of experiments, equipment, technicians, and student users.
- Establishment of a periodic review process to evaluate the progress and development of the facility, to assess the laboratory needs, and to ascertain the necessity of making modifications in the original plan.
- Development of plans for proper replacement or upgrading of both software and hardware after a designated period of time.
- Establishment of a maintenance plan for the upkeep of equipment and instruments.
- Development of a complete training and safety program for all individuals who use the facility.

It is not often that a complete new laboratory is built from the ground up. More often than not, an existing laboratory has to be renovated and updated. The criteria discussed in this paper are applicable in either case. Additionally, there are many textbooks[4-7] that provide a survey of experimental methods, experiment planning, instrument selection, accuracy and economy, analysis of data, and report writing.

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ChE **book review**

ELECTROCHEMICAL ENGINEERING PRINCIPLES

by Geoffrey Prentice: Prentice Hall, Englewood Cliffs, NJ 07632 (1991)

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This book is an introductory-level textbook on electrochemical engineering that could be used in a senior-level undergraduate course or in a first-year graduate-level course. The book contains nine chapters and seven appendices and is 296 pages long.

The nine chapters are entitled: Introduction, Basic Concepts, Thermodynamics, Phase Equilibrium, Electrode Kinetics, Ionic Mass Transport, Modeling and Simulation, Experimental Methods, and Applications. The seven appendices are entitled: Conversion Factors, Standard Electrode Potentials, Equivalent Conductances, Activity Coefficients of Electrolytes at 25°C, Mass Transport Correlations, Computer Program for a One-Dimensional Cell, and Computer Program for a Two-Dimensional L-cell. A solutions manual is available for the problems given in the text, and the computer programs given in the last two appendices can be obtained in electronic form from the author.

The first chapter is short but points out the importance of electrochemical engineering in terms of the amount spent annually ($28 billion in 1986 dollars) on products such as aluminum, which are produced by electrochemical methods, and in terms of the annual cost of corrosion (approximately $200 billion in 1991 dollars).

The second chapter presents basic concepts that are needed in the study of electrochemical systems. The author reviews electrochemical cell conventions, Faraday's laws, the concepts of current and voltage efficiencies, ion conduction, and transference numbers. Unfortunately, the author does not cite the

references he used to prepare the figures in this chapter nor in subsequent chapters; however, he does provide a bibliography at the end of each chapter.

The third chapter is on the thermodynamics of electrochemical cells and includes a section on Pourbaix diagrams which is very useful for understanding phase equilibria and cathodic protection. This chapter should be studied by all chemical engineering students.

Chapter Four presents discussions of phase equilibria and the concepts of electrochemical potential and mean activity coefficients solutions containing ionic species. The author also includes in this chapter a detailed discussion on the Debye-Huckel theory for electrolytic solutions. The author finishes this chapter with discussions on the two concepts of a potential in an electrolytic solution and liquid junction potentials.

The fifth chapter is on electrode kinetics. The author begins the chapter by presenting a useful description of the electric double layer on an electrode. The author continues this chapter by presenting a derivation of the Butler-Volmer equation, which is the commonly used reaction rate expression for electrochemical reactions. He then presents and discusses simplified forms of the Butler-Volmer equation: the so-called linear and Tafel forms of the Butler-Volmer equation. He continues by presenting a practical description of reference electrodes and their use in measuring potential distributions in electrolytic cells. He also presents in this chapter a description of a study of the reaction mechanism for the anodic reaction of zinc in an alkaline electrolyte. He presents a reaction rate expression for this reaction which is similar to the Butler-Volmer equation but includes a potential-dependent pre-exponential term. Finally, the author presents a very useful discussion of the kinetics of corrosion processes and Evans' diagrams. Finally, he provides a lucid description of simplified forms of the reaction rate expressions for corrosion reactions and associated expressions for the corrosion potential.

Chapter Six contains a very useful presentation of the fundamental equations used to describe mass transfer in electrolytic solutions. This chapter should be required reading for all chemical engineers. The author uses the rotating disk electrode to demonstrate how electrochemical reactions can be used to develop mass transfer correlations in the form of the Sherwood number as a function of the Reynolds and the Schmidt number, for example. The final section in Chapter Six is a brief discussion of how to treat the time dependence of a simple electrochemical reaction.

In Chapter Seven, the author presents a classification scheme for the types of current distribution problems that have been modeled in the past. He also presents a discussion of the Wagner number which can be used as a characterizing parameter for current distributions in electrochemical cells. Next, the author presents a summary of analytical and numerical methods that can be used to predict current distributions. The next topic in this chapter is on gas-evolving electrodes, which are found in many electrochemical cells used in industry (*e.g.,* chlor-alkali cells), and the author presents a mass transfer correlation for vertical, gas-evolving electrodes for such cells. The final section in this chapter contains a presentation of the equations that are used for mass and charge transfer in porous electrodes, which are important in such areas as batteries and fuel cells.

Chapter Eight is entitled "Experimental Methods" and presents material on several popular experimental systems used in electrochemical engineering. These are the rotating disk electrode, the rotating ring-disk electrode, rotating cylinder electrode, and parallel plate electrode systems.

The last chapter in the book contains descriptions of several applications of electrochemical engineering principles. These include energy storage and conversion, electric vehicles, thermally regenerative electrochemical systems, and the electrochemical production of adiponitrile. The author also includes descriptions of monopolar and bipolar electrochemical cells, the chlor-alkali process, and thermal management of electrochemical cells. The final section of this last chapter is on future developments in which the author speculates that "the premium on efficiency will stimulate additional research on electrochemical energy conversion and storage." I hope he is right. ❐

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