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Bioprocess Monitoring and Control

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Foreword

In the last decade, the practical application of monitoring and control capabilities to fermentation processes has become widespread not only in the laboratory and pilot plant but also in commercial production facilities. Therefore, it is necessary for individuals who practice industrial fermentation and biotechnology to acquire a comprehensive knowledge of a range of related technologies not covered in conventional academic curricula.

These include predominantly continuous measurement and sensor technologies, process control and optimization techniques and system design and implementation approaches. Until recently, these technologies have been presented in the literature as separate unrelated disciplines.

Consequently, in order to develop even a basic understanding of these areas, biotechnologists have been required to sort through a wide variety of academic texts and scientific journals. This has been an onerous task even for those with engineering backgrounds. For individuals with life science backgrounds, the lack of a comprehensive but still understandable source of the required information has in a very real sense limited the ability of many to fully use the potential of computer control.

BIOPROCESS MONITORING AND CONTROL contributes significantly to resolving this problem. It presents each of the required areas in a thorough and complete manner. In several of these areas, particularly the discussion of both chemical and biochemical sensor technology, the presentation is among the most comprehensive to be found in the literature. As such, Dr. Pons' volume should be an important source of information for both the recently introduced user of computer controlled fermentation systems as well as the accomplished practitioner.

Dr. Daniel R. Omstead
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Raritan, New Jersey

April 1991

Preface

This book addresses bioprocess engineers who are not specialists in process control and who seek information about new devices and advanced control techniques for solving problems. It also serves control engineers who are used to classical problems in mechanical, electrical or chemical engineering but who may not be familiar with the specifics of non-linear, time-dependent and difficult-to-instrument bioprocesses.

We note the increased recent use of living microorganisms for converting organic substances and especially renewable resources of the biosphere. Clearly biotechnological transformation of living cells in efficient chemical plants calls for knowledge of applied microbiology, genetic engineering and chemical engineering. Thus control of these factors in bioreactors - really complex industrial plants at the cellular scale - can be much more difficult than control of classical chemical reactors.

The problem is no more one of regulating one or two variables, but rather of controlling a large number of parameters which define an exact environment required to keep microorganisms alive. For profitability in large-scale industrial applications, less-predictable natural substrates tend to be used rather than synthetic media of well known composition. Moreover, despite lack of reproducibility of the quality of natural substrates, the final product of most bioprocesses must maintain all of its elemental characteristics.

There are certain parallels between the chemical engineer and the biochemical engineer, but the complicated nature of living material makes the latter's task harder. Microorganisms are particular about their environment. A first problem to be solved, the core of this book, is gathering information on the quality of this environment, and therefore having reliable physical, chemical and biochemical sensors.

To this end, Chapter 1 is a review of the existing physical and chemical devices with a discussion of their advantages and drawbacks. Chapter 2 discusses biochemical sensors, still for the most part on the research laboratory bench.

Chapter 3 treats control basics and describes the different levels of control structure: low-level loops for temperature, pH, etc.; high level configurations with estimation techniques required to counterbalance the lack of direct sensors; advanced control strategies including

setpoint optimization, optimal trajectories, adaptive control, etc. The high nonlinearity of most bioprocesses, characterized by exponential growth, requires design of special control algorithms also discussed here.

Chapter 4 presents the methodology of automation as it should be applied step by step in research and development: modeling, simulation, identification, data acquisition, etc. Finally Chapter 5 describes some industrial and semi-industrial examples of bioprocess control and introduces new trends in process automation such as expert systems and neural networks, discussing their future in biotechnology.

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