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DEVELOPMENT AND IMPLEMENTATION OF NEW METHODS IN BIOENGINEERING

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Consultant report: Trip to Sophia, Bulgaria
June 20-27, 1987 (5 working days)

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ABSTRACT

The Laboratory of Bio-engineering and the University of Sophia have purchased, installed, and tested new fermentation equipment with computer interfacing. The data-gathering features have been implemented, but computer control is not yet functional. The consultant inspected the facilities and discussed in great detail the research projects that require this sophisticated equipment. A new initiative on using computers for teaching was started, and the consultant furnished 75 programs for education. There was some joint work on computer modeling, and equations developed in Bulgaria were incorporated into a simulation program for personal computers. Some new projects that might be good opportunities for Bulgaria were suggested.

INTRODUCTION

A group of Bulgarian engineers and bioscientists has financial support from the United Nations Industrial Development Organization (UNIDO) to establish a modern computerized facility for fermentation research and to develop methods for design of bio-equipment. Their reputations and credential are excellent because of sigrificant publications and contributions in the international literature, and they are in a position to assume even greater importance worldwide if they can pursue their projects in state-of-the-art equipment.

The initial phase of UNIDO support included purchase of two

completely modern computerized fermenters, and other bioreactors have been connected to computers. In particular, a design with a Bulgarian computer and a Bulgarian fermenter is nearing the manufacturing stage, and several of these units are in various laboratories. Although intended for education, the Bulgarian bench-top fermenters are also suitable for research. They are not as sophisticated as some commercial fermenters, but essential features for good research are well designed.

This consultant spent one week in Sophia. Most of the interactions focussed on the details of research. Topics discussed were: bioconversion of ferrous ion to ferric ion, the inverse fluidized bed reactor, microbial protein from cheese whey, biogas production, modeling of bioprocesses, specific problems in computer interfacing and control, and new topics for research. A project for using personal computers for teaching was started.

COMPUTER-ASSISTED FERMENTATION RESEARCH

The stated goals of the project supported by UNIDO are to create a world-class facility for fermentation research and to develop advanced methods for design of bio-equipment. After contacting several manufacturers, a European company was selected to supply two computerized fermenters. The consultant and some of the Bulgarians met with the manufacturer's representatives at an exhibition that was part of the European Congress of

Biotechnology in Amsterdam the week prior to the visit to Bulgaria. Details of the equipment, the computer, and the software were discussed. There are many ways to approach these problems of design, and the consultant feels that this company has sound ideas and solutions on a par with any company in the world. The computer programs are written in C code that is an accepted standard, but the source programs are not available to the customer. This is common practice because companies have a great investment in these programs and cannot give secrets away. Unfortunately, this means that the customer must request and pay for modifications and is restricted in what can be done without such assistance.

The commercial fermenters have been installed and tested in Bulgaria. The computerized collection and display of data work well, but computer control of the bioreactors has not yet been achieved.

Constructive Criticism:

1. The consultant does not like the strategy of two levels of control. The European manufacturer and most other companies continue to control fermenters with old, reliable analog methods. The digital computer receives signals from the analog equipment and can treat the data and provide elegant output. However, much of the power and flexibility of the computer is wasted when analog control is employed. Industry is shifting more and more to direct digital control because all analog control modes can be

surpassed and because logic and advanced control are easily added. Furthermore, the analog equipment adds something to the system, of course, but the cost is way out of proportion to the benefit. It may have been a good idea for the very first computerized fermentation system in Bulgaria, but a strong recommendation is made that future units bypass and omit the expensive analog controllers.

2. Having no access to the source code for the computer programs may be acceptable to an industrial user, but an academic group needs to understand all aspects of their system. The consultant recommends that the Bulgarians develop their own computer program so that they can cut the umbillical cord to the manufacturer and can procede independently in improving Bulgarian expertise in computer control. The existing commercial software provides a standard for comparison.

3. The consultant proposed methods for power measurement and for other sensing techniques and was prepared to assist in construction and testing. The Bulgarians showed interest but prefer to purchase commercial devices. If they wish to reach their stated objective of developing advanced methods for design of bio-equipment, they will have to gain skills in constructing needed devices. It is recommended that they avoid purchase of expensive equipment, except for comparisons, and that they manufacture their own devices whenever possible.

NEW REACTOR DESIGNS

The Bulgarians have a leadership position with inverse fluidized bed reactors and have novel ideas for the use of rotating biological contactors. The inverse fluidized bed reactor employs particles of styrofoam that float and are fluidized downward by liquid circulation. When used in a bioreactor for converting ferrous ion to ferric ion, the biofilm has a very high specific gravity, and affects the particle density. Heavy particles settle to a region of high shear where excess biofilm is removed. The result is formation of particles with a nearly constant thickness of biofilm, and this is a marvelous tool for some types of bioengineering research. This important research should continue, and this type of bioreactor should be connected to a computer.

The rotating biological contactor is not at all new, but the Bulgarians are studying rather high angular velocities and have a very interesting hydrodynamic analysis that led to a simple but powerful model. Again this is well worth continuation and computerization.

SPECIFIC RESEARCH AREAS

1. Treatment of iron wastes.

Drainage from mines has ferrous ions at fairly low concentrations, and wastes from refining and metalurgical industries can be rich in ferrous ion. While ferrous salts are

fairly insoluble in water, ferric salts such as the hydroxide are extremely insoluble. The pH of treatment and the amount of reagents are improved by oxidation of ferrous ion to ferric ion. Chemical oxidation is possible, but oxidation by microorganisms is very rapid and creates much less pollution.

The Bulgarians are very skilled in this research, and their advances in reactor design mesh very nicely with this project. There is a possibility that they will leave this research because of a shift in their priorities, but the consultant thinks that continuation has much merit.

2. Microbial protein from cheese whey.

This project was not discussed for very long, and there was an impression that there were no features of great novelty. For a related project in the U.S., the consultant found that the logistics of collecting enough cheese whey to supply a plant of practical size were uneconomic. The Bulgarians felt that the situation was different for their country. Most groups justify this research on the basis of deriving value from cheese whey - an objectional waste. Unfortunately, there will still be waste from the process of making microbial protein, and the product is too cheap to provide much income. There is nothing wrong with this research, but the consultant feels that there are better research opportunities.

NEW RESEARCH AREAS

A number of research areas such a bioprocess for fuel alcohol were discussed, but the topic of most mutal interest was biomass refining. The consultant has written a book that includes this topic and conducts research on fractionation of wood chips after steam explosion. Short rotation of special hybrids of poplar trees is of great interest in the U.S. and Canada, other other fast growing species are studied in Europe. This crop to produce wood chips should be considered for Bulgaria. A new process under development at Rensselaer Polytechnic Institute (RPI) produces crude sugars for feeding cattle, pure glucose for conversion to fuel alcohol, and lignin that should command high prices for use in formulations for adhesives. The Bulgarians have been invited to send one or more of their people to RPI to learn the details of this process, but a source of funding must be found.

COMPUTER PROJECTS

1. Models for bioreactors.

The Bulgarians have made impressive progress in this area. The consultant spent an hour or two helping to convert one of the models to a personal computer for convenient testing and for fitting curves to actual data.

2. Programs for control of bioreactors.

The consultant presented a book about FORTH programming to his hosts and tried to convince them that this interactive, multitasking language is ideal for bioprocess control. Examples of programs used at RPI are being sent for their consideration. The consultant also gave them a pile of brochures about inexpensive devices for interfacing equipment to personal computers. Most of the companies furnish software for their equipment at low or no cost. The consultant is also sending them excerpts from thesis and reports about RPI projects, reprints, computer programs, and small equipment items that can be mailed easily.

3. Teaching with computers.

The consultant has just finished the draft of a book that coordinates with 75 computer programs for teaching. The consultant gave the Bulgarians a copy of the draft and gave them several free floppy disks with the programs. There were several demonstrations at the computer, and it is highly likely that some of the programs will be used in Bulgarian courses.

OVERALL IMPRESSIONS

This is a healthy project. Providing intelligent, creative people with good equipment is certain to lead to significant research. Although the consultant would have done some things differently, the choice of equipment was highly sensible, and many of the project objectives have been achieved already.

There is one serious criticism. The establishment of a general purpose research facility must be questioned on several grounds. First, it is likely that some features are not important and will seldom if ever be used. Second, uncommon features may be essential to some research, and it may difficult to accommodate these features into a final installation of computerized fermenters. The present strategy is not appealing: provide a modern facility and the Bulgarians will devise uses for it. The consultant strongly favors precise definition of the project objectives and of the experiments that support these objectives. This will spotlight these exact equipment needs, and the research facilities can be designed optimally.

FUTURE COOPERATION

There are a number of area of common interest between the Bulgarians and the consultant. We have agreed to share ideas about biomass refining and to encourage a visit of a Bulgarian engineer to RPI. We will also share information about techniques for measuring fermentation variables and for computer interfacing and control. The Bulgarians are expert in fuzzy set theory and can advise on projects at RPI. Professional contacts and correspondance may be independent of UNIDO.