AN EVOLUTIONARY EXPERIMENT

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MANY CHEMICAL ENGINEERS are involved in the development of industrial processes which consist of several articulated operational steps. Since data for such development are frequently lacking and are only obtainable through experimentation, the engineer must be capable of devising experimental equipment and procedures.

The usual undergraduate laboratory courses do not prepare the engineering student well for such tasks. **Most experiments are intended to demonstrate a single rather than a sequence of concepts or operations, and their interdependency, which is so essential for industrial processes, is not apparent. Since the experimental apparatus is usually provided, the student is primarily required to follow an established procedure and analyse his results. He plays virtually no role in selecting the experimental equipment and techniques.**

Hence, in order to give students some experience with developing a process, an "Evolutionary Experiment" was recently introduced into an existing, Senior laboratory course at UBC. The term "evolutionary" suggested itself because students worked on the process in turn and it thus evolved during the academic year. The present note describes an Evolutionary Experiment on electrowinning of copper and emphasizes the organizational rather than technical aspects. This approach was taken because the latter are thought to be of less general interest.

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ORGANIZATION

The class was divided into groups of three or four students and each worked on the project for two days spaced one week apart. Since only a brief outline of the process was provided and students were required to investigate all major aspects in the course of the academic year, the first group started by making a literature survey. In addition it formulated a detailed work plan and documented its findings in a technical report. Subsequent groups always began by reading previous reports and determining their specific objectives commensurate with the general work schedule. These decisions were discussed and sometimes modified in a brief meeting with the laboratory instructor before the groups proceeded. When experimental equipment had to be built or modified, this could usually be accomplished during the week between laboratory periods. The work of each group concluded with writing a technical report and making recommendations to future groups. The very last group in the academic year prepared a summary report.

THE PROCESS

Due to time limitations, a simple process had to be chosen and electrowinning of copper from a leachable ore was selected for the first Evolutionary Experiment in 1970. This process is quite well understood and consists of three basic operational steps: ore leaching, purification of the leach liquor and electrolysis to yield copper. A further advantage of this process is the production of an important, final product rather than an intermediate requiring further chemical treatment. The relevancy of this project was therefore clearly apparent to the students.

Approximately 300 lbs. of ore were kindly provided by the Anaconda Company from its mine in Weed Heights, Nevada. The ore is readily leachable with dilute sulphuric acid and yields a liquor sufficiently strong for electrowinning. No

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special problems of analysis arose since the acid consumption and copper content of the rock or leach liquor could be determined by titration and atomic absorption spectroscopy, respectively.

ACHIEVEMENTS

Based on the literature survey prepared by the first group, the second group decided that the leaching operation should be conducted by either percolating the acid upward or trickling it downward through a fixed bed of ore. The important variables were thought to be acid concentration and flow rate. Temperature and rock size could also be varied but were regarded as less significant. The supplied rock was approximately −3 +5 mesh and was used in this form without further crushing or screening.

The second group designed and assembled a simple leaching apparatus whose main component was a 3 in. ID, 2 ft. long glass column containing the rock. The acid was delivered by a centrifugal pump from a 10 gallon holding tank through a valve and rotameter to the leaching column from which it returned to the tank. The piping, which consisted of polyethylene, was arranged to permit operation in the percolation and trickle modes. Samples of leach liquor were withdrawn from the holding tank to determine copper content and acidity.

Initial tests showed that the liquor flow rate could not be kept constant and it was up to the third group to rectify this problem. Careful experimentation revealed that small rock particles became lodged in the valve thus restricting the flow. After several other attempts which proved unsuccessful, a by-pass was installed around the pump. This allowed the valve to be opened more fully and thereby reduced the chance of blockage.

The subsequent three groups studied the leaching rate as a function of acid concentration, flow rate and mode of operation. By applying Levenspiel's tests[1], the results were found to be representable by the unreacted-core model with the major resistance to mass transfer lying in the leached, outer layer of the rock particles. Hence varying the flow rate and operational mode did not significantly affect the leaching rate. The acid consumption was almost stoichiometric with respect to copper indicating that few other rock constituents were attacked.

The sixth group was originally scheduled to investigate purification of the leach liquor necessary for electrolysis. However, since the iron and particulate content of this liquor were unexpectedly low, the group concentrated on designing an electrolytic cell and washing the leached rock. The latter ensued from the realization that copper sulphate adhering to the rock constituted an economic loss and environmental hazard if discharged. Washing with water was shown to be complete in less than one hour.

The electrolytic cell consisted of a 3 in. by 5 in. lead anode and similar copper cathode situated in a rectangular, plastic tank. The spacing of the electrodes was variable and the leach liquor was continuously passed between them by letting it overflow the anode and discharge through the bottom of the cell. Poor liquor distribution resulted and the evolution of gas bubbles interfered with the electrolysis. These problems were resolved by the seventh group which modified the cell by introducing the electrolyte at the bottom and forcing it to flow upwards between the electrodes. The effects of flow rate, electrode spacing and current density on copper deposition were investigated and current efficiencies in excess of 90% were achieved.

The final group prepared a summary report and indicated areas requiring further work. Furthermore, it considered the problems associated with scale-up of the laboratory data.

STUDENT REACTION

Student response to the Evolutionary Experiment was quite favourable because it provided a break from the more traditional laboratory work. They enjoyed the flexibility of the project and the ability to formulate their own objectives. Since each group started where the previous one had left off, the work seemed more original than usual. Finally, students appreciated the opportunity to study an industrially significant process and gain practical experience with developing experimental equipment.

Since each group worked on a different aspect of the Evolutionary Experiment, students recognized the necessity for clear and concise technical reports. Needless to say, they were not overjoyed by this realization, but it made the task easier.

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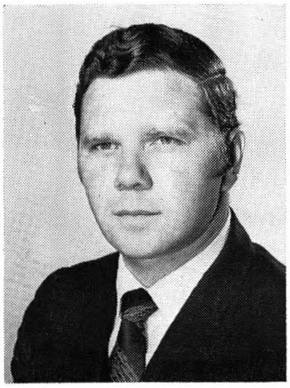

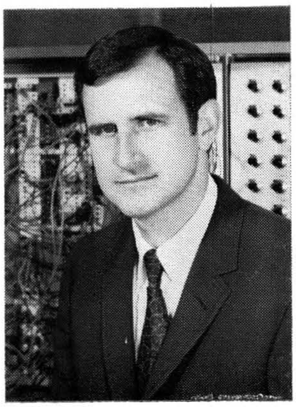

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in compression with dense foam rubber (in our case, rubber backed carpeting) gaskets used to insulate the cylinder from the mount and to maintain the compressive force as the ends of the cylinder sublime. Preparation of the cylinder is very simple, if somewhat novel. An ordinary three pound block of dry ice is set-up in our machine shop metal lathe. It is quickly turned to the required diameter by standard machining techniques and immediately brought to the wind tunnel for the demonstration.

After mounting the dry ice cylinder in the wind tunnel the air flow is turned on and is quickly adjusted to correspond to the desired Reynolds number. It was found that at prevailing air relative humidities of approximately 50%, the streamline patterns of condensed moisture were clearly visible at air velocities of approximately 50 ft./sec. For the 2-inch diameter cylinders used in the demonstration, this corresponds to a Reynolds number of about 50,000. At this Reynolds number the laminar boundary layer separates before it becomes turbulent, the point of separation occurring at an angle of about 80 degrees from the forward stagnation point. The streamline patterns clearly show the separation point and the angle of separation is easily estimated by the students to be at approximately 80 degrees

The department sub-sonic wind tunnel is used for demonstrations in fluid mechanics and heat and mass transport phenomena.

fro mthe forward stagnation point. The streamlines in the downstream turbulent wake are also clearly visible particularly near the rear stagnation point.

After running the demonstration for about five minutes the wind tunnel is turned off and the dry ice cylinder may be inspected. This length of time is sufficient for a protruding ridge to appear at the separation point. This ridge indicates the sharp minimum in the local mass transfer coefficient that occurs at the point of boundary layer separation.

REFERENCE

1. Sandall, O. C., and Mellichamp, D. A., "A Simple Forced Convection Experiment", **Chemi. Engi. Edu.** Vol. 5, 134-136 (1971).

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Report writing was further simplified by the fact that students did not primarily write for the instructor but rather for their class-mates whose technical competence they knew.

CONCLUDING REMARKS

Although it is clear that not all undergraduate experiments should be replaced by Evolutionary Experiments, the addition of one or two can considerably enliven a laboratory course. In order to maintain student interest, the topics should be frequently changed. The following projects, which have either been conducted or are planned at U.B.C., may serve as further examples of Evolutionary Experiments: production of crystalline copper sulphate from an Arizona ore, extraction of protein from fish meal, manufacture of furfuraldehyde from sawdust and recovery of metals from scrap tin cans. The latter two projects were initiated by Dr. K. B. Mathur and Dr. A. P. Watkinson, respectively.

REFERENCE

1. O. Levenspiel, Chemical Reaction Engineering, p. 338, John Wiley and Sons, New York, 1962.