A Program in

PLANT ENGINEERING AT LOUGHBOROUGH

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THE DEPARTMENT OF CHEMICAL ENGINEERING at Loughborough runs three courses at undergraduate level:

- **Chemical Engineering**
- **Chemical Engineering and Management**
- **Food Processing Technology**

The first of these is the main course and is taken by about 80% of the students. All undergraduate courses in the department come as 3- or 4-year courses with the third year of the 4-year course being spent in industry. Some 85% of students opt for the 4-year courses.

At the graduate level the department runs two Masters courses:

- **Advanced Chemical Engineering**
- **Plant Engineering in the Process Industries**

The former course has been running since 1969 and was described in an earlier paper [1]. The latter course was started in 1976.

There are some 23 staff in the department, as shown in Table 1. It is found convenient, both for undergraduate and for graduate education and for research, to operate through the medium of specialist groups:

- **Transfer Processes**
- **Process Technology**
- **Particle Technology**
- **Plant Engineering**
- **Food Processing Technology**

These are loose groupings, however, and many members of the staff have a foot in several camps.

PLANT ENGINEERING STUDIES

THERE ARE TWO BASIC REASONS for the development of studies in plant engineering at Loughborough. One is the belief that the subjects which we group under this heading are important to the chemical engineer but have received insufficient emphasis in many undergraduate courses in recent years. The other is that the job of the plant engineer is an important one but tends to be neglected by engineering schools.

Frank P. Lees graduated in chemical engineering at Imperial College, London. He worked for two years in the steel industry and eleven years in the chemical industry. He came to the Department of Chemical Engineering at Loughborough University of Technology in 1967. He holds the Chair in Plant Engineering in the Department and is course tutor for the M.Sc. in Plant Engineering in the Process Industries. His teaching and research interests include plant engineering, loss prevention, reliability engineering and process control. He is a member of the Advisory Committee on Major Hazards set up by the UK Government after the Flixborough disaster. He is author of the book **Loss Prevention in the Process Industries.**

One working definition of plant engineering is effectively the body of knowledge useful to the plant engineer. In the U.K. it is normal practice in process plants for there to be a plant manager, who is responsible for plant operation, and a plant engineer, who is responsible for plant maintenance and modification. The former is typically a chemical engineer and the latter a mechanical engineer. Increasingly, however, chemical engineers are working as plant engineers.

A central theme of plant engineering is that of the failures which occur on plant. Almost all the topics which we deal with under the heading of plant engineering are related to deviation, maloperation, and failure in some way.

The Plant Engineering Group in the department is led by the author, who holds the Chair in Plant Engineering which was funded by the Institution of Plant Engineers. The group takes the lead role in undergraduate teaching of topics broadly in the plant engineering field, such as

mechanical engineering, electrical engineering, instrumentation, reliability engineering, loss prevention, energy, maintenance. It also takes responsibility for the Masters course and research in plant engineering.

MASTERS COURSE IN PLANT ENGINEERING

THE WORK OF THE PLANT engineer has often been taken for granted, but this situation is changing. The economic importance of the maintenance function is receiving recognition, while the importance of other aspects of the job, such as loss prevention, energy conservation and pollution control, does not need to be emphasised. Consequently, there is a growing appreciation of the need for people with a more fundamental education in plant engineering, particularly one which both increases the engineers' effectiveness as a junior manager and also gives him the background needed for senior management.

A central theme of the course is the plant engineering information system. This approach focuses attention on the decisions which the plant engineer has to make, on the information required to make those decisions, and on the information system needed in order to obtain the information. In addition, emphasis is also placed on the decisions which the plant engineer's colleagues need to make, whether they be the designer, the buyer or the accountant. They, too, require information and often it is the plant engineer who should supply it. The plant engineer needs, therefore, an information system which will furnish the data which he and his colleagues need, as effectively and as economically as possible. The concept of this information system for the plant engineer provides a framework for the integration of specific plant engineering studies and enables the plant engineer to argue his case within the organisation on a level with his colleagues in the other engineering disciplines.

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Of course, for most plant engineers the short

TABLE 1
Staff of the Department

R. J. Aird, Lecturer; B.Sc. 1962, Durham University; Plant Engineering, Reliability Engineering

R. J. Akers, Senior Lecturer; Ph.D. 1972, Westfield College, London; Particle Technology, Filtration, Flocculation

P. K. Andow, Lecturer; Ph.D. 1973, Loughborough University of Technology; Fluid Mechanics, Process Control, Hazard Assessment

R. H. Beresford, Senior Lecturer; M.A. 1955, Cambridge University; Petroleum Industry Economics, Operational Research, Computer-Aided Design

B. W. Brooks, Senior Lecturer; Ph.D. 1964, Leeds University; Polymerisation Reactions, Electrochemical Reactions

B. A. Buffham, Senior Lecturer; Ph.D. 1969, Loughborough University of Technology; Thermodynamics, Mixing Phenomena

D. W. Drott, Lecturer; Ph.D. 1972, University of Minnesota; Process Control, Reaction Engineering

A. Foord, Senior Lecturer; Ph.D. 1956, Birmingham University; Process Economics

D. C. Freshwater, Professor; Ph.D. 1954, Birmingham University; Distillation, Energy Economy, Particle Technology

J. Glover, Lecturer; M.Sc. 1954, Birmingham University; Thermodynamics, Reaction Engineering

T. A. Kletz, Industrial Professor and Division Safety Adviser, ICI Petrochemicals Division; B.Sc. 1944, Liverpool University; Safety and Loss Prevention

F. P. Lees, Professor; Ph.D. 1969, Loughborough University of Technology; Plant Engineering, Reliability Engineering, Loss Prevention, Process Control

P. J. Lloyd, Senior Lecturer; B.Sc. 1956, University College, London; Particle Technology, Particle Characterisation, Filtration

J. Mann, Professor; Ph.D. 1965, Cambridge University; Food Processing Technology, Management, Economics, Process Control

G. Mason, Lecturer; Ph.D. 1979, Council for National Academic Awards; Porous Media

C. P. Murphy, Research Fellow; Ph.D. 1979, Loughborough University of Technology; Computer Science

P. Rice, Lecturer; Ph.D. 1970, Loughborough University of Technology; Heat and Mass Transfer, Reaction Engineering

B. Scarlett, Senior Lecturer; M.Sc. 1964, Durham University; Particle Technology, Particle Characterisation, Packed Beds

J. Selman, Lecturer; B.Sc. 1972, Reading University; Food Processing Technology

J. I. T. Stenhouse, Senior Lecturer; Ph.D. 1973, Loughborough University of Technology; Particle Technology, Gas Cleaning

A. S. Teja, Lecturer; Ph.D. 1972, Imperial College, London; Thermodynamics, Phase Equilibria

C. R. G. Treasure, Lecturer; B.Sc. 1950, University College, London; Particle Technology, Particle Characterisation

A. S. Ward, Lecturer; B.Sc. Tech. 1960, Manchester University; Particle Technology, Filtration

continuing education course (lasting typically one week) will be the principal method of further education. This is right and proper. The department is very much involved in this type of course, but there is a difference between what can be achieved in such short courses and what can be done in a longer period of study.

The Masters course starts in early October and lasts for exactly a year. There are two 10-week terms of lectures, tutorials and seminar/workshops separated by a break of about 3 weeks at Christmas. Written examinations are completed by late April and the remainder of the year is devoted to a project. About half the projects are done in industry and half at the University.

The course has about 7 to 8 graduate students per year. Students split roughly half and half between chemical and mechanical engineers. Usually rather more than half have substantial industrial experience. The course provides a basic tool kit of relevant subjects for both mechanical and chemical engineers who propose to make careers as plant engineers. It is not assumed, however, that graduates from the course will necessarily practice as plant engineers. A chemical engineer may take the course to strengthen his knowledge of the mechanical side of the process industries, while a mechanical engineer may take it to strengthen his knowledge of the process side of these industries. In effect, the course is neither a purely specialist nor a purely conversion course, but has elements of both.

TABLE 2
Outline of Masters Course in Plant Engineering in the Process Industries

PART 1
- Process Economics
- Financial Analysis and Control
- Project Engineering
- Maintenance Management
- Human Relations
- Probabilistic Methods
- Reliability Engineering
- Materials Technology 1
- Materials Technology 2
- Loss Prevention
- Plant Services
- Electrical Plant
- Noise and Vibration
- Process Instrument Systems
- Computer Laboratory

and either (A)
- Mechanical Design
- Process Machinery
- Process Vessels and Structures
- Manufacturing Technology Workshop

or (B)
- Process Instrumentation
- Chemical Engineering Principles 1
- Chemical Engineering Principles 2
- Chemical Engineering Laboratory

PART 2
- Project

An outline of the course is given in Table 2. Normally option A is taken by the chemical engineer and option B by the mechanical engineer. Although lectures are an important part of the course, extensive use is made of other teaching methods, in particular tutorials (which have long been strongly emphasised in the department) and on workshops, laboratories, seminars and project work.

DOCTORAL STUDIES

STUDENTS ENTER THE DOCTORAL program either directly or through one of the two Masters courses. In the former case there is a program of formal graduate studies, while in the latter case the Masters program fulfils this function. For students who take the Masters route, the research topic for the doctorate is typically a development of the Masters project, which, in such cases, is chosen with this in view. Presentation of the doctoral thesis normally occurs two years after taking the M.Sc.

RESEARCH IN PLANT ENGINEERING

IT MAY BE HELPFUL to supplement the rather generalised description above with a brief account of some of the specific areas of plant engineering in which the department is working.

There is a long-term program of work on the generic problem of the propagation of faults in process plants. There are currently a number of specific techniques which deal with this problem. They include, in plant design, failure modes and effects analysis, hazard and operability studies, fault trees, event trees and cause-consequence diagrams, and, in process control, alarm analysis, which is virtually synonymous with disturbance analysis. Disturbance analysis is one of the techniques which the Nuclear Regulatory Commission has recommended for assessment following the Three Mile Island incident. This work started some ten years ago on the alarm analysis side and has led to two systematic methods of obtaining the data structure for process computer alarm analysis. Currently the emphasis is on the generic

Another related area of work is the relation between inspection and reliability.

problem of representing the fault structure of a plant, whether for design or control. A computer code with interactive facilities has been developed in which the fault propagation structure of the plant is synthesised from a library of models of plant units.

Knowledge of the fault propagation structure should also assist in the creation of improved alarm systems and work is being done both on this and on other aspects of alarm systems.

Another area of research is the application of the techniques of reliability engineering to process plants, and in particular to plant maintenance. Failure data from operating plants are analysed to identify the failure regime (early, constant, or wearout failure). There are a number of problems, particularly of small samples and of observation intervals, associated with such analysis. It turns out, somewhat unexpectedly, that early failure is often the prevalent regime, even in plants which have been operating for many years. The failure data analysis is therefore followed up by observation of the task to determine the causes of early failure. These include such things as poor diagnosis, lack of training, dirty working conditions and so on. The correction of these problems has led to substantial reduction of failure rates and improvements in plant availability.

Another related area of work is the relation between inspection and reliability. There is a large and increasing number of techniques for monitoring the condition and performance of plant. It is important to be able to select those techniques which are really useful and economically beneficial. Work has been done on the relation between the reliability and the inspection signal, whether this be for equipment which fails in an obvious manner or for equipment failure which can be predicted only from a monitoring signal.

LOUGHBOROUGH—U.S. LINKS

THE DEPARTMENT HAS LINKS WITH institutions in the U.S. in several ways. At the level of student interchange the department cooperates with Georgia Institute of Technology in running a Masters course in particle technology. This is based at the Loughborough end on the Particle Technology option within the M.Sc. course in Advanced Chemical Engineering. There is an exchange of students with six months being spent in each institution. This scheme is now in its tenth year. There is also intervisitation of staff particularly, but not exclusively, in the particle technology area.

Another link is with the University of Delaware. Students from Loughborough take the Masters course at Delaware. This is another tradition which is about ten years old. Currently there is one Loughborough student at Georgia Tech. and one at Delaware and one Georgia Tech. student at Loughborough who took the Masters course in Plant Engineering two years ago and is now doing a doctorate.

At the level of continuing education the department has for some years run post-experience courses in particle technology in the U.S. in cooperation with the departments of chemical engineering at City College, New York, and at the University of Houston.

Finally, at the level of research the department has numerous links with the American academics and industrialists in the particle technology field and is a founder member of the recently formed International Fine Particle Research Institute.

FINANCIAL SUPPORT

THE BASIC SOURCE OF finance for U.K. graduate students is the Science Research Council, which corresponds broadly to the NSF. The SRC funds studentships for both Masters and doctoral courses. These student grants cover the student's bare living costs and pay his fees, but they are well below industrial salaries.

The SRC also awards research grants, which may include support of Research Assistantships. Until quite recently the rules did not permit a Research Assistant on a SRC grant to work for a doctorate, but this restriction has been relaxed. As a consequence, since the Research Assistantship's salary is closer to an industrial one, there is a growing tendancy for doctoral students to be supported in this way.

Another basic source of finance is industrial research grants, which again may fund Research Assistantships. Students from overseas are often supported in this way. □

REFERENCES

1) Freshwater, D. C. and Lees, F. P., Chem. Engng. Educ., 6, 190, (1972).