

AD-A089 767

OFFICE OF NAVAL RESEARCH LONDON (ENGLAND)
EUROPEAN SCIENTIFIC NOTES, VOLUME 34, NUMBER 8, (U)
AUG 80 W V BURT, D J PETERS

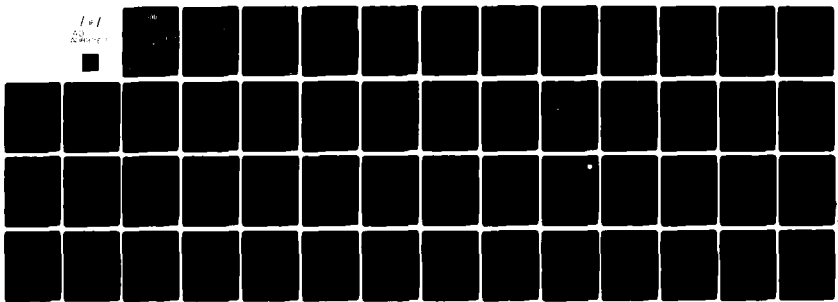
F/6 5/2

UNCLASSIFIED

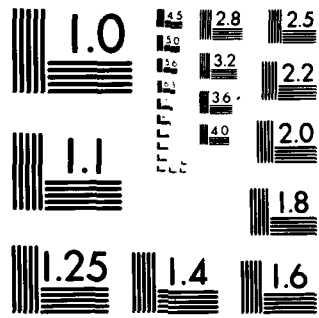
ESN-34-8

NL

1-1
25



END
DATE
FILMED
11-80
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

5c
AD A 089767

OFFICE OF NAVAL RESEARCH
LONDON

LEVEL *II*

12

EUROPEAN SCIENTIFIC NOTES

ESN 34-8

31 August 1980

DTIC
ELECTE
SEP 30 1980
S C



Distributed by the
Office of Naval Research Branch Office,
London

This document is issued primarily for the information of U.S. Government scientific personnel and contractors. It is not considered part of the scientific literature and should not be cited as such.

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

ODG FILE COPY

80 9 29 037

scientific staffs of the United States Air Force's European Office of Aero-space Research and Development and the United States Army Research and Standardization Group. Articles are also contributed by visiting Stateside scientists.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DDC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	<input type="checkbox"/>
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	

**EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON**

Edited by Wayne V. Burt and Don J. Peters

31 August 1980

Volume 34, No. 8

BIOLOGY

Biological Effects of Non-Ionizing Radiation

J.B. Bateman 369

**COMPUTER
SCIENCE**

Computer Technology in Israel

R.E. Machol 371

EDUCATION

Educational Innovations at the UK's Open University

T. Duffy 372

ENGINEERING

Acoustics at the Technical University of Delft

T.C. Cheston 376

Antennas, Image Processing, II-V's, and Other EEE at Sheffield

I. Kaufman 377

Professor Lueg of Aachen's Institute of Electronics

T.C. Cheston 380

Semiconductors at T.H. Aachen

I. Kaufman 382

**MATERIALS
SCIENCE**

Coatings Technology at the Chemical Congress

W.D. Bascom 385

Composite Research at the DFVLR Institute for Structural Mechanics

G.F. Zielsdorff 389

Fifth International Conference on Erosion by Liquid and Solid Impact

A.M. Diness 391

Molten Spray-Formed Coatings An International Conference

H. Herman 394

Plastics Technology in Ireland

W.D. Bascom 395

Personnel Neutron Dosimeters—Developments in Italy and Israel

M.A. Greenfield 398

**MEDICAL
PHYSICS**

A Thoroughly Modern Merlin—The Magic Modeler of Shelf Seas Currents

W.V. Burt 401

The Department of Maritime Studies—Liverpool Polytechnic

W.V. Burt 404

The Department of Oceanography at the University of Southampton

W.V. Burt 406

OCEANOGRAPHY

ESN 34-8 (1980)

**OPERATIONS
RESEARCH**

How Many Therms to a Degree Day? R.E. Machol 408

Operations Research at the
Pupin Institute in Belgrade. R.E. Machol 411

NEWS and NOTES

News 414

Personal 415

ONR Cosponsored Conferences 416

ONRL Visiting Scientist Program 417

ONRL REPORTS

ONRL Reports 418

European Scientific Notes is a Class I Periodical prepared and distributed by the Office of Naval Research London in accordance with NAVEXOS-P-35. Prepared and submitted by the scientific and technical staff.

W. J. CondeLL
W. J. CONDELL
Chief Scientist

P. F. Gibber
P. F. GIBBER
Captain, USN
Commanding Officer

Dr. W.V. Burt
Mr. T.C. Cheston
Dr. P. Fire

Dr. M.A. Greenfield

CDR J.A. Holt
Dr. I. Kaufman
Dr. R.E. Machol

Dr. J.R. Neighbours
CDR S.E. Sokol
LCDR C.H. Spikes

Oceanography & Meteorology
Underwater Acoustics & Radar
Communications and Informa-
tion Theory
Radiological Science &
Medical Physics
Undersea Systems
Electronic Engineering
Operations Research &
Systems Analysis
Physics
Weapons Systems
Environmental Systems &
Military Oceanography

BIOLOGY

BIOLOGICAL EFFECTS OF NON-IONIZING RADIATION

IMPI is not, as one might imagine, the pet name of Maxwell's demon. It stands for International Microwave Power Institute, an organization which concerns itself, in its own words, with "non-information, non-communication applications" of microwave energy. The impish exclusions would seem to preempt the whole field. To the chicken in the microwave oven, the medium is the message with a vengeance: "get cooked."

Not so, they assure us. "It's (sic) fields of interest", continues the background statement, "therefore include all industrial applications of microwaves, including microwave heating, chemical and biological effects, and advanced scientific and power transmission systems using microwaves." A large area indeed, and one within which both scientific and technological concepts are still mobile. The free flow of information among all levels of involvement, from basic research on lipoproteins to the marketing of plastic bags, is thus vital. This is what the IMPI sets out to promote through its *Journal of Microwave Power* and through sponsorship of conferences that cater to both scientific and commercial interests.

The 1-day seminar organized by Prof. E.H. Grant and Dr. R.J. Sheppard (Queen Elizabeth College, Univ. of London) and chaired by Prof. J.C. Gallagher (Bradford Univ.) provided an example of IMPI sponsorship. Exemplary it was, and at the same time unique, being the first such venture undertaken by the newly opened (January 1980) UK office of IMPI under the management of Mr. Percy Giles. Some 60 people gathered at a famous public (i.e., private) school in Croydon, Trinity School, to listen to seven lectures under the title "Biological Effects of Radiowaves and Microwaves." Three of the lecturers sketched the physical principles in simple terms and addressed the question of microwave safety standards seen in the light of recent research. Two speakers, themselves active in clinical research and practice, reviewed their chosen fields: one, the influence of induced currents on wound healing;

the other, hyperthermia in cancer therapy. Cooking, a more extreme form of hyperthermia, also came into the picture, though there was little biology in the lecture on microwave ovens and still less in the one that surveyed—or rather, listed—industrial-heating applications.

All the talks were of necessity geared to the motley qualifications of the audience. Judged from the listed affiliations, it included appliance manufacturers; gas, coal, and electricity board representatives; borough and county health authority officials; food processors and retailers, with a sprinkling of research students and medical people. The aim was to educate, and perhaps to reassure, people whose business it is to be aware of the uses and hazards of radiowaves and microwaves. For this reason the more thorough treatment that the subject has received at other gatherings was neither possible within a single day, nor desirable. Those proceedings have been duly reported (*ESN* 29-12:546; 31-11:433; 32-3:85; 32-11:363; 32-12:404; ONRL Conference Report C-14-77); it is necessary here only to select points illustrating new departures. The clinical and industrial material included little that would be new to *ESN* readers.

The most significant development since the publication of the articles just cited has been a refinement of safety standards recommended in the United States and in Western Europe. Adoption of these standards, embodied in a draft directive for the European Commission would of course make their acceptance obligatory in the United Kingdom.

The experimental basis for the recommendations was lucidly stated by Grant and elaborated by F. Harlen (National Radiological Protection Board). There must of course be acceptable underlying principles. These are still anchored to the idea that the dangers of excessive exposure are thermal in nature. However, whereas originally it was thought sufficient to stipulate that a "perceptible" heat load should not be greatly exceeded, several limitations of the ability to perceive potentially injurious warming are now recognized. The new criterion is objective, with the aim of avoiding a rate of total power deposition, in the whole body continuously exposed, greater than about half the resting metabolic rate, or 0.4 W.kg^{-1} . This does not solve

the problem in practice, first because it is very difficult to measure the overall rate of absorption, and second because it is necessary to know more about preferential absorption at certain body sites and about mechanisms of heat dissipation.

Upon the foundation of this general principle, the experimental data from which the quantitative recommendations for safe exposure limits have been derived were given as being of three kinds. Models or "phantoms" have been built with internal structures having electrical and thermal properties resembling those of the human organs, and the patterns of heating have been measured as a function of various parameters. Similar measurements have been made on small live animals and attempts made to extrapolate the results to man. Finally, *in vitro* study of the dielectric properties of biological macromolecules in aqueous solution is beginning to furnish the molecular basis upon which any full understanding of radiowave and microwave effects must rest.

The most important conclusion drawn from these studies is not new, but it is now more readily given quantitative expression. It is that the heat load and its spatial distribution must be dependent on the frequency of the incident radiation. At certain frequencies, for instance, the body will behave as a half-wave or quarter-wave antenna. At others there will be internal resonances. The depth of penetration will be frequency dependent. Also at some frequencies energy will be deposited preferentially in the water immediately adjacent to the cells and organelles of particular anatomical elements.

The resulting picture is complicated, yet, in the present state of knowledge, sketchy. It is no simple task to arrive at a set of safety rules that can be recommended with any confidence. Harlen, indeed, warned against undue refinements which would make safety regulations unworkable. The permissible exposure thresholds that are being advanced by the American National Standards Institute (ANSI) for the time being, in mW.cm^{-2} , are: Up to 3 MHz, 100, falling as $900/f^2$ to 1 at 30 MHz; 30 to 300 MHz, 1; 300 MHz to 1.5 GHz, rising from 1 to 5; 1.5 to 30 GHz, 5. The European Commission's values are slightly different. They specify that threshold exposures must not be exceeded when averaged over any given period of 0.1 h.

Inevitably, the possibility of a quite different fundamental approach had to be acknowledged. *ESN* readers know that in Eastern-Bloc countries biochemical, clinical and subjective signs of disturbance associated with exposure to microwaves are given greater weight than calculations of heat load. Such disturbances are said to be produced by exposures far below those that engender significant heat load and the permissible exposure rates recommended on this basis are correspondingly lower than the ANSI standards. The Soviet occupational standard, for instance, is 0.01 mW.cm^{-2} for continuous exposure to microwaves during the working day, compared to the 5 mW.cm^{-2} based on heat load.

The meeting provided ample opportunity for mental doodling, and it was interesting to reflect on the prevailing attitudes to this long-standing disparity, as Dr. Servantie called it on another occasion (*ESN* 32-3:88). Not altogether irrelevantly I recalled St. Paul's letter to the Romans and it occurred to me that if he were to address a gathering of scientists he might add a third admonition to a minor variant of the familiar two: "Abhor that which has been shown to be wrong, cleave to that which has been proved correct, and preserve an open mind toward that which is still uncertain." The scientists addressing the meeting obeyed all three injunctions irreproachably. One cannot fault a physicist for giving greater weight in practical matters to arguments from well-tried physical principles, if at the same time he presses, as Grant did, for further research on phenomena, real or imaginary, for which satisfactory explanations are at present lacking. It is different for denizens of the marketplace, who all too readily adopt a condescending attitude. They evince an amused, but hard-headed, disinclination to be influenced by neurotic complaints and a distrust of anything from politically unsavory sources. One can only hope that the advocates of dispassionate research will prevail. (J.B. Bateman)

COMPUTER SCIENCE

COMPUTER TECHNOLOGY IN ISRAEL

Elbit Computers Ltd. is a company of moderate size—some 1,500 employees, mostly in and around Haifa. The first part of the name of Elbit comes from that of its parent company, Elron, an Israeli holding company which owns 31% of its stock. Half of the rest is owned by CDC, a major American computer manufacturer, and the other half by the public (traded on the Israeli exchange). Elbit itself has some daughter companies, one called Elrand (half owned by Rand, a software company in California, and half by Elbit) and another called Eltech, of which Elbit owns 66%. Elrand is entirely concerned with software, and Eltech manufactures printed circuits (but not chips). The second half of Elbit's name is, of course, a familiar buzz word in computers, but its actual origin is from a Hebrew word meaning "defense"; Elbit still does about 60% of its business with the military and only 40% commercially.

I met with Rapahel Mor, Vice President, Military Marketing & Operations, and with Moshe Carmeli, head of the Commercial Software Department, at Elbit's major installation (with half of all its employees) in the Advanced Technology Center in the southern suburbs of Haifa. This advanced technology center is much like the research parks in many American cities. It was set up by the municipal government of Haifa, with funding from the Israeli government, for scientifically oriented industry. It is 8 km from the Technion, Israel's first engineering school, which is one of its primary drawing cards; as in the US, Haifa is in competition with other cities in attempting to attract desirable, research-oriented light industry.

I asked Mor why Israel is in the computer business, and he said that computers represent a technology more than a product, a technology which Israel cannot afford not to participate in. Thus, it is desirable for Israel to market computer systems, and Elbit wishes to market them for reasons of profit. Theoretically one should be able to purchase all the necessary components of such a system from other manufacturers and then sell the completed system, but in practice an

organization attempting to do so would be at a significant disadvantage. Elbit has been quite successful in marketing such systems internationally, and has sales offices in Britain, France, and Germany. They were in the minicomputer business as early as anyone—in 1967 was producing a first-generation mini with 4k of storage. The second-generation computer, code named CR-17, came out in 1974, and the present third-generation computer, the PACT, has 128k CMOS storage and 900 ns cycle time, with a 600 ns option. A minimal system weighs about 20 kg, and with CRT terminal, communication controllers, some peripheral storage, and appropriate software, sells for about US \$25,000. (People don't quote prices in Israeli currency because their terrible inflation makes prices obsolete in a matter of weeks). They prefer, however, to sell a slightly more expensive minimal system including a couple of 10-megabyte discs, a couple of floppy disks, a printer, several terminals, etc. They manufacture none of these peripherals except the terminals.

Because of their relationship with CDC, which is both technical and financial, their computers have been compatible with CDC software. The old CR-17 model was in fact sold in the US under a CDC label, and a few are still being sold to people who have the appropriate software which they don't wish to rewrite. The PACT is widely compatible with CDC software, but not with IBM software. The next generation of Elbit mini's, a new and more capable machine which will be available shortly, will be fully compatible with IBM software. I was told that the hardware of PACT itself was virtually identical with that of the CDC system 18, and that the software of PACT was completely compatible except for about three instructions; but the PACT is more compact and the Elbit people felt that it was a better computer.

Elbit sales totaled about \$33 million last year, and will be bigger this year. Almost 50% of this was outside Israel, which is important because of their need for foreign currency. In their military work they sell systems for weapon delivery, navigation of combat aircraft, tactical trainers, war games, ELINT (electronic intelligence), and CCC (command,

control, and communications systems); in their commercial work they sell fiber optics, antennas, RF components, and computer software as well as hardware. Finally, they manufacture terminals at the rate of 400 per month, sold either alone or with a minicomputer which makes it a "smart terminal." These terminals are used to access a large mainframe computer, usually IBM or CDC.

There is remarkable internationality in the manufacture of computers these days. I noticed "Taiwan" on some of the electronic components in the plug-in units which constitute the heart of the computer. Apparently the chips which hold the computer logic are purchased from US manufacturers such as TI and then sent to Taiwan where they are encapsulated in plastic before being delivered to Elbit in Israel.

Carmeli, like so many people with responsible positions in the computer business, is a startlingly young man, supervising 42 software people, of whom about one third are doing continuation work with the old system, one third are doing development work with the new system, and one third are in support (documentation and the like). As indicated above, the old system uses basically CDC software, while the new system uses a good deal of IBM software. Development implies, among other things, an operating system (without which the new system is unsaleable), and I was impressed by the confidence with which Carmeli assured me that it would be ready on time.

I asked Mor why they did not develop some computer systems for Israeli banks and other commercial operations—I had noticed that bank service appeared to be slow and inefficient. He assured me that they would be happy to do so, but that there was no demand for such systems—primarily because Israel is desperately short of capital, and has little incentive to develop capital-intensive automated systems in the commercial sector. Most of their systems are sold to the military, or to foreign markets, where the availability of capital is not so much of a problem.

I was impressed with the engineering competence at Elbit, and with the performance of their product. I had not expected that such a small country could compete in such a business with the industrial giants, but Elbit Computers Ltd. appears to be doing very well indeed. (Robert E. Machol)

EDUCATION

EDUCATIONAL INNOVATIONS AT THE UK'S OPEN UNIVERSITY

Editor's Note: Earlier *ESN* articles (23-10:276, 27-2:42, 32-6:207) described the history, development, and operating policies of the Open University. This article brings the reader up to date.

The Open University (OU), Great Britain's unique innovation in higher education, is located in Milton Keynes, approximately 50 miles north of London. Milton Keynes is the first of England's designated "new cities" and was chartered so in 1965. It is currently a rural area of 22,000 acres encompassing 12 or so villages. However, the city is undergoing a planned development with an expected population of 150,000 by 1990. When the city is developed, the university will be on the outskirts. In terms of sightseeing, Woburn Abbey—home of the Duke of Bedford and housing the largest game preserve (including a "wild animal" park) in Great Britain—is only a 5-minute drive from the university.

Part of my purpose in visiting the university was to learn about its unique educational approach and the educational research being carried out in support of that approach. The university has certainly been successful. It was chartered in 1969, and the first students arrived in 1972, only eight years ago. Today with an enrollment of 78,000, it is one of the largest universities in Europe. The goal of the university as specified in its charter is to "provide opportunity at both the undergraduate and postgraduate levels of higher education to all those who for any reason have been or are being excluded from achieving their aims through an existing institution of higher education." This charter, along with the firm intent of providing academic standards equivalent to those of existing residential universities in the UK, has provided the challenge to OU.

In meeting the charter requirement of providing broad opportunities, the university has taken several steps. First, there are no prior education or testing requirements for entrance. The only restriction, outside of certain quotas, is that enrollees must be UK residents over the age of 21. The age restriction is aimed at minimizing the extent to which the OU

might attract students who would typically apply to more traditional universities. Thus OU can offer greater opportunity to the working adult. Second, tuition is low, an average of \$200 per course, and only a token portion of that tuition is required at the onset. Students are provided a 3-month trial period to see if they can cope with the course along with their job and family requirements. Only after that trial period is the full tuition payment required. Finally, the courses are designed for home study; there are no undergraduate students at the OU campus. Thus while there is a full campus with research facilities at Milton Keynes, there are no classrooms, student facilities, or students. It is truly a researcher's paradise and, indeed, faculty members are expected to spend fifty percent of their time carrying out research programs. The remainder of their time is spent in course development.

Low-cost correspondence instruction available to most people meets the charter requirement, but is certainly not innovative. The uniqueness of the OU system and the part which has resulted in the achievement of high academic standards is the course development and delivery process. The money savings from the reduced physical plant requirements and the time savings resulting from the faculty members not having to meet regularly with students have been poured into the course-development effort. The courses presented by OU may be characterized as multimedia ones involving intensive student involvement and activity and providing ready access to remedial and tutorial assistance.

A correspondence text authored by OU staff members forms the core of the course. The text is supplemented by a 25- or 50-minute weekly television broadcast over the BBC open airwaves and may be further supplemented by BBC radio programs or audiocassettes, field and laboratory work, homework assignments, practice examinations, and a 1- or 2-week period of classroom instruction at a neighboring university. Thus, the media for a course may include text, instruction through audiocassettes and television, hands-on exercises, as well as face-to-face tuition. The specific combination of media will depend on the specific course requirements as well as resource availability (television time, total money requirement, etc.).

The above multimedia approach is backed up by assistance provided locally at study centers. The OU has provided over 300 Study Centers throughout the UK, usually by renting space in the evenings and weekends at local schools. Each study center contains necessary reference materials, equipment for carrying out special laboratory experiments and computer terminals for both instructional use and for some course management, e.g., test scores. Most importantly however, tutors who are generally staff members at nearby universities are hired to work on a part-time basis at the study centers. Every student enrolled in an OU course is assigned to a study center and to a specific tutor at the center who serves as a counselor. The primary task of the tutors, however, is to serve as the OU representatives for specific activities: administering tests, holding group discussions, directing laboratories, and providing individual assistance. At a study center there is a tutor representative for each course in which students from that center have enrolled. Of course, a tutor will represent more than one course if only a few students are enrolled. On the other hand, high enrollment will result in the assignment of more than one tutor to the study center. Before assuming responsibilities, a tutor will have reviewed the entire course and will have been provided with an orientation package from the course developers providing guidance for specific segments of the course.

It is this approach, local learning centers operating in conjunction with centrally produced correspondence materials, which is perhaps of greatest relevance also to military training. The military, like the OU, have "students" widely scattered with many in isolated locations. Also like the OU, the military need to provide a variety of training programs to these people. As it now occurs, the training is either strictly correspondence instruction or strictly classroom instruction. The OU has found that a combination of the two approaches is more effective. The correspondence approach reduces the instructor requirement, which is of considerable importance to the military in these days of manpower shortfalls. The study centers provide the opportunity for laboratory work (which is even more vital in training courses) and for individual remedial work,

both of which are serious shortcomings of the usual correspondence training. The growing use of interactive computing systems would eventually further reduce and potentially eliminate the instructor requirement.

OU students are expected to be working adults and thus they may only enroll in two courses at a time. There is a guideline that courses should require approximately 14 hours of work per week, inclusive of all course presentations, homework assignments, and expected student study requirements. To maintain some control over the student's pace of work, course materials are mailed in segments (every four to six weeks) and homework assignments included in the course material have specific deadlines for completion and return to the university. Obviously examinations also control the pace of learning and the OU system involves "continuous" assessment. Courses involve frequent multiple choice, computer-scored testing as well as essay testing scored by tutors.

One of the early guidelines at the OU, which has been substantiated through later evaluation, was that with the individual isolation resulting from homestudy, the courses must be designed to involve the student actively in his coursework. Thus, there is an emphasis on laboratory and field work. "Home experiment kits" are provided with every science and technology course and with many courses in the other faculties. The kits are designed to be both interesting and challenging. For a biology course a brain is issued to each student for laboratory dissection. A course on computers involves the issuance of a microcomputer to each student. For another science course, each student is provided with a laser, holographic film, and other equipment necessary to produce a hologram.

More recently the University has added the opportunity for classroom instruction to supplement some courses and provide further student involvement. During the summer, OU staff members are dispersed to universities around the UK to give an intensive week of full-time instruction in a traditional university setting. The week is spent in residence and attendance is required. This approach is believed to develop student camaraderie as well as to provide exposure to and identification with the university experience. It also provides the staff members the opportunity to get back into direct teaching.

Like the delivery system, the instructional development procedure demonstrates the OU's innovative approach to education. A course is developed over a period of three years by a team of technical and academic experts. The team varies in size from three people for a small course to 30 for a major foundation course. In addition to the subject-matter academics, committee membership may include BBC producers, educational technologists, editors, and graphic designers. A course "by committee" sounds initially like the process would be chaos and the result a watered-down curriculum by compromise. Chaos is perhaps appropriate for describing some of the efforts; however, the curriculum is by no means watered-down. The OU courses are of extremely high quality and have received acclaim throughout the UK. Many of the course texts have been adopted at other universities.

The success of the effort, I think, lies in the interesting mixture of group and individual efforts. After the course strategy and course units have been decided upon by the committee, individuals (up to 3) are assigned to prepare specific units in their areas of expertise. They receive full authorship for their work, with their names and sometimes their pictures being on the unit texts. For producers there are the normal credit presentations associated with the showing of their television and radio programs. Thus, the writers are authors of textbooks and subject to all the pressures and concerns of both student and peer acceptance associated with authoring. Indeed, the review process is even more severe because of the OU "committee" system. An author's first draft is reviewed by all committee members. Since all have an investment in the course, the review is quite detailed. The reviews are then thrashed out in committee meetings (much like being thrown to the wolves) before the author is finally ready to write a second draft. After all second drafts have been completed the course is sent to an outside consultant reviewer for comments. The recently completed Cognitive Psychology course, for example, was reviewed by Prof. Don Norman from the University of California, San Diego. The result of this high-pressure system is both a high-quality product and severely worn nerves. The extreme effects of the process on the individuals are widely recognized. One study of the system described authors as passing through extreme mood changes as well

as engaging in avoidance behavior like psychosomatic illnesses and taking "essential" trips as the due dates for their drafts approached. The process of arriving at decisions is chaotic. Since it is a university setting, academic staff members do have academic freedom in preparing a course segment; however, the committee has a responsibility to establish a consistent approach in the use of media and the instructional strategy throughout the course. Thus there is continuous negotiating, with individual authors having some unspecified degree of freedom to ignore committee decisions. While this course planning process does not follow any instructional-system development model, it appears to be very successful as well as traumatic. The very fact that serious attention is given to front-end planning is itself unusual for an academic course.

In addition to the review process, the committee effort insures that appropriate front-end planning is carried out. An outline of the course is completed; learning strategies, e.g., didactic or discovery, are decided upon; the use of the various media is identified; and the assumed entry skills of the students are discussed and agreed upon. The decisions are based on the subject-matter expertise and curriculum-development experience of the committee members as well as on evaluation data on the successes and shortcomings of already existing related courses.

The development effort does not end with the completion of the course package. In some cases a course will undergo developmental testing, i.e., a closely monitored administration of the course to a small group of students. This formative evaluation process has proven very successful. Data documenting the approach and the effectiveness of alternate strategies have been widely published by members of the Institute of Educational Technology. Unfortunately, however, the process is expensive, and therefore fewer courses are being authorized funds for developmental testing. For all courses, a maintenance team is assigned to monitor the effectiveness, attend to new developments in the course topic area, and recommend modifications or elimination of the course when necessary.

A total of 28 full-year courses and 90 half-year courses have been developed and are being presented by the OU. This is roughly 75 percent of the expected steady-state condition. The

courses have an average life expectancy of 6 years and enrollment averages about 1,500 per first year course and 400 for the other courses. The undergraduate program includes courses in the arts, social sciences, mathematics and computer science, science, education, and engineering technology. While most of the emphasis is on the undergraduate courses, there is a growing emphasis on continuing education. In addition to general-interest courses, this program will offer many professional courses for the experienced tradesperson or professional. There is also a postgraduate program with both master's and doctoral degrees offered. There are, however, no formal courses, but rather supervised research and an individually designed tutorial program.

The success of the OU program in providing stimulating distance teaching has been great. As I said at the outset, it is one of the largest universities in Europe. There are, however, other indicators of success. Most distance-teaching programs have high initial enrollment but sustain a very high dropout rate. The OU, with the low tuition and a student body of working adults, has surprisingly low attrition. There is only a 25 percent attrition during the trial period. Of these people who pay the full tuition of approximately \$200, 80 percent complete the first course and 70 percent complete the upper-level courses, which I think is a very good record.

The interest in the OU system expressed by other countries also speaks well for the program. The OU has assisted in setting up distance-teaching programs in Israel, Iran, and Pakistan. The OU courses have been utilized in many other countries and many of the texts have been translated into Italian, Spanish, Dutch and Danish.

The great expense involved in developing and delivering OU courses is offset in large part by the savings accruing from large course enrollment and the multi-year life expectancy of the courses as well as the previously mentioned savings from not having to provide a physical plant for a student campus. Nonetheless the OU budget this year for recurring expenses is \$110 million, 10 to 15 percent of which comes from student fees. More stringent budgets, expected in the future, have led to considerations for ways to cut costs without reducing quality.

The television production and presentation budget has come under the most fire in the economy move. The BBC contract with the OU consumes 17 percent of the university budget while it provides only 10 percent of the educational materials. More significant than the amount received per pound paid is the concern over the effectiveness of the BBC materials. The BBC is contracted to produce 300 television and 300 radio programs, each of 25 minutes duration, every year. In addition, they are to broadcast over open airwaves 30 hours of television and 35 hours of radio per week for 40 weeks. While the programs are of the highest quality, only 50 to 60 percent of the students in a course view any one program. This low viewer rate, while it can be explained, weighs heavily against BBC when the financial ax is waved. The low viewer rate has to do, in part, with the broadcast times provided for the programs—between 6:00 and 8:00 a.m. on weekdays and 7:00 a.m. to 2:00 p.m. on weekends. In addition, however, the "openness" of the OU is a factor. The OU cannot (or will not) be restrictive in terms of an individual's financial condition or where he lives. Since some people cannot receive the BBC transmission or cannot afford a television set, the TV programs must always supplement the rest of the course. In course assessment, questions cannot be asked which would have required TV viewing. Thus with students knowing they will not be tested on the programs and with the inconvenient presentation times, there is little incentive to view.

As has been described to me, however, the television programs have played an invaluable public relations role. Open University is known and highly regarded throughout the UK primarily through its television programs. This increases enrollments and provides public support. In addition, however, the programs play an essential role in the pedagogy of many courses. Many science and engineering courses would simply not be credible without the capability of demonstrating complex laboratory exercises (beyond what can be done with the home-experiment kits). In addition, the programs can significantly contribute to arts courses in presenting examples of artistic styles in painting, architecture, and the other visual arts as well as comparisons of orchestras or musical instruments.

The OU is monitoring developments in videodisc technology for possible cost savings in their broadcast systems. For now, however, authors are being encouraged to consider audiovision, i.e., audiotape supplement to a graphic text, as an alternative media. In addition, audiocassettes are likely to replace radio broadcasts in the near future.

My stay at OU was with the Institute of Educational Technology (IET). The IET was begun to provide educational research and advice (service) for the OU program. In a later article I will describe the research work as well as the practical experience in applying research findings. As my description of the OU system indicates, the university is a potential panacea for the educational researcher. Virtually every research issue outside of developmental education can be addressed, at least theoretically, with experiments having high ecological validity. (Thomas Duffy, Naval Personnel Research and Development Center, San Diego, CA)

ENGINEERING

ACOUSTICS AT THE TECHNICAL UNIVERSITY OF DELFT

The Technical University of Delft has a modern campus at the edge of town. It has about 10,000 students of whom some 500 are in the Department of Physics. My host for the visit was Prof. A.J. Berkhout, head of the Acoustics Group in the Department of Physics. The Acoustics Group has a permanent staff of 7 professionals and, at this time, 6 additional members who are supported with government or industrial grants. Berkhout's background is in seismic work and he has written a book on seismic imaging that is due to be published this summer.

I arrived at an interesting moment; undoubtedly it was not a very opportune moment for Berkhout, but it was interesting for me. Berkhout, with members of his team, had been up most of the night pumping chirped (frequency-modulated) acoustic pulses into Delft's brand-new concert hall. The hall had been readied for the following week with no less than the Queen coming down to

open it with official ceremonies. At the last moment it was discovered that the acoustics were unacceptably poor. Berkhout was brought in. He came with his acoustic-pulse generator and digital-recording equipment and programmed his own friendly computer—and then used a little magic. He discovered that some wall coverings gave much too much attenuation. Subsequent to my visit I heard that the whole operation had indeed been most successful. When the reflection coefficients were increased, the acoustics improved and the concert hall gave a good response. Berkhout explained to me that the absence of echoes is quite undesirable in a concert hall, but that the actual desirable reflective characteristics are different for the different types of music or speech. Since then, Berkhout has been asked to consult on another concert hall which is being built.

Berkhout and ir. J. Ridder discussed the work of the Acoustics Group. A considerable amount of effort is devoted to echo acoustics where active systems are analyzed that use what they call synthetic-focusing and which they define as a class of imaging techniques where basic data is collected from a discretely sampled aperture and processed by computational means, usually digital, to produce (reconstruct) an image. Such techniques were discussed recently at a conference in London, "Signal Processing in Ultrasonics" (ESN 34-4:206). In some form or other, these methods are used in seismic exploration on land or offshore with towed arrays (ESN 34-4:179); in nondestructive testing (ESN 34-4:206); in medical diagnostics; and in "synthetic aperture radar" except that in this last application the aperture is sampled continuously using microwaves. The well-known CAT (computerized-axial-tomography) scanner uses this technique but the radiation there is x-ray whereas here we are interested in acoustics. Berkhout and Ridder use ultrasonics, 1-10 MHz, for medical diagnostics. These relatively low frequencies offer the advantage that the signal may be digitized and recorded, retaining phase information. During the reconstruction stage allowances can be made for unknown inhomogeneities in the medium (i.e., variations in the velocity of propagation). The calculations use the "backward wave" method where the received signal field which is known over an aperture is projected back by calculations to determine the originating

functions. These methods of sampling the aperture use a large array of elements, where all elements are used to receive. The transmitter also uses all elements, but sequentially, one at a time. A system has been simulated using short pulses (6 cycles/pulse) and a 256 element array. A paper describing this work is about to be published. Experimental work has been started in cooperation with the Erasmus University Medical School in Rotterdam. Data will be digitized and brought to Delft.

Another study undertaken concerns silting and silt detection which is of considerable importance to Holland with its vast system of harbors and waterways. In the proposed system holes will be drilled at 1 km intervals. The local acoustic velocity of propagation will be obtained from the core, and propagation characteristics will be calculated. The results will be compared with measured propagation from hole to hole. Agreement will signify substantially unvarying strata.

Passive air acoustic investigation are directed mainly toward traffic and industrial noise control. One study looks at propagation through the air in the presence of wind and wind gradients and uses numerical techniques. Noise from buildings is examined and a highly directive acoustic antenna has been developed for this purpose. It is 10 m in length and operates from 500-1000 Hz, giving a broadside beamwidth of about 2° at the highest frequency. The beam can be steered electronically. The Acoustics Group in Delft is unique in Holland and has already established itself in the field of concert hall design and ultrasonic medical diagnostics. (T.C. Cheston)

ANTENNAS, IMAGE PROCESSING, III-V's, AND OTHER EEE AT SHEFFIELD

The buildings may be old on the outside, but a number of the laboratories on the inside are new and have the latest in research equipment. Moreover a lot of the research is very much up to date. That's Electronic and Electrical Engineering (EEE) at the University of Sheffield.

In 1965, while I was delivering some lectures at Sheffield, my very gracious hosts were two individuals who were lecturers in EEE at that time: Dr. F.A. Benson and Dr. P.N. Robson. When I returned to Sheffield recently,

I was therefore returning to visit old friends, for both Benson and Robson are now professors and the senior persons in the department. Benson, a Fellow in IEEE, is head of the department and also has been serving as dean of engineering (an elected position). Robson, who heads the research in solid state devices, has spent time at Stanford University and is well known for contributions in the microwave solid-state device area. The department has also recently elevated Dr. G.S. Hobson, whose field is circuits, systems and microprocessor applications (and whom I did not meet) to the rank of professor.

Sheffield, a city with a population of about 600,000, lies at the foot of the Pennines, the upland spine of northern England. It is around 150 miles northwest of London, in South Yorkshire. (It was in Sheffield that I discovered that Yorkshire pudding actually is not a pudding, but is more like an American popover, baked in the drippings from roast beef.) The history of Sheffield dates back 2,000 years to when it was a Roman station. History buffs may also remember that Mary Stuart, Queen of Scots, was imprisoned in Sheffield castle for 14 years. What caused the city to become one of the leading industrial centers of England, however, was metal working. There is evidence that smiths and cutlers were active in the Sheffield area as early as the 14th century. The city eventually became world renowned for its outstanding cutlery. (Alas, it is now possible to buy good imported cutlery in England cheaper than can be manufactured in Sheffield.) Sheffield plating (diffusion of silver into copper) was invented by Thomas Boulsover in 1742 and set the standard for quality in metal utensils for about 100 years, until it was supplanted by electroplating processes. The year 1742 also witnessed the invention of the crucible-steel-making process by Benjamin Huntsman, in Sheffield. Sir Henry Bessemer's process of making inexpensive steel in large quantities was first demonstrated in Sheffield in 1856. Then, 58 years later, the process of manufacturing stainless steel was discovered there, to be followed by the development of a malleable type of stainless steel in 1935. In addition to continuing work in the metal working industry, although now at a reduced rate, the city has paper mills, book binderies, and food processing plants, and manufactures

optical instruments, bicycles, chemicals, and even snuff.

In the academic world, Sheffield was one of the first English towns to provide secondary education. University College at Sheffield was created in 1897; it received a charter as the University of Sheffield in 1905.

The Faculty of Engineering of the university is divided into the Departments of Chemical Engineering and Fuel Technology, Civil and Structural Engineering, Control Engineering, Mechanical Engineering, and of course, EEE. The enrollment in EEE includes approximately 250 undergraduates and 40 graduate students. While among the undergraduates only 20% are foreign students, most of the graduate students are foreigners. (I have found this to be typical of English universities. This somewhat unbalanced situation probably arises because British industry has not encouraged students to continue toward graduate degrees.)

As at other English universities, the undergraduate program extends over 3 years, following 2 years of intensive preparation in mathematics and physics by students who have been previously selected through the so-called O-level examinations. Since throughout the 5-year period instructions are limited to principally technical courses, the claim of many British professors that a person graduating after 3 years has reached a level somewhere between a bachelor's and master's degree obtained from an average American university seems quite reasonable.

Research in EEE is in the areas of (1) antennas, microwaves, ultrasound, image processing and transmission lines; (2) solid state devices; (3) medical electronics; (4) electrical machines; (5) computer applications and computer-aided design; (6) circuits, systems, and microprocessor applications; (7) vacuum and plasma devices; (8) weed control by electrical methods; and (9) electro-coating. Areas (1) and (2) are by far the largest. Research in the first area is being performed by what is now known as the Antennas, Propagation, and Digital Image Processing Group (APDIP), headed by Dr. A.P. Anderson. The main theme of the work of this group is long-wavelength data acquisition, digital data processing simulating the parallel processing schemes familiar to optics, and the display of processed images and other

distributions in forms which maximize human interpretation. The group therefore combines the more traditional aspects of antennas and propagation with an unusual emphasis on the complex field data which grew out of holography. Principal support for these efforts comes from a grant from the Science Research Council (SRC). Some examples of the work recently or presently performed by the group are described below.

(1) Microwave image filtering and stereoscopic display. The imaging of small objects using microwaves produces pictures with a significant amount of "noise" because of "background" reflections around the object, the specular nature of the object, and system noise. By the use of Fourier transform and Fourier-domain filtering techniques Anderson's group has produced stereoscopic displays in which the desired image is much more clearly identified because it appears either above or below the plane of the noise.

(2) Three-dimensional target mapping and image display by recording two-dimensional Fourier transforms from each of three octagonal planes of data, using a 2.25 m² scanning unit with automatic scan control and data logging.

(3) Investigation of the properties of superdirective signal-processing aperture functions and application through long-wavelength holographic imaging. This method of restoring essential features to a severely diffraction-limited image has been applied to microwave image enhancement and to the measurement of the aberrations of large microwave reflector antennas.

(4) Application of super-resolution techniques to time-domain reflectometry. This is achieved by Fourier transforming of a signal into the frequency domain, weighting each frequency component by a complex coefficient of a suitable synthetic array whose Fourier transform has a narrower main beam than that of a uniformly weighted array of the same size, and simultaneously giving adequate frequency side-lobe suppression.

(5) Location of buried pipes and cables (metallic and nonmetallic). Here the soil is first characterized by measurement of its complex permittivity vs. frequency. The antenna of a radar system is then matched to the soil. In a typical result, plastic pipes 5 cm in diameter and 0.3 m apart at a depth of 0.5 m have been resolved. The technique makes use of depolarization

of the radiation by cylindrical targets

(6) Development of new techniques for prediction of antenna behavior from measurements in the near-field. The method employs a synthesis approach to obtain the plane-wave response of an antenna by appropriately weighting and summing near-field data.

(7) The application of the volume hologram principle to antenna design and digital image processing.

(8) A specific project to perform large reflector antenna diagnostics.

(9) The development of an imaging array configuration for quasi-real-time underwater applications.

(10) A synthetic-aperture approach for sonic mapping of the seabed.

Somewhat related to the above techniques is the work of Dr. K. Barker in the field of psychoacoustics. Specifically, Barker is trying to determine in detail how persons pinpoint the location from which a sound originates.

For years, Benson and his students have measured propagation characteristics of various transmission-line and waveguide systems. The present work in this area deals with the effect of leakage from braided cables and modeling to determine such factors as coupling from one leaky cable to another.

Perhaps most notable among the solid-state device activities is that two years ago Robson received a grant of £200,000 from SRC to set up a national facility for growing thin films on III-V semiconductors. These SRC Central Facility Laboratories have recently been completed and III-V layer growth by liquid phase epitaxy (LPE) is now underway.

Among the projects in progress in the area of solid state devices are the following: (1) Transport and growth studies in III-V compounds. As an example, abrupt one-sided InP p-n junctions have been grown by LPE with cadmium as the p-type dopant. Junctions of excellent characteristics have been produced and used to perform measurements of electron and hole ionization coefficients in InP. (2) Quaternary layers on lattice-matched InP substrates of In_{1-x}Ga_xAs_{1-x}P_y have been grown by LPE across the lattice-matched range. Measurements are underway on the drift-velocity electric-field dependence as a function of alloy composition, to see if these materials offer advantages over either GaAs or InP. (3) The growth

of low-doped p- and n-type GaAlAs by LPE is being studied and layers suitable for microwave DOVETTs are being attempted. (A DOVETT is a double velocity transit time device invented by Robson.) (4) Two techniques of producing GaAs charge-coupled devices (CCD's) are underway. (5) The group has been fabricating amorphous hydrogenated silicon by rf sputtering of Si in an a-hydrogen atmosphere, for possible use in solar cells. Studies of conductivity, optical absorption, activation energy, solar-cell performance, rectification ratio, hydrogen evolution, and studies of steady-state luminescence and decay as well as other measurements have been performed for materials with a wide range of parameters. Solar cells of 30 cm² have been fabricated with open-circuit voltages of 600 mV. (6) There are studies underway to produce amorphous GaAs with techniques similar to those used for silicon. (7) The production of optical waveguides by deposition of metallic Schottky barrier stripes evaporated on GaAs has been demonstrated and these waveguides are being investigated. (8) There are studies that deal with computer modeling of semiconductor devices of various types. (9) The group has detected narrow-band infrared radiation in thin film parallel plane chalcogenide devices when they are switched to the ON-state and believes that stimulated emission is responsible for this radiation.

Among the medical-electronics efforts carried on by Dr. I.L. Freeston, together with Prof. M.M. Black and others of the University Medical School, is an analysis of respiratory wave forms for infants, to observe possible deterioration in premature babies and also as part of studies into the causes of cot-death. Freeston has also been trying to measure the distribution of conduction velocities in nerves and, during the time of my visit, was initiating work in stimulating nerves by time-varying magnetic fields. Other work by Freeston deals with the use of microprocessor systems in intensive care units, to derive such parameters as the maximum rate of change of blood pressure during a heartbeat and other measurements of value in determining patient conditions. Finally, Freeston has started a new project aimed at using unconventional methods for communicating audio information to deaf people.

In the research dealing with electrical machines sufficient progress has

been made in the steady-state analysis of motor dynamics to permit negotiations with Crouzet, a French company that wishes to utilize some of the results of these analyses to improve their motor designs. There has also been considerable work on the redesign of permanent magnet systems in motors and generators. One result of this work was the successful redesign of an air turbogenerator which boosted the output from 50 W to 400 W in the same frame size.

Among the work in computer applications has been the assembly of a data bank for qualified electronic components approved by the military. As many as 15,000 distinct components or component groups have been characterized and stored in the data bank.

Among the other projects that came to my attention during the visit was an effort aimed at killing fungi but not necessarily bacteria in soil by the use of microwaves of critical intensity and power level and an attempt to kill weeds by electric current. With regard to the latter project, a machine is presently being designed that will travel at 2 1/2-3 mph, will have a power capacity of 40 kW, and will treat 23 rows of sugar beets at one time by killing the weeds in the rows electrically through contact. Finally, under a grant from the Wolfson Foundation, a team is investigating various aspects of electrocoating in chrome-rich solutions.

In summary, it can be stated that EEE at Sheffield is engaged in interesting work by a staff that appeared very enthusiastic. Rather than influencing members of the department to work only where he would like them to work, Benson appears to let capable individuals develop their own interests. As a result, and under his guidance EEE has prospered and is a most active department. (Irving Kaufman)

PROFESSOR LUEG OF AACHEN'S INSTITUTE OF ELECTRONICS

My host for a recent visit to the Technical University of Aachen was Professor Lueg, the dynamic head of the University's Institut für Technische Elektronik. The University moved recently to a large, new, modern compound just outside town. From Lueg's window one has a beautiful view and can see

right across the nearby borders to where Holland, Belgium, and Germany meet. His institute is one of five that are substantially autonomous, all within the Electrical Engineering Department. Altogether, there are some 2,500 electrical engineering students at the university, taking classes at any or all of the institutes. Students attend the university free. They are not required to actually attend classes, except laboratory sessions, but they do have to take examinations that cover the whole range of work and are allowed to resit an examination only once. On the average it takes about 6 years to obtain the title Dip. Ing.

In Lueg's institute there are 40 people involved in research, including 16 doctoral candidates. Funding is obtained mainly from outside agencies and Lueg has been able to get adequate support with about 85% coming from the various government ministries and the rest from industry. His lecture notes on impulse technology were first printed in book form in 1964. The fourth edition of the notes has been in print since 1978 and contains much additional material.

The senior member on Lueg's staff is Dr. C. von Winterfeld, who also runs a division at FGAN, a civilian research institute near Bonn, described in a recent volume of these notes (ESN 34-6:274). Von Winterfeld is about to publish a book on propagation of electromagnetic waves. Here, as at FGAN, he is heavily involved in similar aspects of conformal phased-array research. The 3-D (crow's nest) antenna, mentioned in the ESN reference, was started at Aachen. It is a sphere, randomly populated by 39 loop radiators, and represents an extreme example of a thinned phased-array.

Perhaps it is the vision of treasure hunting that the following evokes, but to me, the most interesting of Lueg's endeavors was what he called his "earth radar": a radar to search below the earth's surface for treasures of old. An old culture on the island of Santorin, north of Crete, was destroyed by volcanic eruption, probably at the same time that Crete was destroyed. The island was deeply covered with ash, and it is hoped that the radar may be able to look through the ash and locate old structures as far as 10 m below the surface. Mr. Lotfi, who is working on this project, is presently trying to develop a matched radiator for this purpose. The system will transmit a 1 nsec-wide delta function (a dc pulse) and hopefully will

be matched over a 10 to 1 band from 1 GHz down to 100 MHz. The antenna has not been defined as yet but an exponential horn-type radiator, without side walls, looked promising and was fed directly from a coaxial cable. The equipment would be a present to the Greek government from the German government through the Ministry of Research and Technology. The method of processing is uncertain as yet, but it may be related to holographic systems as employed, for example, in fields as far apart as oil exploration and nondestructive testing. It was hoped that some viable experiments might be started in summer 1980, and I wish this exciting adventure the best of success.

Research work on phased-arrays was started by Lueg in about 1966. PIN-diode phase shifters were investigated then. Later, von Winterfeld analyzed phased-array edge effects both analytically and experimentally. The radiating elements of a phased-array are closely-spaced and mutually-coupled. This makes matching difficult, especially with scanning, when deliberate changes in phase between elements are introduced, and even more so near the edge, where the element impedance changes. One very effective technique for assessing the impedance match of an array is to measure the radiation pattern of one element with all surrounding elements resistively terminated. Von Winterfeld used this technique to investigate edge effects with an experimental 63-element line array where the elements were spaced by half a wavelength. The array aperture could be arbitrarily reduced in size by covering elements with a sheet of metal. Element radiation patterns of an array having one, three, five, or more elements were obtained in this way for comparison, to study the effects of edges. It was found that the pattern did not change substantially when the array had nine or more elements, suggesting that, in that case at least, edge effects extended some two wavelengths.

Phased-array matching was studied by Dr. Ing. V. Riech. Impedance matching over wide scan angles is normally achieved with structures at the array aperture but such matching is also possible by introducing suitable coupling networks that interconnect the feedlines. One such network was derived by Riech and confirmed experimentally with a nine-element linear array with waveguide feeds.

I was introduced to two assistants of Lueg, G. Zeehausen and Martin Malkomes; both are doctoral candidates. Zeehausen is working on a conformal phased-array system. He has studied the mutual coupling effects between two waveguide radiators on a sphere both theoretically and experimentally. It is planned to extend this work to include many radiators. At this time he is working on an active system and showed me an experimental X-Band model. It consists of 27 radiating elements on the equator of a sphere. A 1:3 switch selects one of the three adjacent groups of nine elements. Each array element uses a Gunn diode as amplifier, giving about 100 mW of power and a nominal gain of 15 dB. Analog-phase corrections are obtained with a varactor that varies the load on the Gunn diode. Only $\pm 90^\circ$ of phase adjustment is possible but this is adequate in the system for beam forming and for a moderate amount of scanning. Scanning is mainly achieved by switching the aperture over the sphere, using only a fraction of the elements at a time. There are some problems of temperature sensitivity still to be overcome.

Malkomes is working with printed circuit radiators. This type of antenna is receiving much attention at this time. It can be produced cheaply and accurately by printing on circuit boards, and, being quite thin and flat, it has a good form factor for many applications. Malkomes is concentrating on shaped, printed patches, many of them rectangular or square, fed from a strip-line on the same surface as the patch. He is working at X-Band and uses a board $\frac{1}{2}$ mm thick. He is investigating the input impedance for different feed geometries, as well as searching for optimal ways of controlling the radiated polarization.

A corridor at the university has been converted into an anechoic chamber. It has an unusual shape, being rather long and narrow, but clever design using buttresses has avoided the possibility of first-order specular reflections. The microwave-absorbing material that lines the room is from Hartman and Irünzweig in Germany.

The visit was interesting and enjoyable. It was impressive to see how Lueg's vigor was reflected throughout the institute. (T.C. Cheston)

SEMICONDUCTORS AT T.H. AACHEN

A recent visit to Aachen (FRG) illustrated clearly to me how generously Germany is supporting universities and research. It also demonstrated how one plus one can be greater than two. For the joint efforts of Prof. Dr. P. Balk, a physical chemist, and Prof. Dr. H. Beneking, an electronics engineer, have resulted in a most productive research endeavor in the field of semiconductor technology and device research. I believe that their combined achievements have been more than twice as productive as either would have accomplished without the other. Their organization is the Institut für Halbleitertechnik (IfH-Institute for Semiconductor Electronics) of the Rheinisch-Westfälische Technische Hochschule Aachen (THA-Technical University of North Rhine—Westphalia Aachen). Another productive semiconductor group in THA is the Institut für Theoretische Elektrotechnik (IfTE—the Institute for Theoretical Electrotechnology), headed by Prof. Dr. W. Engl. (The designation is something of a misnomer, for IfTE is actually an integrated circuits facility.)

THA was founded in 1870 as the first Prussian technical university; it has awarded doctor's degrees since 1898. (These degrees are generally written as "Dr. rer.-nat.") THA now has over 200 "institutes" and professorial chairs. The total student enrollment numbers close to 28,000. Of these, about 6,000 are in liberal arts, 3,000 of these in education; the rest are in technological fields. About 2,500 are foreigners. The university recently consolidated its facilities by moving to a large, new campus at the edge of Aachen, very near the border between Germany and The Netherlands.

Some interesting aspects of the university are that only recently, in 1966, did it acquire a faculty of medicine, and that the hospital/medical school for this faculty is presently being built at a cost that was quoted to me to be of the order of 1.3 to 1.4 billion marks (approximately 750 million dollars). Another interesting fact is that construction at THA is in line with a government regulation now in force that it must be possible to see daylight in all new public buildings. As a result, I saw no blank walls or windowless towers on the campus.

Although universities in Germany receive a lot of their research support from the federal government, they are funded for building and instructional purposes by the state of the Federal Republic in which they are located. THA is in North Rhine—Westphalia.

IfH is one of the institutes of the Electrical Engineering Department (EE) of THA. There are approximately 2,100 students in EE, all working towards their first degree, the Diplom. Formal study for the Diplom requires a period of at least 5 years; the majority of students actually take 6 or more years to complete the program. According to Balk, my principal host, several professors have suggested that the time required to obtain the degree be shortened to be comparable to corresponding programs in the US or UK. So far, however, the faculty has resisted such a change. Since the amount of work required for the Diplom is approximately equal to that of an MS degree in the US, reports from the university that appear in English refer to the Diplom as a master's degree. This is quite reasonable, not only because of the long period of enrollment that is necessary but also because every Diplom student must present the equivalent of a master's thesis or report in order to qualify for graduation. The report must be prepared following research or development carried out on a full-time basis during a large portion of the final academic year.

Approximately 15% of the EE graduates continue their work toward the Dr. rer.-nat. Such persons are not generally considered students, however, for there is no formal course work for the Dr. rer. nat. Instead, they work as full-time employees of the university under a 6-year contract and are paid a reasonable salary. A figure quoted to me as "reasonable" was an annual stipend of DM 35,000, which translates into a figure just below \$20,000. (Because the cost of living in Germany is higher than in most places in the United States, these figures do not tell the complete story.) If a person has been working diligently during the 6 years but has not completed his work for the Dr. rer. nat., it is quite possible that another 6 years might be authorized. While considering salaries, it may be of interest to note that a full professor receives on the order of DM 100,000 per year, and can look forward to receiving 87% of this figure after retirement.

An interesting attitude prevailing in Germany, according to my hosts, is that engineers are looked upon with more respect than are pure scientists.

The Electrical Engineering Department of THA is headed by a dean. Unlike his counterparts in US universities, the dean at Aachen is principally a business manager with very little power for the right to do virtually as one pleases is delegated to a professor directly by the state. The fields of electrical engineering at THA are general engineering, communications, power, nuclear engineering, computer engineering, and solid state electronics. My visit was limited to the two institutes that specialize in solid state electronics, i.e., IfH and IfTE.

It is the function of the institutes of THA not only to perform research or development, but also to organize and teach courses. Balk offers a course in solid-state technology, another in thermodynamics and phase equilibria, as well as courses on reactions of solids, surfaces, and various specialties such as gallium arsenide technology. Beneking gives several courses dealing with transistors and circuits plus a seminar on the fabrication of submicron structures. Prof. Dr. D. Bimberg, who joined IfH only recently, offers courses in material characterization and physical analysis of solids. IfH also has occasional visiting professors. Prof. Dr. N. Klein of the Technion, Haifa, Israel, was with IfH in this capacity at the time of this writing.

IfH has an impressive array of equipment—certainly several million dollars worth. Examples are standard x-ray equipment, clean rooms, chemical and photolithography rooms, furnaces for semiconductor processing, equipment for secondary ion-mass spectroscopy (SIMS), electron spectroscopy for chemical analysis (ESCA), Auger spectroscopy, a scanning electron microscope (SEM) for E-Beam lithography, an SEM with energy analysis (for microprobe applications), and a 350 keV ion implanter. A unit for performing molecular-beam epitaxy (MBE) has recently been ordered. Grants for operating IfH are given on a 3-year basis. The last major grant (from the German Research Foundation DFG) was approved for DM 3 million (1 2/3 million dollars). In addition to this, Beneking has another contract from the Ministry for Research and Technology (which spends a total DM 6 billion annually in various institutions).

There are 19 academic positions in IfH. This includes the chairs for the 3 professors. A large percentage of the remaining 16 will eventually receive the Dr. rer. nat. Every Dr. rer. nat. candidate is assisted by at least one Diplom candidate.

Beneking's work deals with micro-wave and opto-electronic devices and their characterization, Balk's with materials and process technology. One objective of the work of Balk is the fabrication of high-speed, microstructure, metal-insulator-semiconductor (MIS) devices processed at a low temperature. He has also worked extensively on non-volatile information (i.e., charge) storage in the semiconductor configurations MNOS, MAOS, MNAOS. (Here letters designate the layer order. For example, MNAOS is a structure made of layers of metal, silicon nitride, aluminum oxide, silicon dioxide, and silicon, respectively.) He has also been heavily engaged in gas phase epitaxy, the kind that could be scaled up to mass production of semiconductor devices.

Another way of classifying the work of IfH is into the areas of electronics, III-V semiconductor technology and devices, silicon technology and devices, material characterization, and micro-structure fabrication.

The work in IfH can be divided into 35 or more different projects. Since it is not possible to cover all of these, I mention a few representative problems here. Under "electronics," for example, a group has been working on dual-gate GaAs MESFET oscillators and self-oscillating mixers—work which has resulted in the design of X-band receivers with an integrated GaAs circuit. A considerable effort has been spent on time and frequency domain measurements of various opto-electronic devices. Another item has dealt with investigating Gunn oscillations in GaAs epilayers for FETs. (They were found to be suppressed in most FET structures.) In the "technology" area a project has dealt with chemical vapor deposition of AlGaAs. Based on a detailed analysis, it was concluded that the deposition of AlGaAs of device quality at practical temperatures is only possible if the source reaction is almost complete. Consequently, efforts were made to bring the source reaction as close to equilibrium as possible. This has given rise to a new source design of 15 cm total height, with which it was possible to deposit films with up to 80% Al concentration at deposition temperatures

of around 750°C and source temperatures below 800°C. Another project has involved chemical vapor transport of GaAs with bromine. Results have yielded epitaxial films of excellent surface quality except at very high supersaturation, when etch pits were formed during growth.

Another study in progress deals with low-pressure GaAs deposition techniques, where the potential advantage compared with atmospheric pressure systems is that the increased diffusivity of the gas species at low total pressure is expected to minimize non-uniformities in growth rate and doping across large wafers. An interesting feature of the design of a system under study is low transduction in the gas flow direction but high transduction perpendicular to the melt surface.

Among other endeavors in the areas of current semiconductor-device research are projects involving epitaxial deposition of InP and related mixed crystals; injection lasers, electron-beam annealir charge storage in insulating films, ion implanted devices, basic studies of carrier lifetime, and such micro-structure work as dry etching and ultraviolet lithography—all in all an impressive amount of up-to-date work.

While IfH concentrates on basic-device and process-technology studies, Engl and his colleague, Prof. Dr. J. Mucha of IfTE, have developed their institute into a silicon integrated circuit (IC) facility capable of IC prototype development for industry. Engl, who spent a semester at the University of Arizona some time ago, told me that he remains in close contact with colleagues in Arizona, especially at Motorola, Phoenix. A brief tour of his facility showed that he has been very successful at obtaining up-to-date equipment. This includes such apparatus as Mann light pattern generators, a 200 keV ion implanter, and virtually all the other equipment seen in a sophisticated industrial IC laboratory.

Engl's laboratory is divided into 4 groups: IC Technology (for bipolar and CMOS), IC Circuit Design, Device Modelling and Circuit Analysis, and Testing. Staff members believe it is their mission to be idea and prototype persons for industry. They originate ideas, build the IC's that develop from these, then transmit the ideas and the circuit designs to industry. Thus, while they receive funding from the

federal government, a large amount of the financial support comes from industry.

In response to my request for an illustration of the type of circuits that have been developed, the staff described an IC switching circuit with a specified amount of cross talk.

I found it of interest that some parallel work was in progress at IfH and IfTE. For example, both groups are working in low-pressure epitaxy; both are working toward devices of ultrafine geometry. Obviously, both have the equipment for working on these tasks. However, while this may seem to be duplication of effort, based on the recent output from these institutes and the present emphasis on semiconductor technology, the funds spent for semiconductor R&D at Aachen appear to be well spent. (Irving Kaufman)

MATERIALS SCIENCE

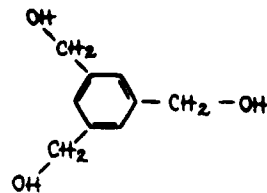
COATINGS TECHNOLOGY AT THE CHEMICAL CONGRESS

The 1980 Annual Chemical Congress which was jointly sponsored in the UK by the Chemical Society (CS) and the Royal Institute of Chemistry (RIC) was held 9-11 April at the University of Durham. This was the last congress to be sponsored by the CS and RIC since the two organizations have been combined into the Royal Society of Chemistry with Sir Edward Jones as President Designate. As in past congresses, there were sessions on physical, analytical, organic, and industrial chemistry. This report covers the industrial session which was devoted to coatings, mostly organic coatings, and coating technology. It was organized by Dr. James Feast (Univ. of Durham). No preprints or proceedings were published for the conference. The subject matter, like most industrial topics, is highly interdisciplinary, a fact which makes it difficult to achieve a coherent meeting and to develop good discussion of the presentations. The participants, who include scientists, engineers, and technologists, often find it difficult to understand one another's specific problems and points of view. Not infrequently, the most useful part of such meetings are the conversations that develop between sessions. This interaction was aided in the Durham Conference by having the participants housed in university dormi-

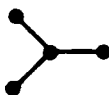
tories, each of which had its comfortable pub for serious shop talk during the evening.

The presentations were a mix of review papers and reports on new research and technology. Dr. David H. Kaelble (Science Center, Rockwell International, Thousand Oaks, CA) offered a somewhat philosophical overview of the adhesion of polymer coatings. He noted that the theories of adhesion tend to fall into two categories: continuum, and short-range interaction theories. The continuum point of view emphasizes the mechanics of coating adhesion: bond strength, fracture toughness, etc. The surface chemistry theories of adhesion, on the other hand, tend to emphasize short-range intermolecular interactions at the interface. In Kaelble's view, the mechanics and the surface chemistry of adhesion cannot be separated, and moreover, any comprehensive theory must include the time-dependent (rheological) aspects of polymeric coatings. As he pointed out, all of these factors come into play in any evaluation of the environmental durability of coating adhesion. Accordingly, through surface energetics and fracture mechanics arguments, Kaelble has been able to predict the effects of aging and water exposure on the bond strength of adhesive joints.

Another of the review papers was given by Prof. Manfred Gordon (Univ. of Essex), a highly respected authority on polymer network theory (ESN 33-11:460 [1979]). Gordon made his presentation deliberately qualitative in the hope of getting across some important basic principles; normally he is not so merciful to his audience and delivers highly analytical lectures filled with the statistical mathematics of network theory. He began by pointing out how important to organic coatings, plastics, and biochemistry is the conversion of liquids to what he calls a "jelly": the early stages of network formation. In general, gelation is preceded by an increase in viscosity until a critical branching stage is reached after which cross linking continues until the matrix reaches a rubbery stage. According to Gordon this process can be modeled by graphical representation; i.e., a monomer such as



can be represented by



and the key parameters are functionality ($f=3$ for the above triol) and the fraction of conversion (α). As the reaction proceeds a chemical forest develops with the largest aggregates having the highest functionality until finally one huge molecule dominates the reaction. At this point the jelly forms within which the most common specie is the monomer since it has the lowest functionality. Cyclic linking reactions of the monomer with the structure lead to gelation and a rapid increase in viscosity and stiffness. Gordon went on to discuss the fact that in the initial stages of cure, as the temperature increases there is actually a drop in viscosity and he emphasized that this is important to processing and is usually to be avoided. For example, a paint coating may begin to run off (sag) before it sets. Consequently, it is desirable to adjust the cure rate in some fashion so that the jelly forms as early as possible.

Dr. K.L. Mittal (IBM, East Fishkill, NY) reviewed the various technologies used in the electronics industry to determine the adhesion of metallizations to inorganic (usually ceramic) substrates. He stressed the point that it is rarely possible to measure the interfacial adhesion between a metal coating and substrate. Indeed, the strength of the metal film in the interfacial region usually exceeds the cohesive strength of the film and it is the latter which is measured. The techniques which Mittal described included the scratch test, the blister test, and the ultracentrifuge test. In the scratch test, a stylus is dragged over the film and the force required to cut through to the substrate or the number of passes to expose the substrate is determined. The blister test involves drilling a hole in the substrate and then depositing the film so that it covers the hole. Air or liquid is forced through the hole and the pressure is measured when the metallization begins to debond. In the ultracentrifuge test, the film and substrate are fitted on the centrifuge rotor and the centrifugal force required to cause the film to separate is determined. On the basis of his own work,

Mittal considers the scratch test and the ultracentrifuge test the most promising for routine work.

The surface chemical aspects of coating adhesion were reviewed by Dr. H. Schonhorn (Bell Laboratories, NJ). He noted that the surfaces of commercial plastics contain low-molecular-weight polymer, lubricants and antioxidants which act as weak boundary layers to prevent good adhesion. In his opinion, surface treatments (such as corona discharge, exposure to acid or ion plasmas) that are used to enhance adhesion to polymers remove surface contamination and produce a thin layer of cross linked polymer. He does not believe that the changes these treatments may cause in the surface wettability are of critical importance to the improvement in bondability.

One of the more fundamental research papers of the meeting was that given by Dr. D. Packham (Univ. of Bath, UK) on a study of the peel adhesion of polyethylene (PE) to metal surfaces. PE melted onto smooth copper, steel, or zinc surfaces usually exhibits very poor adhesion; this is attributed to the presence of anti-oxidants in the PE which prevents oxidation of the polymer and the formation of chemical bonds between the PE and the metal substrate. Packham has shown that if a thin fibrous oxide is formed on the metal surfaces, PE penetrates this to topography and very high peel stresses are obtained. In his experiments with polished copper, he observed that if air bubbles were inadvertently trapped at the interface the peel strength was quite substantial. He followed up this surprising observation by adding a blowing agent to the PE to deliberately form a scattering of air bubbles at the interface. The result was a very high peel strength. His explanation is that because of the stress concentration at the mid-point of a bubble, failure is focused into the ductile polymer along a mid-plane of the bubbles and the weak interface goes unstressed.

There is a growing use of powder-coating techniques to avoid the problems involved in using solvent-based coatings. These problems include national and local legislation against the use of certain solvents. The state of the art of powder coatings was given by Dr. F.C.J. Ruzicka (T.I. Drynamels, Birmingham, UK) on behalf of the Powder Group, British Paint Association.

In Ruzicka's view thermosets are replacing thermoplastics largely because they are polar materials and amenable to electrostatic coating processes. A major problem in powder coatings is the recovery of overspray, the paint that in the spraying operation misses the substrate and would be totally lost if not recovered. Presently 80-90% of overspray is recovered. Another problem is in changing color which currently necessitates a complete cleanout of the equipment and a loss of material and time. Finally, there is coating efficiency—how much of the spray hits the substrate? Currently the figure is 60% but there are new technologies that could push this to 90%. The principal production paint resins are dicyandiamide (dicy) cured epoxies but there is increasing interest in co-reacting epoxy-polyester resins. Ruzicka indicated that the prominent areas of R&D in powder coating are the mechanism of charging in electrostatic coating, grinding methods to produce less dust, and faster-curing resins.

One of the best presented and best received papers was given by Dr. J.A. Cross (Univ. of Southampton, UK) on electrostatic polymer coating. This technique involves the spraying of charged polymer particles onto oppositely charged substrates. Particles are held by electrostatic attraction and are later coalesced into a coherent coating by heating the substrate. If the polymer is a thermosetting resin, the resultant coating is cross linked. The principal advantage of electrostatic coating is that it involves no hazardous solvents. The disadvantages are that the coating materials are more expensive than solid base paints, the initial coating must be heated to temperatures of about 190°F, reentrant angles are difficult to coat, and the technique is generally more complex than simple painting. Cross indicated that the work at Southampton is focused on the aerodynamics of particle deposition; proper control of the air flow can, among other things, help in obtaining coating uniformity even into recesses and in insuring that paint particles that flow past the substrate move on into a downstream collection and recovery channel. A major difficulty in maintaining particle aerodynamics is the back ionization of the paint particles. Because of high charge density between the ionization gun and the substrate, there is an electrostatic breakdown of the air which creates particles of the

opposite sign which travel back toward the gun and discharge the oncoming charged particles. The result is a sudden drop in coating efficiency. The group at Southampton has built an apparatus to observe back ionization.

To get a better control on air flow, a cyclone gun was developed at Southampton. This gun has advantages over the conventional linear-flow gun but the cyclone gun developed by the Southampton people was preceded in the market place by one that was developed and patented in Japan. The gun developed at Southampton uses only frictional charging and may be more efficient, all other factors being equal, than the Japanese gun which uses both friction and electrical charges.

Current work at Southampton is on particle-charging mechanisms—why particles do not get the expected charge. Their early conclusions are that the high air-flow rates that are employed result in low charging but that this is not the whole story. They suspect that the surface chemical properties and the shape of the particles play a role, but the details are uncertain.

A very different type of coating was discussed by Dr. R.L. Nelson (UK Atomic Energy Agency, Harwell) who described metal oxide protective coatings produced from colloidal suspensions of metal hydrates or hydrous oxide sols. The sol particles have a negative charge and when a metal is dipped into the suspension a weakly coherent film of the colloid is deposited. Subsequent firing at 300-500°C "cures" the deposit into a coherent and adhesively strong coating. When the colloid particles are non-aggregated crystals, a compact coating is formed but when the crystals are in suspension as small aggregates an open, porous network forms. Coating materials include silica, alumina, ceria, titania, and zirconia. Nelson described the coating of stainless steel components used in nuclear reactors by silica and ceria for corrosion protection. In this application the coating must be dense and cohesively strong. On the other hand, he described the formation of porous metal oxide coatings (using crystal aggregate sols) which can withstand temperatures of 1000°C and are used as the catalysts for the control of automobile emissions. Most of the coatings, coherent and

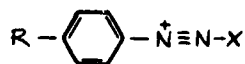
porous, are about 1 μ thick and cost about 2.5¢/m².

Plastic film coated with a thin aluminum metallization (Al-film) is used as a packaging material almost as extensively as paper and aluminum foil (Al-foil). Because Al-film is a good moisture and UV radiation barrier, it is widely used for food packaging. It competes well with Al-foil; they cost about the same 5 years ago but now the Al-film is slightly cheaper. Dr. A. Windle (Univ. of Cambridge, UK) explained that this cost difference is likely to widen since the energy cost to produce foil is 10 times that of the metallized plastic film. He noted that the metallization coating is only 500 Å which on the usual polyester film substrate is equivalent to a tablecloth on a table 1 m high. However, Al-foil packaging is not without its problems and, because it is produced by what Windle called "middlemen" with a low profit margin, the industry has little capability for technical backup. With funding from the UK Department of Industry, Windle elected to look at one specific problem: the fact that the barrier performance of the majority of aluminum film is excellent but suddenly the production line will produce material with a considerable number of pinholes in the metallization. Windle found that the pinholes have dimensions of 2-3 μ in diameter dispersed in a background of holes of 1 μ and less. He was able to show that these pinholes are due to 1-3 μ dust particles on the polymer film which are accompanied by fine particles of less than 1 μ . Initially the metallization coating covers these particles, but as soon as the film is handled the particles break through the metallization. Since it is extremely difficult to prevent dust deposits on the film or to remove the dust before metallization, Windle is attempting to develop a bi-film process in which the metallization is sandwiched between two sheets of plastic film. The aluminum is deposited at the nip where the two films come together. The bi-film which Windle has been able to produce thus far has been rather unsatisfactory because of poor adhesion between the layers.

Dr. S.T. Harris (Nether Witacre, West Midlands, UK) spoke about some current trends in the formulation of organic powder coatings. The epoxy resins dominate these materials and are cured either by catalysts or by coreactants. Dicy is the principal

latent catalyst (the resin must be heated to melt the dicy and initiate the reaction) although the demand for ever-lower cure temperatures has brought forward some more reactive catalysts chemically related to dicy. Harris commented that these reactive catalysts present compounding problems; e.g., local heating during mixing or grinding initiates cure. According to Harris, coreactant systems such as epoxy-polyester resins are beginning to replace dicy-cured materials. These paints have good flow properties and less mixing problems but water created as a reaction byproduct must be driven off.

UV-cured coatings are especially attractive since no heat is required and formulations do not usually include a volatile solvent. Cure of the coating is achieved either by direct photopolymerization of the monomer or by a photoinitiation scheme where the radiation causes a chemical additive to decompose and release a polymerization initiator. Dr. R. Phillips (Metal Box Ltd., Reading, UK) discussed two types of photoinitiated systems; free radical and cationic. Polymers based on styrene can be UV cured by free radical initiators but the reaction is relatively slow and the acrylate-based polymers are preferred. However, the acrylates are highly toxic and Phillips indicated the number of acrylate monomers not outlawed by health legislation is decreasing rapidly. Nonetheless, acrylate UV coating systems are very attractive; cure time can be of the order of seconds, the initiator is quickly scavenged, and the cure stops immediately when radiation is removed. Cationic initiators such as



where X=BF₄, PF₆, AsF₆, or SbF₆ are used in epoxy coating systems (mostly the cycloaliphatics). The radiation releases the X moiety, and current thinking is that subsequent reactions release H⁺ which acts as the active curing agent.

There were two papers on the degradation of polymer coatings by sunlight. Dr. D. Phillips (The Royal Institution) gave a general talk on the photochemical-oxidation cycle

which so effectively degrades polymers by a free radical mechanism. He showed how degradation can be reduced by interrupting the cycle by shielding off or adsorbing UV radiation or introducing either a free radical scavenger or a singlet oxygen scavenger in the coating formulation. Dr. J. Peeling (Univ. of Petroleum and Minerals, Dhahran, Saudi Arabia) described a photoelectron spectroscopy (PES) study of polymer photo-degradation. He noted that most of the oxidation occurs in the surface and so PES can be used to follow the important events. For polystyrene and polycarbonate exposed to 254 nm UV radiation in the presence of oxygen, these events include a rapid increase in the oxygen peak, conversion of C-C bonds to C=O and -COOH, but after 24 hours -COOH predominates and half of the carbon in the surface layer has been oxidized. In the case of polysulfone, the change in carbon moieties are similar but no change occurs in the sulfur until after 24 hours of exposure when -SO₂ groups appear. There seems to be a selective removal of carbon and oxygen relative to sulfur. The rate of oxidation is similar for all these polymers. Those polymers that do not absorb at 254 nm show a similar degradation behavior except that the process is much slower, i.e., it takes 50 hours before a stable PES spectrum is obtained. Peeling found that these reactions are similar to the behavior of the same polymers exposed to sunlight in field tests.

The majority of the presentations in this industrial chemistry session were technology oriented—coating formulation and application—with relatively few reports on basic investigations. This imbalance was understandable on two counts. First, coating materials and processes are exceedingly complex and do not lend themselves to simple theoretical treatment or experimental investigation. Secondly, paint technology is not a glamorous research area and so, with a few exceptions, does not attract academic interest. Nonetheless, specifically directed research into the chemistry and physics of coating could bring cost savings to the industry itself and, for society as a whole, the development of coatings that can reduce the enormous losses due to corrosion and food spoilage. (Willard D. Bascom)

COMPOSITE RESEARCH AT THE DFVLR INSTITUTE FOR STRUCTURAL MECHANICS

I visited the DFVLR (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt) Institute for Structural Mechanics (Braunschweig, FRG) from 23-25 January 1980 to learn about their work on the mechanics of fiber-reinforced plastics. Dr. W.H. Bergmann, director of the institute, spent the first morning of my visit discussing his background and that of the institute; he also provided an overview of the scope of their efforts. Since his arrival at DFVLR over two years ago, Bergmann has been planning a major program in the damage mechanics of carbon-fiber-reinforced plastics (CFRP). As of 1 January 1980, he received funding to support the plan at a rate of approximately half a million dollars per year for at least three years. The DFVLR Board of Directors and the German Ministry of Science and Technology decided to provide funding mainly because of strong support and backing from the German aircraft industry. Bergmann also reviewed some of the current interactions of the institute with German industry. The most interesting of these are the development and testing of substitutions for parts of the A-300 Airbus. The substitutions currently being tested are a CFRP window frame and a new flap track, with titanium extrusions, CFRP bonded for stiffness, in place of the current steel design. These parts will not find their way into the A-300, but may well find application for weight reduction in the A-310.

The organization of the institute is difficult to describe in terms of functional names, but the effort can be divided into the Fatigue and Life Evaluation Group, the Structural Mechanics Development Group, the Environmental Effects Group, and the Nondestructive Testing Group.

The Fatigue and Life Evaluation Group, headed by Dr. R. Prinz, is responsible for all repeated load testing and evaluation at the institute. The major test currently being pursued is the full-scale flap track for the A-300. Leading up to this test were a number of component and design development tests of the more critical features of the design. These included tests of the CFRP stiffness reinforcement on the titanium extruded tracks in the areas of the reinforcement runouts, and also tests of the wear characteristics of the titanium tracks. The current

test is expected to continue for about a year and should last approximately five lifetimes (250,000 flights). As his part of the program on damage mechanisms in FRP, Prinz will carry out fatigue tests of a large number of specimens. These tests will be of un-flawed and flawed specimens (delaminated with freon during manufacture). He will test between 100 and 200 specimens this year, depending upon the length of time he needs to substantiate his compliance-measurement techniques and establish confidence in the nondestructive evaluation (NDE) techniques. Almost all tests will be tension-compression tests, and substantial effort has gone into developing the test fixtures.

Next I met Drs. B. Geier and K. Rohwer of the Structural Mechanics Development Group. This group has been largely responsible for the development of analytical methods and the substantiation of these methods with tests. Their interest has focused on the buckling behavior (initial and post-buckling behavior) of thin shells and panels. Their work in this field is well known, and even though one of the better-known members of the group, Dr. M. Esslinger, has recently retired from DFVLR (she still consults), there is a substantial core of people working in this area.

The Structural Mechanics Development Group is performing three main tasks. The first is the development of 3-dimensional finite element models in the vicinity of delaminations in CFRP. These 3-D models will be converted to 2-D representations at areas away from the delaminations. By correlating these models with the tests being conducted by Prinz, the group hopes to find an appropriate relation between far-field stresses, local 3-D stresses and strains, and material properties, and to develop from this an analytical definition of the delamination growth. This is recognized as a long-term objective with quite a few problems to be overcome.

A second effort within this group is the development of a computer code for optimizing the buckling load of the panel. This is a rather new field for the DFVLR staff; they are investigating the sensitivity of the buckling load of panels to the various geometric parameters (i.e., lamina stacking and fiber orientation).

The third effort is the testing of panels and shells and the generation of computer codes for the post-buckling analysis of glass-and carbon-fiber-reinforced plastic (GFRP and CFRP)

shells and curved panels. I witnessed the testing of a curved sandwich panel (GFRP facesheets and foam core) and a CFRP-filament-wound cylindrical shell 0.5 m in diameter, 0.5 m long with a 2 mm wall thickness. The curved panel failed as predicted. The load was held at the first buckling mode, and then an increase in load resulted in a change to what they described as the third mode, where a shear-type failure occurred across the panel width. They were delighted to have me take pictures of the failure as they had forgotten to buy film for their camera. (I promised to send them prints.) The shell test was conducted in a unique, very stiff, displacement-controlled test machine. They have been testing shells in this 40-ton-capacity machine for almost ten years and claim they have just begun to explore its capabilities. The test I witnessed was the fourth and fifth loading of this particular shell into buckling. The buckling load attained had dropped consistently by about 1% at each loading but the shell returned from the deeply buckled state to a condition where no damage was evident to the naked eye. They have not decided when they will remove and examine the shell by nondestructive and destructive means.

The last group I met was the Environmental Effects Group headed by Dr. G. Niederstadt. They are involved in an extensive water absorption test program in support of the damage mechanics evaluation of GFRP and CFRP. Water absorption by specimens under various conditions of temperature and humidity (including steam-bath immersion) over long durations is being studied. Work also is being done to evaluate the mathematical absorption models available and to test the effect of moisture distribution in the laminate, as well as total moisture content on the mechanical properties of the laminate. In addition, they are conducting water absorption tests on the mechanical properties of adhesives. This group's past efforts were directed to the development of independent-axis, filament-winding machines and techniques. They are continually called upon to assist in this area (currently they are helping to establish this capability in Brazil), but they are turning over much of their equipment to German industry.

Bergmann escorted me through the Nondestructive Testing Group's laboratory and pointed out x-ray and ultrasonic equipment which will be used

for composites work. He also showed me a laser holography lab which he thinks will be phased out in the near future. No research, per se, is planned for the NDT Group as it will be supporting the efforts of other groups. (G.F. Zielsdorff, European Office of Aerospace Research and Development)

FIFTH INTERNATIONAL CONFERENCE ON EROSION BY LIQUID AND SOLID IMPACT

The Fifth International Conference on Erosion was held at Cambridge University, on 3-6 September 1979. The conference presented the scientific accomplishments in a broad area of erosion processes, which included liquid impact, solid impact, and cavitation erosion. This broad range of topics was unusual in that the four previous conferences had been focused primarily upon the engineering aspects of rain erosion.

The contributors to the conference came from 15 countries and among the attendees even more countries were represented. The technical backgrounds of the participants were also quite varied. They included physics, materials sciences, tribology, applied mathematics, and chemical, mechanical, and metallurgical engineering. The timing of the conference was quite opportune. Much work has been done in recent years on impact phenomena, both theoretical and experimental, and there has been increasing interest in this field because of pressing technological needs and new scientific opportunities.

The manner in which the meeting was run was superb. Most importantly, the proceedings were available at the time of the meeting. (Unfortunately, the proceedings in their original form will not be part of the archival literature.) There was also ample time for individual discussions.

The conference left several general impressions. It is clear that there has been a great advance in understanding solid particles impacting upon brittle solids. Relations have been developed for damage velocity threshold in materials removal rate both in terms of materials and impactor properties. In addition, there is more understanding of the damage threshold for liquid particles impacting brittle solids although not for materials removal. For particle impact and erosion of ductile materials (metals) the situation is more descriptive. The most useful framework for treating particle erosion of metals

still seems to be that of I. Finnie, developed well over ten years ago. Several investigations on metals were concerned with 90° impacts, although from the viewpoint of maximum materials removal and/or damage, phenomena near 25° impingement angle are of greater interest. It would also be interesting to see more research done on the erosion of higher-strength and higher-hardness alloys.

The cavitation erosion situation is somewhat different. Much work seems to have gone into cavitation mechanics and the stress levels developed from bubble collapse and jetting effects. Materials screening under cavitation conditions has also been done to a significant extent. On the other hand, a thorough understanding of the mechanisms of materials damage and materials removal for the cavitation situation has yet to be developed. From the Proceedings of this meeting, it seems that mechanisms of materials removal and predictive models for cavitation erosion damage cannot yet be done reliably.

In the erosion research field, it appears that more attention might be paid to understanding the various test methods used. For example, ranking and screening schemes of the phenomena and mechanisms involved have not been evaluated.

Approximately 75 papers were presented in 14 conference sessions. The main topics included the following: Liquid impact (theory, pressure measurement, drop deformation, test facilities, meteorology), Solid impact (theory, brittle solids, brittle-ductile transition, ductile solids, surface analysis, coupled erosion-corrosion), Cavitation (bubble dynamics, cavitation damage, cavitating jets), Protectional Applications (coatings, optical materials, structural materials, coal conversion plants, turbomachinery, hydraulic machines, mining, cutting, ship propellers).

A more extensive report on this meeting will appear as an ONRL Report. Thus, only a few of the interesting highlights are summarized here. One of the discussions involved the complex situation during early stages of liquid-solid impact. Another involved the fluid mechanics of the impact of rounded-front liquid drops with a rigid surface. There was also an interesting presentation on impact damage thresholds in brittle materials impacted by water drops. This study was a combined analytic and numerical approach. The

damage threshold was taken as the activation of pre-existing surface cracks. The three important target parameters are fracture toughness, elastic wave velocity, and flaw size. Damage in brittle solids is well-described by the stress intensity factor reaching the critical value at pre-existing cracks. Time dependent effects were seen for crack opening, which indicated that the pulse duration of the stress ahead of the crack is critically slow enough for crack growth to occur. The threshold value of stress intensity is important because it is the condition to design to. Several directions for making improved materials now exist. They include: (1) controlling flaws to a very narrow size distribution; (2) development of surface compressive stresses; (3) maximization of the ratio of critical stress intensity factor to wave velocity via microstructural modification. These must yet be verified across several classes of materials.

Numerical simulation work showed that a large flaw might modify the stress field so as to suppress crack activation for ceramic targets. The numerical techniques as used by Rosenblatt, et al, were shown to be very valuable in developing general understanding of complex phenomena, especially where detailed phenomena cannot be controlled or varied experimentally.

The presentations on "Liquid Impact: Material Response" covered a range of materials including polymers, ceramics, metals, and composites. Much screening or comparative data was given on threshold values found for fracture or materials removal upon liquid particle impact. In addition, liquid drop erosion test facilities, including the ASTM interlaboratory test program were discussed. This "round robin" among liquid impingement facilities presented erosion resistance and incubation resistance rankings of materials including stellite 6B, stainless steel 316, nickel 270, aluminum 6061-T6, aluminum 1100-0, neoprene and plexiglass-55. Predictive accuracy for erosion rates was found to be superior to that for incubation times. Other work on testing in rain or dust environments showed that an order of magnitude of time to destruction for above supersonic velocities can be measured which correlates with real lifetimes of components in flight.

The session on solid impact theory was led by B.J. Hockey and S.M. Wiederhorn (National Bureau of Standards,

Washington, DC) with a paper of great clarity and importance: "Erosion of Ceramic Materials: the Role of Plastic Flow." The paper presented evidence for plastic flow during the erosion of brittle solids by solid particles. Studies of microdeformation that accompanies erosion help in understanding the erosion of ceramics. Several theories were summarized which included elastic-plastic erosion as well as the fundamental properties of the target material and the impacting particle. Dislocations were identified at impact sites in a variety of crystalline ceramics. The extent of crack formation compared with plastic deformation is related to the relative magnitudes of the hardness, H , and the critical stress intensity factor, K_{IC} . Low H/K_{IC} values favor plastic deformation, while high H/K_{IC} values indicate fracture at the impact site. An interesting paper on "The Effect of Temperature and Load on the Indentation Hardness Behaviour of Silicon Carbide Engineering Ceramics" was authored by M.G.S. Naylor and T.F. Page (Cambridge Univ., UK). The work is part of a long-term wear program on SiC and Si₃N₄. Of particular interest were the roles of indentation plasticity and indentation fracture in near-surface deformation of brittle ceramics. Microstructural differences were seen. This work is important in understanding the mechanical response of ceramics undergoing surface contact loading (such as in abrasion and erosion).

P.G. Shewmon's (Ohio State Univ., Columbus) presentation on erosion of aluminum alloys had to do with large steel balls impacting on solid surfaces, and concentrated on surface fracture from normal incidence impacts. Shewmon presented evidence for adiabatic shear, causing melting of the metal, which fractured in the molten conditions.

Several sessions had to do with coal conversion and turbomachinery. Erosion wear of solid particulates in such systems can significantly reduce their useful lifetimes. Work was also presented on erosion-hot corrosion by alumina, magnesia and aluminosilicate powders. In oxidizing environments, the attack was erosion-dominated. For hot corrosion conditions, the impacting particles promoted severe sulfidation. In these cases, the effect (erosion coupled to corrosion) is not the simple sum of each mode of attack. Work on erosion of NiO scales

on pure nickel at 1000°C was reported upon as well. When impacted by angular SiC particles at 100 m/s, these scales exhibit several of the mechanisms proposed for brittle solids. This work points out that predictions of erosion rates and mechanisms must consider the real character of the substrate.

Considerable time was devoted to discussion of cavitation and cavitation damage. The information presented on cavitation erosion resistance included effects of elastic resilience, high-yield strength, stress-induced phase transformations and toughened microstructures. The materials studied included low- and high-alloy steels, cobalt and nickel alloys, sintered carbides and polymers including polytetrafluoroethylene, nylons, polyacetal copolymer and polyethylene. Methods of materials removal observed included (1) low energy transgranular cleavage, (2) intergranular grain removal, (3) high energy ductile extrusion and rupture, (4) fibrous tearing of resilient polymers, and (5) plastic deformation.

J.V. Hackworth (Bell Aerospace Co., Buffalo, NY) presented "Predicting Cavitation Erosion of Ship Propellers from the Results of Model Experiments." His work was part of an effort to predict the service life of propellers as a function of ship-operating conditions, but was based upon experiments with model propellers in water tunnels. The erosion predicted for one year of steaming time based on this work was in agreement with in-service experience.

The results of a metallurgical study on effects due to cavitation induced stresses were also presented. K.C. Antony and W.L. Silence (Cobot Co., Kokomo, IN) found that cobalt-base alloys can surface transform during cavitation into a hcp structure. This phase has high fracture strain energy. The proper cobalt-base alloys are alloyed so as to control the stacking fault energy between 10-15 mJ/m². Nickel is harmful in this regard. "Some Aspects of Metal Perforation by Liquid Impact," by A.G. Rozner (Naval Surface Weapons Center, White Oak, MD), had to do with cutting of metals by liquid jet impact. Rozner reported on liquid jets formed in a pyrotechnic torch. (The jet is made up of the molten products of the exothermic reaction between nickel, aluminum, ferris oxide and Teflon). Steel and aluminum were perforated (up to 10 cm) in one-half second. Stresses generated by impact of this liquid jet were above the yield strength of the target material.

The final session, "Coatings," was of interest for practical modes of protection. At this time, however, only general rules are known. For example, soft, rubbery coatings protect against erosion damage via complex mechanisms. Of course, the compressibility of the coating is important. Coating adhesion assists in stress distribution. When coatings are evaluated, dynamic values of modulus and Poissons ratio need to be considered, since their strain-rate dependence can vary greatly. One must keep in mind that impact conditions can produce strain rates of up to 10⁶s⁻¹. Work on "Rain Erosion of Lightning Protection Coatings for Carbon Fiber Composites" was presented by H.W. Schroöder (Dornies GmbH, Friedrichshafen, FRG), relating to the use of carbon-fiber-containing materials in aircraft. The coating systems investigated were aluminum foils, flame-sprayed aluminum, aluminum-mesh, and metal-powder-loaded paints. Erosion resistance was poor in all cases.

The need for a practical coating system for rudders to reduce corrosion and cavitation from the propellers was considered in another presentation. The focus was on elastomeric properties at high strain rates. A theoretical analysis of stresses experienced at coating/substrate interfaces was presented, and polyurethane having a test tunnel performance 2000 times better than epoxide formulations was described.

Attendees were left with several impressions at the end of the meeting. These included an awareness of the need for a more careful and thorough understanding of mechanisms of materials damage and materials removal (for situations other than solid particles impacting upon brittle solids). The goals of the conference were met in pointing to directions for future work on understanding of erosion phenomena. It should be noted that some good work of a fundamental nature continues on erosion. In summary, the conference helped to critically identify useful theoretical and experimental advances in the field. The volume containing the *Proceedings of the Fifth International Conference on Erosion by Liquid and Solid Impacts*, edited by J.E. Field (Cambridge) is currently available from the Cavendish Laboratory (Cambridge, UK). (A.M. Diness, Office of Naval Research, Arlington, VA)

OLTEN SPRAY-FORMED COATINGS AN INTER-
ATIONAL CONFERENCE

Thermal spraying, a form of continuous splat cooling (the ultra-rapid solidification of molten materials), has become an important means of creating protective coatings. The technique involves the melting (through plasma, electric arc, or combustion gas) and spraying of the molten particles at high velocities onto the previously prepared substrate to be protected. In the plasma-spray method, it is possible to spray virtually any material, starting in powder form, at near-sonic, and in some cases, supersonic velocities. The main limitation on the choice of material is that it undergoes no chemical decomposition prior to melting. Thus, it is possible to form high-density coatings of plastics (e.g., nylon, polyurethane), metals, alloys, oxides, carbides, nitrides, and cermets.

Approximately every 3 years the various national trade and industrial groups concerned with the interests of thermal sprayers (for the US, the C-2 Committee of the American Welding Society) convene an international conference. In spring 1980 (May 19-23), the venue was the 9th International Thermal Spray Conference, where over 70 reports were presented, resulting in a preprint volume of over 400 pages. The sessions broadly covered techniques, materials, applications, and testing. The participants were generally enthusiastic and rather sanguine about the future of thermal spraying. In fact, a bit of folklore widely heard—and to some extent true—was that thermal spraying is at its commercial best during highly inflationary times, when maintenance expenditures must be kept to a minimum. Spraying can both extend life and aid in the salvaging of worn and damaged machinery parts.

The introductory papers at the opening ceremonies placed thermal spraying in a proper perspective relative to other coating techniques. The central thrust was that more research is needed if thermal spraying is to achieve a genuinely competitive edge in many sectors of industry (i.e., various chemical and physical vapor deposition and diffusion coatings).

This report provides a brief review of the high points of the conference. A more comprehensive ONR London conference report is being published for those wishing to learn further details.

Far away the most exciting development discussed at the conference was low-pressure-chamber plasma spraying. This technique is becoming widely accepted by the aerospace industry, where high-temperature protective coatings are being sprayed onto gas turbine parts. The reduced pressure gives substantially improved plasma flame control and higher velocities—several times Mach 1 is commonly claimed. The surface to be coated is prepared by a transferred arc, yielding a very clean substrate. These coatings, as seen through micrographs, appear similar to wrought alloys. Truly, a formidable development.

Shrouds and barrels were described in which a flame carrying the melted particles can be controlled chemically and geometrically. And new materials were discussed (though this is usually proprietary stuff), and the properties of many types of coating were evaluated. One major paper discussed the use of Laser-Doppler anemometry and optical pyrometry to study plasma-spray particle velocity and stream temperature, respectively. A number of scientific practical conclusions were forthcoming. Solidification kinetics depend on spray velocity, temperature, and viscosity. This last material property would be worthwhile considering in designing coatings.

Nondestructive evaluation of the sprayed coating was the subject of a number of papers, emanating, for the most part, from university and government laboratories. Topics included ultrasonic imaging and attenuation, acoustic emission, and holographic methods. There was considerable interest in these methods, but the consensus was that testing of thermal sprayed coatings has some way to go.

A most interesting aspect of the conference was a series of papers on corrosion protection through metalization, i.e., electric-arc or combustion-gun spraying of active light metals, such as aluminum and zinc, and their alloys. This technique has been used extensively in Europe. It is ironic that a major impetus (if not justification) was given to the Europeans through a 1974 publication of the American Welding Society, which reported on the results of an extensive 19-year exposure test of aluminum and zinc flame-spray-coated steel in

a wide range of environments, from total immersion in sea water to dry industrial locales. The coatings behaved beautifully. Little application of metallization for corrosion protection has evolved in the US, though the US Navy will now become a major user of this technique for shipboard protection. Furthermore, an interesting report from Quebec outlined the on-site aluminum flame spraying of the 1-kilometer-long Pierre-Laporte Bridge. No major maintenance of this bridge is expected until the turn of the century!

It is difficult to report on this sort of conference, where 70 papers covered so diverse a range of topics. Anyone concerned with long-term materials protection or with the salvaging of machine parts ought to examine the proceedings volume of preprints (available through Nederlands Instituut voor Lastechniek, Laan van Meerdervoort 2-B, 2517 AJ The Hague, Netherlands). I would be willing to respond to specific questions about the Conference. Again, an ONR London Conference report will soon be available. (H. Herman, State Univ. of New York, Stony Brook, NY)

PLASTICS TECHNOLOGY IN IRELAND

The economy of the Republic of Ireland is in a state of growth today. A part of the growth has been the development of a sizable plastics industry. Two factors that have contributed to this economic growth have been the efforts made by the government to attract industries in the US and Europe to Ireland, and to set up an educational system to create the technically trained people needed by these industries. Although some of the multinationals like Imperial Chemical Industries and National Cash Register already had manufacturing branches in Ireland, many other companies that are not usually inclined to establish foreign subsidiaries, like Loctite, Becton Dickinson, and Beckman Instruments have been attracted by the tax benefits, low labor costs, and ample space for plant sites that Ireland can offer.

Eire is blessed with one of the finest universities in the world, Trinity College (University of Dublin). Trinity College alone, however, could never hope to produce the volume of technically skilled people needed by a growing and very diverse industrial base. Consequently, a system of

regional technical colleges (RTCs) was established to produce the additional technicians and engineers needed. It was at the RTC in Athlone that a conference was held on "The Role of Polymer Technology in Ireland" which gave insights not only into plastics technology in Ireland, but also into the organization of the RTCs and into the general attitude in Ireland toward industrial development.

Dr. R. Devlin (RTC, Athlone) described the Technical College at Athlone. The course system offers 3 types of degree: (1) After 2 years of instruction the student receives a National Certificate and is graduated as a technician; (2) If he or she continues for a third year, a National Diploma is granted and the recipient is designated a technologist (the graduating body in both cases is the Irish National Council for Educational Awards); (3) By continuing for a fourth year, the student is awarded a Professional Qualification. This highest degree is granted by the Plastics and Rubber Institute (PRI) in London.

The RTC at Athlone is the only center that trains people for the plastics industry. Devlin pointed out that the Irish plastics industry is overwhelmingly one of plastics conversion rather than raw materials production. Consequently, the coursework has a heavy emphasis on processing, fabrication, and mechanical engineering. In the third year emphasis is given to polymer rheology as it relates to molding, while much of the fourth year is spent on detailed aspects of all types of processing. This plastics engineering program was started 8 years ago and according to Devlin, all of the graduates have gone to Irish companies.

During the discussion following Devlin's presentation, a member of the audience suggested that the faculty at Athlone was rather brave to start coursework in plastics engineering when, eight years previously, there had been no clear need by the industry. Devlin responded by pointing out that there had been and continued to be a big shortage of engineers in Ireland and that in fact the government was spending money to induce more science majors to go into engineering. Dr. P.P. Benham (Queen's Univ., Belfast) asked Devlin whether the RTC at Athlone had any heavy processing equipment for hands-on training. Devlin replied

that they had some machinery which had provided by the plastics industry, but that they certainly needed more.

Industrial research and development in Ireland is not extensive. Much of the innovation comes either from the foreign-based parent companies or, in the case of native industry, from other foreign sources. Mr. P.C. Toal of the Industrial Development Authority (IDA) described a program to stimulate innovation in Irish industry: the Products and Process Development Scheme. The Irish government provides direct financial support for R&D projects on a 50% matching-fund basis, with a normal maximum of \$107,500 per project. This sum can be increased, however, if the program involves joint efforts by 2 or more companies. Grants to private industry are favored over support to projects at the RTCs or universities (however, the RTC, Athlone has a grant to obtain plastics processing equipment). The IDA plays an advisory role, especially to small companies, and progress reporting is done largely by on-site visits instead of paper reports. The scheme began in 1972 and £2 billion have been spent thus far. Toal indicated some specific goals for the program: (1) Defense against market changes, government legislation, and raw material shortages; (2) Diversification into new product applications; (3) Cost reduction by automation; (4) Energy saving by improved processing methods and waste recycling. He listed some of the plastics companies that have benefited from the scheme. They range from a molding company (German-owned) that was helped to enter the automobile component market to an Athlone plastic company that was given assistance to redesign and streamline its production process.

The remaining presentations were concerned with specific aspects of polymer technology. Dr. V.J. McBrierty (Trinity College, Univ. of Dublin) gave an interesting paper on using nuclear magnetic resonance (nmr) to determine the "bonded rubber" fraction in carbon-filled elastomers. Bonded rubber is that part of the polymer network that is adsorbed on the surface of the carbon filler particles and thereby restrained from the normal molecular motion of the remainder of the polymer network. Unfilled rubber exhibits only one nmr spin-spin relaxation time (T_2) which increases systematically with increasing temperature. (The magnitude and temperature dependence of T_2 relaxations reflect

the molecular mobility of the polymer chains.) Carbon-filled rubbers exhibit two distinct values of T_2 : one equal to that of unfilled rubber; and a second, short relaxation time characteristic of a more rigid chain structure. McBrierty has been able to show that the intensity of the short T_2 signal is proportional to the fraction of rubber restrained by the carbon particles. He examined a series of compounded rubber samples which varied in the degree of dispersion of the carbon filler. In a poor dispersion, when the particles were agglomerated, the intensity of the short T_2 signal was reduced relative to rubber with well-dispersed filler. Indeed, the relation between T_2 signal intensity and the degree of dispersion was quantitative, and McBrierty suggested that nmr be used to determine filler dispersion in vulcanized rubbers rapidly. Alternatively, it might be used for on-line quality control of the master batch mixing of carbon and unvulcanized rubber.

Dr. R.S. Charnock (Loctite [Ireland] Ltd., Dublin) described the newly developed tough acrylate adhesives. These materials are the offspring of those rapid-curing "superglues" that are so useful in mending household china and which are widely used as sealants in industry. However, superglues have a major shortcoming—a bonded joint cannot withstand bending stresses which promote cracking of the adhesive.

The chemistry of these adhesives, both old and new, is based on a free-radical polymerization of diacrylates to form a rigid three-dimensional network. In one type, the cyanoacrylates, the free-radical cure reaction is inhibited by oxygen and so remains liquid in the container until applied to a thin bond line when the liquid is quickly starved of oxygen and cures to a rigid polymer. The second type, based on simple diacrylate monomers, requires an initiator to start the free-radical polymerization. This initiator is usually applied to the adherend surfaces; when the joint is put together it diffuses into the adhesive resin to promote the cure.

Charnock described two approaches to toughening initiation-activated acrylate adhesives (he did not mention the toughening of cyanoacrylate anaerobic adhesives). In one, the acrylate monomer is modified by introducing short urethane units to form a urethane diacrylate. In the cured adhesive the urethane moieties allow some degree

of the molecular flexibility necessary for fracture resistance. Alternatively, elastomers are dissolved into the acrylate monomer and during the cure of the adhesive the elastomer precipitates out to form a dispersed phase of rubber particles. As in the rubber-toughened epoxies and polystyrene, the dispersed elastomeric phase provides various deformation mechanisms which inhibit crack growth. Elastomer-toughened acrylate adhesives are a relatively new development which could have important industrial implications. There has always been a need on production lines for a rapid-setting and high peel-strength (high-toughness) adhesive. Charnock presented data showing that a peel strength of the unmodified acrylate adhesives was essentially zero, but that with the inclusion of a dispersed rubber phase, the peel strength was a respectable 55 Ncm². Bond strength in pure tension was unaffected by the additive.

Dr. P.J. Mallon (Beckman Instruments Ireland, Inc.) made a plea for better communication and planning in the design, production, and marketing of plastic products by the Irish plastics industry. In his talk, "Design and Development of Plastic Products", he claimed that because of this lack of communication the per capita consumption of plastic materials in Ireland is relatively low compared to the rest of Europe; for example, it averages only 50-60% of that in West Germany. His solution: careful planning from product conception, preliminary design, materials selection, and prototype manufacture to production and marketing. On close scrutiny, Mallon's scheme seems a bit idealistic. Some of the participants in the planning scheme may be unable or unwilling to be involved. The resin is frequently supplied by a small formulating company which buys the basic polymer from a large chemical company outside Ireland. The processor, a plastics molding company, is also likely to be small, especially in Ireland. These companies generally have less than 25 employees (typically 5-10) and lack the expertise or resources for materials selection or product design. It would seem that product design and development rest with the customer, and if the customer is a large instrument manufacturer or automobile company, it has the necessary resources if not the expertise. The problem which Mallon has identified also exists in other countries and is addressed by government funding to create

engineers and an engineering data base for the plastics industry.

Mr. T. de Lasa (General Plastics Engineering, TEO, Donegal) described the technology of glass-reinforced plastic (GRP) pipes and tanks and the use in the chemical processing industries. De Lasa began by noting the large difference in the volume of GRP used in the US as compared to western Europe; in 1978 it was 400 million ton per year in the US vs 100 million ton per year in Europe. He reviewed the types of reinforcement resins and the different ways of manufacturing GRP and then discussed current design standards. The first British standard for GRP (BS 4994) was introduced in 1973 and was based on US standards and an internal standard of Imperial Chemicals Industry, Ltd. De Lasa noted that unlike design standards for metal BS 4994 (and others) recognized the anisotropic nature of GRP by introducing the concept of unit loads and extensibility, e.g., ultimate tensile strength is given in N/mm per kg/ μ^2 of reinforcement.

The last talk, by Dr. R.J. Crawford (Ashby Institute, Belfast), was on recent developments in determining "The influence of injection molding conditions on product performance." In the past, simple test specimens were molded to determine the effects of mold conditions on mechanical properties. As Crawford put it, "The results had little relevance to the molding of a complex part; they failed to address the interactive effects that strongly influence mechanical properties, e.g., combined effect of the flow rate and cooling rate on crystallinity." The recent trend has been to mold simple (pseudo-component) geometries which incorporate specific features of a complex part; e.g., holes, sharp corners and inserts, but are still simple enough to test in the laboratory. To illustrate this approach to determining molding performance, Crawford described a program which began at Queen's University (Belfast) in 1970 and which characterized the effects of molding conditions on the fatigue behavior of a molded tubular specimen. He presented a considerable amount of data but, although the work was laudable, it was clear that a major testing effort was required to characterize this rather simple geometry. It would seem that a rather large data base is needed to predict the performance of a molded product of any complexity.

The people I met at this meeting and during a short visit to Loctite [Ireland] in Dublin seemed to have enthusiasm and optimism about the growth of the plastics industry in Ireland. They expressed the belief that they are becoming large enough to compete not only for markets in Ireland, but in Europe and elsewhere as well. There may be some compelling reasons for the stagnating economies of western Europe, but the Irish seem determined to overcome them. (Willard D. Bascom)

MEDICAL PHYSICS

PERSONNEL NEUTRON DOSIMETERS—DEVELOPMENTS IN ITALY AND ISRAEL

In recent years there has been a considerable effort to improve personnel neutron dosimeters. This effort is due to a number of factors. Currently there is a renewed interest in using neutrons for treating cancer. There is also an increase in the use of relatively high-energy accelerators (18 MeV is commonly used in the US) for radiation therapy. Worldwide more nuclear power stations and fusion power laboratories are being planned and built. All these activities have resulted in an increase in the number of workers employed at facilities that produce neutron radiation, with an attendant increase in the possibility of a radiation exposure hazard for these workers. This report reviews some recent developments in the improvement of personnel neutron dosimeters in Italy and Israel.

The most commonly used types of personnel neutron dosimeters have been neutron-sensitive film (NTA film), thermoluminescent dosimeters, and fission track detectors. These types have not been satisfactory for universal application for a number of reasons. The NTA film requires a light microscope to count tracks. Fading of tracks, deficient energy response, sensitivity to beta and gamma radiation and the use of radioactive material are some of the limiting factors for these dosimeters.

In recent years a number of new concepts have been introduced to overcome these deficiencies. One of these is the idea of using an electrical breakdown phenomenon in a solid dielectric to initiate a catastrophic but controlled event at sites of radiation

damage, produced by a single charged particle. This was first reported by Drs. L. Tommasino and W.G. Cross in the early 1970s as a "spark counting technique for damage track neutron dosimetry." Dr. Tommasino works at the Centro Studi Nucleare (CSN) laboratory at Casaccia, some 30 km from Rome. He has also collaborated with a number of American scientists at the Lawrence Livermore Laboratory in California and at the Oak Ridge National Laboratory in Tennessee. Dr. Cross did his work at the Chalk River Nuclear Laboratories in Ontario, Canada. Figure 1 illustrates how this method works for counting tracks induced in a thin plastic film (or foil) through which fission fragments have passed, leaving damage tracks. (A typical foil material is polycarbonate 10 μm thick). A subsequent chemical etching produces perforations in the foil. The etched plastic foil is placed between two electrodes, one of which is a thin layer of Al evaporated on Mylar. A spark is then caused to pass through a track hole with enough energy to evaporate a larger hole in the Al. The discharge jumps from one hole to another, only passing once through each hole in the foil. The evaporated holes in the Al are of the order of 0.1 mm in diameter and provide a visible replica of the pattern of tracks in the plastic foil.

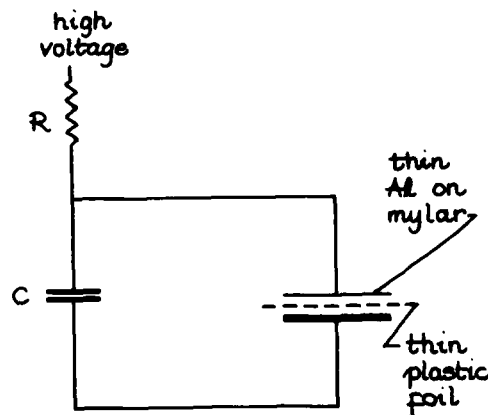


Fig. 1.

While the spark-counting technique works well for counting fission fragments, it is not reliable for the detection of damage tracks produced by relatively lesser ionizing particles like alphas and recoil particles

resulting from neutron captures. This difficulty was overcome by Tommasino and his colleagues by developing an electrochemical etching (ECE) technique which enlarged to macroscopic sizes all types of damage tracks, whether due to low or high ionizing particles.

The ECE occurs when the damage track detectors are stressed by an ac electric field during a chemical etching process. Figure 2 shows how the ECE was first accomplished by Tommasino.

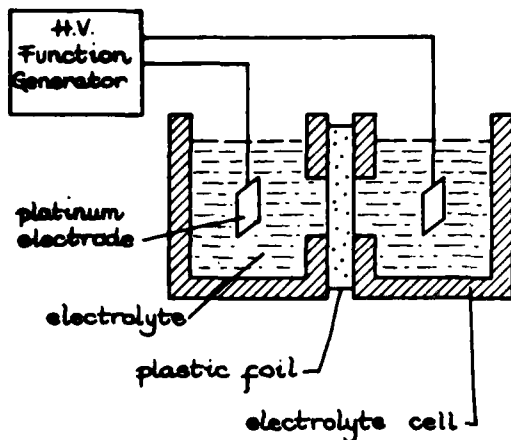
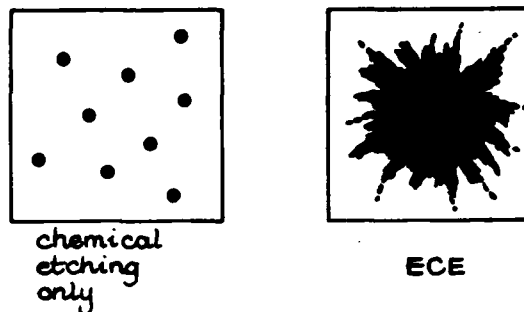


Fig. 2.

The plastic foil with latent damage tracks is clamped tightly to provide electrical insulation between the two cells filled with electrolyte solution. Thus the irradiated surface of the detector (plastic foil) is in contact with the electrolyte, typically a 30% solution by weight of KOH in water. The platinum electrodes are connected to a high-voltage generator. Typically potentials of 800 to 1000 volts (rms) at 2 KHz are applied across the foil for 4 to 5 hours. The plastic foils used as ECE detectors are usually 0.25-mm thick, commercially available polycarbonate.

Figure 3 illustrates the difference between chemical etching only and ECE for a polycarbonate foil which had damage tracks due to fission fragments (after Tommasino).

The enlargement to macroscopic sizes of tracks of fast neutron-induced recoils had made it possible to apply this technology to personnel neutron dosimetry. This was first demonstrated by M. Sohrabi in 1975 (in his doctoral thesis at the Georgia Institute of Technology).



50 μ m
Fig. 3.

ECE is limited to detecting neutrons with energies above 1.5 MeV. This is a serious limitation since the energy range below 1.5 MeV is quite important in practice. It is this problem which a group of Israeli scientists from the Soreq Nuclear Research Center addressed. Headed by Dr. T. Schlesinger, Chief of the Radiation Protection Department (ESN 34-6:28 [1980]), this group has developed a dosimeter system which they hope will cover the vast energy range from 1 eV up to 14 MeV.

The system consists of three separate parts as shown in Figure 4. The first part (A) is a ^{10}B "miniature spectrometer," as they term it, intended to cover the energy region from 1 eV to 30 keV. The second part (B) is a ^{10}B albedo detector for determining the dose due to neutrons in the energy range from 30 keV to 1 MeV. As Figure 4 indicates, the ^{10}B material is in contact with a polycarbonate foil (or another commercially available plastic called CR-39). The third component (C) is a plastic detector which can be a bare polycarbonate foil covered with a thin polyethylene proton radiator for the highest energy region from 1 to 14 MeV.

The Dosimeter

The ^{10}B spectrometer consists of the three ^{10}B layers with thicknesses of 60, 360 and 1500 mg/cm² as shown in Figure 4. The 3 layers are all in contact with the plastic detector. The entire assembly is covered on all sides except the front by an absorbing coating of Cd and borated plastic. The spectrometer works as follows: assume neutrons are incident on the detector from the open front part (no absorbing

Cd nor borated plastic). The neutrons react with the ^{10}B , and the reaction $^{10}\text{B}(n,\alpha)^7\text{Li}$ produces alpha particles and ^7Li nuclei. All three layers of ^{10}B are thicker than the maximum range of the alphas and ^7Li nuclei. Thus the number of alpha and ^7Li particles reaching the plastic detector depends on the number of neutrons which are not absorbed and reach the region (about 1 mg/cm^2) in contact with the detector.

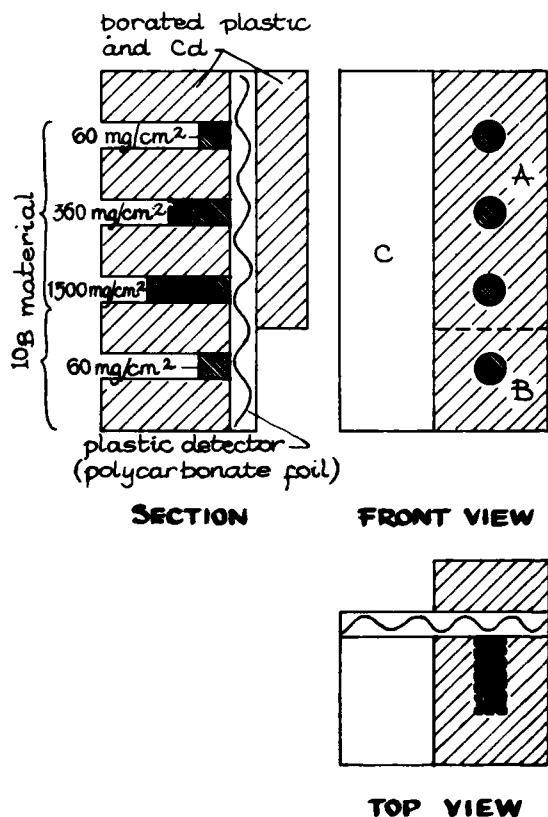


Fig. 4.

It is the $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction occurring in this layer which provides the alpha particles that reach the detector. At low neutron energies alpha particles emerge mostly from the thinnest ^{10}B layer, but at high neutron energies the alphas emerge equally well from all three ^{10}B layers. Schlesinger and his colleagues have shown that up to 30 keV there is a linear combination, D ,

of the number of alpha particles emerging from each layer, which is proportional to the dose and almost independent of energy. D is given by: $D = K(N_1 + 4N_2 + 36N_3)$ (1) where N_1 , N_2 , N_3 are the numbers of alpha particles from the respective layers (N_1 for the 60 mg/cm^2 , N_2 the 360 mg/cm^2 and N_3 the 1500 mg/cm^2).

The Albedo ^{10}B Detector

A 60 mg/cm^2 ^{10}B column is used to measure the albedo. This is defined as the number of alpha particles, called N_a , emerging from this ^{10}B column due to the interaction of thermal neutrons backscattered from the body of the subject wearing the dosimeter. Based on theoretical calculations made by another group (Alsmiller and Barish, *Health Physics* 26, 13, 1974), Schlesinger and his colleagues state that a measurement of $N_a/(N_1 + N_2 + N_3)$ can lead to a determination of the effective energy of the neutrons in the range 30 keV to 1 MeV . With this information the dose in this energy interval can be determined.

Bare Polycarbonate for High Energy Neutrons

Polycarbonate plastic some $370\text{ }\mu\text{m}$ thick was calibrated using known monoenergetic neutron sources and known polyenergetic neutrons.

^{10}B Spectrometer

Initial calibration experiments have been performed using known monoenergetic and polyenergetic neutron sources. On the basis of this work they were able to measure the proportional factor, K , appearing in the equation (1) for the dose, D . Their initial results indicate that K is approximately $0.1\text{ millirem}/(\alpha/\text{mm}^2)$.

Conclusion

The work of the Israeli group is preliminary and much more experimental research is being done. However, it appears that a promising start has been made on the difficult but important problem of devising a neutron personnel dosimeter covering the full energy spectrum of importance. The work by Italian and Israeli scientists and those in other countries shows once again the importance and necessity for international cooperation in science. (Moses A. Greenfield)

OCEANOGRAPHY

A THOROUGHLY MODERN MERLIN—THE MAGIC MODELER OF SHELF SEAS CURRENTS

The counties of Cornwall and Devon are replete with sites that are said to be associated with the activities of the legendary King Arthur and of Merlin, his equally famous advisor and soothsayer. I visited the ruins of Tintagel Castle on the rugged southwest coast of Cornwall where a local legend has it that Merlin lived in a cave in the sea cliff below the castle.

Not many miles away, in Plymouth, a modern Merlin divines his predictions using data from satellites and other modern sources and with the help of one of England's largest computers (IBM 360/195, Rutherford Laboratory, Science Research Institute). Like the cave of Arthur's Merlin, our modern Merlin's offices are isolated, not in a rock cliff, but in a far corner beyond the archives on the third floor of the library of the Laboratory of the Marine Biological Association of the United Kingdom. The laboratory is nestled tightly against the walls of the massive Plymouth Citadel between two protruding bastions. Just across the street is the bowling green where Sir Frances Drake is reported to have stated, after being told that the Spanish Armada was in view beyond the harbor, "We have time to finish our game of bowls and beat the Spaniards, too."

Our modern Merlin, Dr. Robin Pingree, has a small team of associates consisting of Dr. Linda Maddock, Dr. P. Holligan, Mr. D.K. Griffiths, and Mr. G.T. Mardell.

This team has developed a fine-mesh hydrodynamic numerical model of the dominant M_2 (semi-diurnal lunar) tidal component in the seas surrounding the British Isles extending from Bergen, Norway to several hundred miles west of Ireland, to Nantes, France, and across the North Sea to the Kattegat and Copenhagen. Since the region of interest covers 15 degrees of latitude, variations of the Coriolis parameter with latitude and the curvature of the earth are taken into account by using spherical coordinates. The model contains 26,000 grid points and gives the tidal-stream characteristics every minute at the 13,000 grid points that are over water. It was derived from the equations of momentum and continuity. Inputs to the model consist of simply the bottom topography of the area and the tidal elevations from 17 bottom-moored tide gauges that

were placed along the outer edge of the continental shelf by the Tidal Institute near Liverpool (ESN 33-10:423 [1979]).

The model was purposely limited in resolution to use only about half of the available capacity of the computer's memory so that its functional complexity could be increased without running out of core memory.

Models of this type sometimes receive disrespect because of overreliance on computers which can lead to confusion between computer solutions and reality. However, Pingree's model appears to reproduce reality faithfully and, where his results conflict with the hundred years' accumulation of data from other sources, he goes into the field and checks the model results with new real data. The M_2 tide is essentially linear and thus is more amenable to mathematical simulation than some other nonlinear processes in nature.

At each of the grid points the output of the model gives elevations, the currents, the tidal ellipses, the phases, and direction of rotation of the current vectors. The model is flexible so that other tidal components can be simply superimposed. Because it faithfully reproduces the characteristics of the tides where these characteristics have been measured, Pingree can basically assume that his results are correct in regions where tidal characteristics have not been measured but have been interpolated from measurements made by shore-based tide gauges and a limited number of seabottom tide gauges away from shore lines. His results can thus be used to correct errors in previous subjective interpretations.

In the past it has been assumed that the tidal phase of high water in the Celtic Sea and the English Channel led in the center with respect to the shorelines. Pingree's model shows that the high-water tidal phase shows up first along the shore and later in the center of the channel.

Knowing the tidal streams over the whole area allowed Pingree to compute the areal distribution of the Simpson-Hunter stratification parameter (ESN 34-5:237 [1980]) which appears to determine whether tidal seas will be stratified or unstratified in summer. Fronts between stratified and tidally mixed unstratified water are assumed to lie along a critical contour of this parameter. Taking into account

the rate of dissipation of tidal energy by bottom friction, Pingree was able to compute the critical value and determine the location of fronts. The locations predicted by the model agreed with positions observed from satellite photographs (warm stratified surface water shows up in darker shades than the cooler mixed water on infrared satellite photographs), and the locations found by research ships were in good agreement even to fine detail. The fact that a model accurately locates the positions of a dozen fronts separating mixed water from stratified water with only a knowledge of boundary tidal elevations is remarkable.

Pingree wondered if the above relationship might be site specific to the area under study, so he made a model of the mouth of the St. Lawrence River and the Gulf of St. Lawrence. His model predicted two frontal areas that also showed up clearly on satellite infrared photographs. A further model was tested to predict possible fronts in Ungava Bay, Hudson Strait, Hudson Bay, and Foxe Basin in Canada.

It was evident during the interview that Pingree's results are all carefully scrutinized by other researchers in his field of expertise. He is very sensitive to this and makes every effort possible to verify and improve his results.

At the present time Pingree is writing the results of the most recent simulations. He has added wind stress on the water surface to his model in order to simulate the distribution of residual currents which are caused by wind stress. These residual currents are extremely important because they move and distribute any pollutant that is introduced into the oceans and seas in some steady direction. At the same time they are extremely difficult to measure and in some areas appear to be very variable. This is especially true near the surface and in shallow water where spurious current components are also introduced into most, if not all, current-meter records, particularly in areas with small residual currents and large tidal varying currents. In the latter situation, the signal-to-noise ratio (of mean residual-current speed to mean tidal-stream speed) may be as little as 0.01 (ESN 33-10:423 [1979]). Presently available charts of residual currents in the North Sea and surrounding areas show some that are either blank or labeled weak and variable. These charts are based on over 50 years of

various kinds of observations. Directions are given but numbers are generally not given for speeds. Some indications of speeds are given by lengths of arrows representing residual currents.

Pingree used the mean annual prevailing southwest winds over the entire area as an input to his model. The features on the resulting chart, which took one hour of computer time to calculate, reproduce most of the features on the charts that have been developed over the last one hundred years and appear from field experience to be more accurate and quantitative. He was able to fill in the blanks on areas of light and variable residual currents. His results showed a remarkably strong current running from east to west along the north coast of Norfolk into the Wash (a very large bay north of London) that was verified by current meter measurements. (After visiting Plymouth, I visited the University of East Anglia. A sedimentologist, in discussing erosion and sediment movements along the north shore of East Anglia, said that while current charts showed coastal currents from the west, the sediments were moving to the west against the mean residual current). It is clear that numerical models represent a powerful technique in helping to elucidate the complex nature of water flow resulting from meteorological effects and tidal input. It is also clear that a need exists for carrying out hydrographic field test programs which provide relevant measurements of the real environment by which such models can be tested, developed, and refined, to achieve their full potential in realistically simulating conditions found in nature.

Pingree also ran his model with winds from other directions to see how the residual currents varied with direction. Several possibly important fundamental discoveries came out of the study. All currents in the Irish Sea and neighboring waters are extremely important because of the concentration of nuclear power plants along the west coast of England. Here the signal-to-noise ratio is very, very low and it may be fruitless to go on trying to measure residual currents there. The model shows, from residual currents in the Irish Sea, that the movement of pollutants including potential radioactive waste and oil spills may have to be considered as that due to tidal diffusion. It is only when tides have diffused the pollutants northward

to the North Channel that stronger residual currents pick them up and transport them rapidly around the north of Scotland (ESN 34-6:293 [1980]). This latter movement has already been clearly shown by the distribution of Cesium 137 from the Windscale nuclear power plant. A second and probably more important point has to do with the memory of shallow seas (ONRL R-1-80). There is a lot of speculation about the memory of residual currents and some speculators believe that, once the wind sets up a residual current, it will last for several weeks after the generating wind has died down or changed directions. Pingree's model indicates that the residual current memory in the North Sea is on the order of a few days instead of several weeks. He attributes this rapid dissipation to the extremely high tidal friction on the bottom in the area.

The group started out with small area models about five years ago. These were used to assist in local problems such as the best location of pollutant outfalls (ESN 33-4:167 [1979]). Now they have gone back to small-area local models to resolve minor inconsistencies in the products of the big model. This endeavor is designed to learn more about the physics of certain topographically generated tidal variations and to use this understanding to improve the large model.

Although he works in Plymouth, Pingree is a member of the staff of the Institute of Oceanographic Sciences at Wormley near London. He moved from Wormley in 1972, spent two years getting a physical oceanography program at Plymouth instrumented and underway, and then began his modeling program.

Most of the intricate computer programming for the tide model was done by Maddock. I was surprised to learn that her doctorate was in parasitology. When I asked her about this paradox, she said that she had taken an "A level" (i.e., passed a difficult mathematics test) in mathematics when in high school. She opined that her success in programming was probably because she did not know enough about it to know what was or was not possible.

Pingree and his associates have made detailed studies of frontal zones, in particular the front that occurs off Ushant in the western approaches to the English Channel. Infrared satellite images indicated the presence of occasional cyclonic eddies along the front with space scales of 20-40 km

and a persistence of about a day. The presence of irregular eddy structures has been confirmed by oceanographic measurements of temperature and salinity across the front.

The eddies bring about cross-frontal mixing of colder, well-mixed, nutrient-rich water on the inshore side of the front with warmer stratified water on the offshore side of the front.

Holligan and other marine biologists have gone to sea with Pingree to study the biological implications of the frontal zones. They have found that organic productivity is relatively low on both sides of the Ushant front. The degree of turbulence controls the availability of light and nutrients. Turbulence can have both positive and negative effects on productivity. On the seaward side of the front, they found that the stratification inhibits vertical turbulence and nutrients become depleted in the surface waters. On the inshore side of the front, the turbulence causes surface-to-bottom mixing and, although nutrients are plentiful, phytoplankton is thoroughly mixed from top to bottom and does not stay near the surface long enough to receive sufficient solar energy to reproduce at a rapid rate. However, subtle combinations of increased nutrients and reduced turbulence occur in the cross-frontal eddy-mixing zone. These are ideal for plankton growth. Here a number of species of plankton bloom and the abundance of some can be contoured and may reflect the shape of the causal eddies. Under some circumstances, the situation is so ideal for primary productivity that red tides occur.

Satellite photographs also show a broad cooler region ($\sim 1^\circ\text{C}$) at the shelf break bordering the western edge of the Celtic Sea. Vertical turbulence is an orographic effect of the sudden change in topography at the shelf edge. Horizontal irregular eddies are also found similar to those found on the Ushant frontal zone closer to shore. This shelf-edge mixing zone is thought to be very rich biologically.

The study of enhanced biological activity in frontal zones has filtered right through the Plymouth laboratory with individuals working on nutrient and chlorophyll concentrations, primary productivity, and the distributions of various components of the plankton biomass in and near the fronts. Cross-

frontal mixing in the shallow shelf seas surrounding heavily industrialized west western Europe is also of interest in the study of transfer and dispersal of other properties, such as heat, radioactive material, hydrocarbons, and industrial wastes, all of much concern to the public.

Sand transport along the bottom of the North Sea and other waters surrounding the British Isles has been subjected to a good deal of study in order to be used as a guide to what is likely to happen to similar material introduced by man. Presently available charts of sand movement are fragmentary over much of the area. These are based on sediment trap studies, tracer movement, sand wave and bank migration, cable burial, and, as inferred from bottom topography, asymmetry.

Pingree and Griffiths have extended their tidal model in such a way as to derive a representation of the M_2 tidal harmonic. Using the M_2 and M_4 tidal currents generated by the model, they can derive the magnitude and direction of the mean bottom stress over the whole area covered by the model. The results are in close agreement with estimates of bottom stress based on sand transport studies and, in addition, show the stress in areas not covered in previous *in situ* studies.

Pingree and his associates have clearly shown that they have made much more progress in their study of many facets of shelf seas by the use of models than would have been possible without them. Their careful attention to *in situ* verification of model results and their use of models to direct physical, chemical, and biological *in situ* studies have made the models very powerful tools.

It should be emphasized that, in addition to Pingree's team, there are also a large number of other groups doing excellent work in using their own models to study shelf seas around the UK and in adjacent waters (ESN 33-9:350, 33-10:423 [1979]). (Wayne V. Burt)

THE DEPARTMENT OF MARITIME STUDIES— LIVERPOOL POLYTECHNIC

The Department of Maritime Studies at the Liverpool Polytechnic has a long academic history closely connected with shipping and port industries. It started as the Liverpool Nautical College in 1892. With a staff of 29 instructors, 5 technicians, and 14 other members,

the department is unique in the breadth and depth of its instructional and research program.

I talked with the head of the department, Captain L.A. Holder, and the director of research, Captain K. Jones. About 100 merchant marine student officers are enrolled in a 26-week course in preparation for their first mate's license and 80 are enrolled in a 26-week master mariner's course. In addition to those taking professional-officer courses, 60 students are working on a BSc in nautical studies, 12 are pursuing the MSc, and 12 are completing PhD requirements.

The BSc degree requires five years of effort. Students spend the first and third years at sea as officer cadets and the second, fourth, and fifth years doing coursework at the polytechnic. Every aspect of the shipping industry is covered. About a third of the graduates become ships' officers; another third go into shipping management positions. Half of the remainder go on to higher education, and most of the rest work in shipping-related occupations: insurance, law, survey, consultancy, and research. Graduates are in great demand and can fill only a third of the available openings.

Current topics for thesis research for graduate degrees include: Ship squat in confined waters (copies of some of the results of this research sell for \$135), computers in cargo planning, port traffic information, radar videotape recording, integrated navigation systems, port pricing policy, decision making in anticollision problems, drifting of large tankers, and training of pilots for Gulf Arab countries. Holder pointed out to me that most of the completed theses are of immediate practical use to the shipping industry and some are published and sold by the department.

One of the most serious problems with long ships such as supertankers is that they tend to squat either at the bow or the stern in shallow water and thus increase their actual draft. Small changes in draft can be quite critical because it is common practice to navigate through shallow coastal waters and harbors with only a meter of water under the keel. Almost half of the major damage done to ships over 500 tons in weight is done by accidental grounding. Prior to recent research on the subject, captains learned about squat the hard way, by grounding. Now

the \$135 book provides a system of nomograms which can be entered by type of ship, a measure of the depth under the keel, speed and channel shape, and then give the amount of squat. This will tell the captain at a glance the maximum safe speed that he can use in each set of circumstances.

While I was visiting the department, Captain Jones was working on a computer program that allows one to use a television screen to study the reactions of ships to various situations. Each ship has its own characteristics such as drag, wind, draft, inertia, etc. A program is written for each type of ship under study. The operator feeds the ship's speed and heading into the computer which generates a line showing the ship's movement. Then the operator may give a change in rudder angle and/or speed. The computer simulates the ship's reaction by updating the lines showing the heading and movement across the screen every few minutes. A student officer can thus use the computer in the manner of a Link trainer to learn the responses of his ship before he actually tries to pilot it.

The second most prevalent cause of major damage to merchant ships is collision. A great deal of research at the department is concerned with collision avoidance. In the UK, ship's masters are required to take a short course in collision avoidance when they obtain their license and must return every five years for a refresher course. In these courses, three officers are taught at a time. Each one mans a simulated ship's bridge equipped with radar screens, autopilot, an engine order, a telegraph, and a helm. Module plugs are used to feed in the individual ship's characteristics such as rudder angle and speed change delays and inertia. The game is started with the three simulated ships placed in position relative to each other in a given restricted water situation. Two teachers also control simulated ships, making a total of five ships in all. The captains being trained try to navigate their assigned courses and avoid collisions by changing speed and direction when they think it is necessary. The teachers try to keep the problems complicated by the way they navigate their simulated ships. After each game, the ship's movements are dissected to see where errors have been made and how avoidance procedures can be improved. Speeds up to 50 knots can be simulated to include high speed hovercraft and hydrofoils in the program. Captain

Holder said that the simulation worked well with most ship's officers but failed completely with a group of oriental pilots who, to save face, absolutely refused to discuss their errors. Captains of large ships that have the advantage of all the latest navigational equipment are given some training on stripped-down simulated bridges to help them understand the navigational problems faced by masters of small, ill-equipped ships.

The department has a navigation aids simulator built around a PDP 11-3C computer. Students can exercise navigational instruments including radar, direction finder, Decca Mk21, Loran A and C, Omega, and a satellite navigation system over a wide playing area. The simulator's basic use is to train mariners to integrate, and assess the value of, navigational information obtained from various sources. Up to 15 simulated ships can be programmed to move about a TV screen. The TV screen even simulates the ships' lights that would be seen at night from the bridge window. The student can call up displays from any of the navigational instruments and show them on the TV screen one at a time. The instructor, on the other hand, can feed typical errors into the various navigational instrument readouts for the student to try to sort out.

The department teaches short courses on various subjects to members of the shipping industry. The newest course was engendered by a recent rash of ship losses under unexplained circumstances that may have been related to insurance claims. The course was for insurance agents, lawyers, surveyors, and shipowners and managers. It was designed to teach them what was normal at sea and what was abnormal and therefore worth investigating.

One of the missions for which there has been a large payoff is a continuing research program on setting up efficient maintenance systems for ships.

I was very much impressed by the excellence of the training and research projects underway at the Department of Maritime Studies at Liverpool Polytechnic which are carried out on the very limited research budget of less than \$200,000/year. (Wayne V. Burt)

THE DEPARTMENT OF OCEANOGRAPHY AT THE UNIVERSITY OF SOUTHAMPTON

As is usual in most cases, the inception and early growth of the Department of Oceanography at the University of Southampton was largely due to the efforts of one individual, Prof. J.E.G. Raymont. He became a professor of zoology at the University of Southampton in 1946. His primary interest was in plankton productivity in the ocean. The oceanography program began in the Department of Zoology and then grew into the Department of Oceanography. Raymont spent some time at Woods Hole Oceanographic Institute, Falmouth, MA, working with Prof. Henry Bigelow. Bigelow gave him the idea that the study of marine science should be an interdisciplinary effort. As a result, when Raymont was able to start the Department of Oceanography in 1964, he began to add staff members who were trained in various marine sciences when he became the first chairman. A new building was erected for the fledgling department in 1966.

Raymont died in the summer of 1979 while diving on the Australian Great Barrier Reef. He was succeeded as chairman by Prof. Henry Charnock, who had been a member of the department from 1966-1971 and had returned to the department in 1978. In the interim he had been visiting professor in the department and director of the UK's largest marine science complex, the Institute of Oceanographic Sciences.

The present academic staff and post-doctoral fellows of the department and their areas of interest are: Charnock, air-sea interaction—general circulation of atmosphere and ocean; Dr. J.D. Burton, estuarine and marine chemistry of trace elements; Dr. E.A. Hailwood, marine geology and geophysics—palaeomagnetic and magnetic anisotropy studies of marine sediments; Dr. A.P.M. Lockwood, osmoregulation in estuarine organisms; Dr. P.J. Ovenden, analytical methods for natural waters and geochemistry of iron and related elements in rivers and estuaries; Dr. I.S. Robinson, circulation and tidal dynamics in coastal waters and estuaries; Dr. M. Shearer, benthic and estuarine ecology with special reference to amphipods; Dr. N. Wells, modelling of ocean and atmosphere circulation; Dr. P.J. leB. Williams, marine microbiology and organic chemistry; B. Imber, experimental modelling of trace metal speciation in natural waters; Denise Wright, role of particulates in chemistry of

metals in estuaries; Margaret Yallop, modelling of oxygen in estuaries in relation to photosynthesis. Dr. N. Hamilton of the Geology Department works closely with Hailwood on problems in marine geophysics.

The department is housed in 5 buildings on the northern end of the campus. It uses Natural Environment Research Council (NERC) vessels for major cruises and its own 10 m launch *LABRAX* for working in local waters including the Solent and Southampton Water.

The primary support for research within the department comes from NERC. Some funds come from the University. The Science Research Council provides funds primarily for research on specific problems in marine technology and engineering. Other funds are derived from contracts with various industries, the Department of Industry, and other governmental departments for work on applied problems related to the marine environment.

The department teaches several undergraduate courses to students electing to do what we in the US would call a minor in oceanography. Majors in mathematics, physics, biology, and geology, for example, would take a degree called Mathematics with Oceanography. Total enrollment in these classes averages about 260 at any given time but some students are enrolled in several classes so that the actual total number of students is less than 260.

At the graduate level students may follow one of two routes. Each year about 25 students enroll in an MSc course. These students first take core courses in biological, chemical, physical, and geological oceanography and learn sampling and surveying methods in coastal waters. Next they select 4 or 5 more advanced courses out of 15 options (including geophysics) that are offered. The last part of their study is taken up with doing a research problem and writing a thesis. Normally the time limit for completion is one full year but students from foreign countries where English is not the mother tongue are required to take two years to complete the course.

The second route leads toward a research degree, either the PhD or the MPhil. The former may be accomplished in three years and the latter in two. Students working toward research degrees

are encouraged but not required to attend some of the classes offered for the MSc candidates. Twenty-five students are presently enrolled in these two programs. Some meteorology is included in courses in fluid dynamics that are taught in the Department of Oceanography.

Charnock has two students working on aircraft observations that were made during JASIN-1978 (the Royal Society Joint Air-Sea Interaction study). The air-pressure field can be mapped very well from aircraft observation, and the difference between radar and pressure altimeters can be used to determine the pressure gradient very accurately as part of a study of the momentum balance in the atmospheric boundary layer.

Charnock is endeavoring to get a research program underway in a lake or reservoir in order to study processes that are hard to scale in the laboratory and sometimes have features that are too complicated to study in the open ocean. He mentioned Langmuir cells, surface and internal waves, the seasonal thermocline, wave run-up, and seiches (standing waves).

Small tidally powered flour mills were in use in England many years ago. These mills were abandoned, however, when labor became powerful enough to resist working the continually changing shifts required to use tidal power. Now with the fantastic increase in the price of fuel oil and the public's general distaste for building more nuclear power plants, the use of tides for generating electric power in the UK is becoming more attractive. The use of the Bristol Channel and Severn River Estuary for extracting energy from tides is being studied because the tidal range there is one of the largest in the world. A tremendous amount of study has gone into the subject in recent years with papers on the subject dating back almost 60 years to 1921, when G.I. Taylor published a paper on tides in the Bristol Channel. Recently Dr. Ian Robertson has spent a good deal of time developing models of the Bristol Channel and the Severn River Estuary in an endeavor to determine how to extract the maximum amount of energy from the system.

The biggest problem is how to make use of an intermittent source of power. Each potential estuarine source of tidal energy has its own phase angle or time difference between the time of high tide and the passage of the moon overhead. Robinson has shown that by proper placement and management of tidal barrages one can "tune" a particular estuary and change its phase angle. He has

suggested, "It might even be possible to design power schemes consisting of electrically interconnected barrages, located in different estuaries with a suitable tidal phase lag between them, such that pumping at one could be powered from the peak production of another, and an almost steady output could be provided to the grid system." Robinson believes that tidal power schemes could be of great use to developing countries where the resulting intermittent electrical energy could be used in some types of smelters and also to manufacture hydrogen which in turn could be stored and used as a steady source of power.

Robinson uses LANDSAT images (bands 4 and 5 stretched as far as possible) and the Plessey IDP 3000 false-color display at the Royal Aircraft Establishment in Farnborough to study estuarine sediment dynamics of the Solent and the adjacent Southampton Water. He hopes to be able to determine the spatial variability of the suspended sediment and/or chlorophyll content at various stages of the tide and also to provide information indirectly on water transport, dispersion, and mixing.

Ground truth for calibration is taken from a small boat whenever LANDSAT passes over in good weather. The problem is that Robinson can only expect to obtain about half a dozen good images a year because of persistent cloudiness. In the meantime he plans to look at SEASAT imagery that was achieved (but does not have ground truth) during the period SEASAT was operational. The pictures that he showed to me clearly revealed the potential in his method with different distributions of sediment evident at different stages of the tide.

Robinson proposed that similar studies should be carried out in all of the major estuaries in the UK. He emphasized that oceanographers should team up with satellite people because both can make mistakes. To be sure of what one is seeing one needs to understand the processes at work.

Lockwood is working with the osmoregulation of estuarine organisms that are subjected to cyclical changes in salinity during tidal cycles. He has developed a microprocessor system which will produce various cyclical changes in salinity. He then subjects the amphipod *gammarus duebeni* to various concentrations and combinations of DDT, lindane, and heavy metals, and monitors the urine output of the animals.

The main effect of these changing environments is an increase in urine output in the presence of increased concentrations of pollutants. This causes a stress on the animals that have to get salt back into their systems in the presence of cyclic salinity changes. Lockwood's hypothesis is that the physiological range of tolerance to one stress is decreased in the presence of another stress. That is, the animals can adjust to the stress of changing salinities from 3‰ sea water to 9‰ sea water in the absence of pollutants but cannot adjust as well in the presence of pollutants.

Williams has developed a system for very rapid and accurate determinations of O_2 concentration. All stages are managed by microprocessors. The system was developed for use in productivity experiments in large plastic bags in Lock Ewe, Scotland (ESN 34-6:293 [1980]). He also has developed improved methods for determining concentrations of dissolved and particulate carbon for the productivity experiment.

Burton's research deals with trace metals that are bound to particulate matter and are found in bottom sediments and marine organisms. His work on trace metals is concerned mainly with problems of chemical speciation and geochemical behavior in river, estuarine, and oceanic waters.

Wells, who recently joined the department, came from the Australian Numerical Meteorological Research Center. He is continuing his research on the physical basis of inter-annual climatic variations that are known to be associated with large-scale changes in the heat content of the upper layers of the ocean. Wells is particularly interested in air-sea interaction feedback processes between the ocean and the atmosphere. His ocean model is used to study a single ocean basin at a time. The model includes the upper 200 m of the ocean and is coupled to a simple atmospheric model of the general circulation.

Wells's second interest is optical oceanography and the use of satellites to determine optical properties of surface waters in bays and estuaries. Southampton Water and the Solent contain suspended sediments, and interesting phytoplankton blooms occur occasionally in the Southampton Water. Wells wants to determine if he can sort out the effects of suspended sediments from the effects of phytoplankton blooms using satellite infrared data.

Drs. N. Hamilton and E.A. Hailwood are mainly interested in magnetic studies of cores taken by the USS *GLOMAR CHALLENGER*. They have found that they are able to obtain finer time zonations from some cores than they can from fossils. Their dating is particularly important in parts of cores that are barren of fossils. They were the first individuals to take a paleomagnetic laboratory on board the *GLOMAR CHALLENGER* in 1976. The laboratory is now used regularly on that vessel. They are also interested in magnetic grain fabric studies on weakly magnetized sediments that have preferred grain orientation and can be related to the direction of the current when the sediment was laid down. These studies are being done to evaluate grain orientation *in situ* rather than by trying to obtain such information from bottom cores. The system is based on magnetic proton-free precession techniques. The Department of Oceanography now has the first instrument of this type in the UK.

The research in this department appeared to be on a par with the excellent work underway at the other two departments of oceanography that have been visited in the UK (ESN 33-10:423 [1979] and ESN 34-5:237 [1980]). (Wayne V. Burt)

OPERATIONS RESEARCH

HOW MANY THERMS TO A DEGREE DAY?

The British Gas Corporation (so-named in 1973) has been a nationalized industry since 1949. Nationalization means that, while British Gas is a corporation like any other, all its stock is owned by the UK government. Few industries have undergone such violent changes as this one in such a short period of time. Twenty years ago, all of the gas used in the UK was manufactured; most of the demand was domestic; and most of it was for cooking. In all of London there were only a few thousand gas-fired, central-heating installations. Today, virtually all of the gas is natural (from the North Sea); there are almost a million gas-fired, central-heating installations in London alone; cooking accounts for a negligible fraction of the demand; and the commercial and industrial uses have significantly increased.

Since the bulk of the gas demand is for space heating, the load is much larger in winter than in summer, and demand peaks dramatically on exceptionally cold days. It would be intolerably expensive to create a sufficient supply to meet, on the average, the demand that occurs only during the occasional peaks, especially in terms of the transmission lines that would be required to transport gas from the North Sea sources. Therefore the maximum supply has been set at a considerably lower level, and peak demand is met in three ways: through interruptibles, peak shaving sources, and lowering pressure in gas lines.

Interruptibles are customers, usually commercial or industrial, who have signed contracts to buy gas at less than the normal price with the understanding that their supply may be interrupted on short notice. Unlike domestic customers, who prize the cleanliness and convenience of gas, these customers are interested only in the energy content of fuel and are quite willing to use coal, oil, gas, electricity, or whatever is to their financial advantage.

Peak shaving is the term used to describe alternate sources of gas. These may be gas-manufacturing plants (some adapted from the old ones which were replaced by natural gas), gas holders (the familiar large gas tanks enclosed in cage-like structures), gas stored in caves and other natural repositories, or liquified natural gas (LNG). Four sites capable of storing a total of 75 million therms (a therm is 100,000 Btu) of LNG are operational in the UK, and three other sites now under development will raise the capacity to about 135 million therms. These sites are generally at the periphery of the system, farthest from the sources of supply; this makes savings in transmission capacity possible because they can be used to backfeed the system in times of high demand. LNG storage can also be used to mitigate the effects of major failures. Because the equipment employed to convert LNG into gas (by evaporation) is cheap, oversized facilities have been provided which can empty the stores in less than a week. On the other hand, conversion of gas to LNG (by liquefaction) is extremely expensive, and it takes about 6 months to refill the same stores. Thus, stores used for one emergency might not be available for a succeeding emergency.

Finally, if a sudden demand cannot be satisfied through interruptibles or peak shaving, the system pressure is lowered, which results in giving at least some customers less gas than they are demanding. This alternative is undesirable for a number of reasons; for instance, when the pressure is lowered, air enters into the system through leaks from which gas would usually escape, and if explosive mixtures form they are surely safer outside the pipes than inside.

It follows that a series of decisions must be made in balancing supplies against demand. Some are tactical (when to cut off interruptibles, and which ones; when to release LNG), and some are strategic (how to negotiate interruptibles contracts; how much LNG storage to build; how much liquefaction equipment to supply at such storage; how many transmission lines to build; and, as discussed below, how to develop and deplete the gas fields).

Three different models are required to supply a rational basis for these decisions: (1) A model which will predict the frequency and severity of cold weather; (2) A model which predicts how demand varies as the weather worsens; and (3) A cost/benefit model which determines how bad are the conditions for which British Gas should plan—in terms of balancing the costs of preparing for exceptionally cold weather with the costs of failing to meet demand.

Employing a cost/benefit model, British gas has decided to prepare for the coldest day which will be met, on the average, once in twenty years (the "1-in-20" criterion) and also to prepare for that cold spell (i.e., several cold days in a row) which will occur once in 50 years (1-in-50). The reason why the peak-period criterion is more conservative than the peak-day criterion is because of the magnitude of the shortfall that will occur if one is not conservative enough with respect to the former. Thus, if one plans for the 1-in-20 cold day, and the 1-in-100 cold day occurs, there will be a shortfall of only 5 degree days (that is, one day 5°F colder, equivalent in gas demand to 5 days, each 1° colder); whereas if one plans for the 1-in-20 peak period and the 1-in-100 peak period occurs, there will be a shortfall of 43 degree days (and even the 1-in-50 criterion yields a shortfall of 15 degree days if the 1-in-100 period occurs).

One must have a precise definition of "temperature for the day"; usually this is the average of the 24 hourly temperatures, but sometimes, one simply takes the average between the minimum and maximum temperatures over the 24-hour period from 6 a.m. to 6 a.m.; this seems to be equally good if it is used consistently.

What, then, is the 1-in-20-day criterion? In other words, how cold is the temperature which is reached, on average, 5 times in every century? Since adequate statistics go back only about 50 years, one cannot estimate these numbers with a high degree of confidence, but this kind of uncertainty is familiar to statisticians, and appropriate techniques are available for making the best possible guesses.

The most interesting model is that which explains demand as a function of temperature. The simplest model would be a linear one: $D = a + bt$, where D is demand, t is temperature, and a and b are constants. Unfortunately, this simple model does not describe observed behavior. In the first place, there is a distinct lag—today's consumption of gas seems to depend on yesterday's temperature. Furthermore, it depends on the time of year. People do not use as much gas when they expect the weather to be warm as when they expect it to be cold. To account for these phenomena, several formulas have been developed for "effective temperature"; a typical one is $t_e = (t + t_y + 2t_s)/4$ where t is the actual temperature for the day, t_y is the temperature for yesterday, and t_s is the average temperature at this season.

People tend to try to keep the temperature in their homes at a certain comfort level, t_c . The consumption of gas depends upon the difference between this level and the effective temperature; that is, upon the difference $t_c - t_e$. Thirty years ago, t_c was about 65°F, but with increasing affluence it has now become 70°F or 21°C. The usage of gas is a nonlinear function of this difference; namely, this difference raised to the n th power, where n is about 1.4 or 1.5. Therefore, the demand is well predicted by the formula $D = a + bT_x$, where $T_x = (21 - t_e)^{1.4}$, and $t_e = (t + t_y + 2t_s)/4$; a and b vary from region to region. This formula worked quite well until early 1979,

when extraordinarily cold weather occurred throughout England. The 1-in-20 demand level was reached on a day whose average temperature was -2°C, although it had been predicted to occur only at -5°C. Hence, still further modifications have now been made to the formula.

While the foregoing is typical of the problems tackled by operational research (OR) analysts at British Gas, it is by no means unique. Each of the 12 regions (of which London described above is one) has an OR Group, as does the headquarters, also in London; the latter, with 23 OR analysts and 3 programmers, is headed by F.K. Lyness, who studied mathematics at Oxford, statistics at Cambridge, and management science at the Sloan School of MIT. D. Clarke, the assistant manager, originally studied chemical engineering and worked for the electricity company before coming to British Gas. He explained to me that a shortfall in gas means an added electrical load (people turn on electric heaters when gas central heating leaves the house too cold), but the reverse is not generally true, except for a minor, "oven door" effect (people turn on the gas stove and open the door of the oven to heat the house).

OR Groups in the regions are involved largely in planning. Every year, each region puts out a rolling 5-year plan for manpower, capital, gas supply, gas demand, and the like. Headquarters tends to make strategic studies, as on industry policy, coordination of regions, the link between government and regions, and the actual running of the transmission systems—involving buying gas from the oil companies and transmitting it to the regions. They have 25 to 30 projects going at any one time, which means that most of the analysts are working simultaneously on two or three different projects. Of the current projects, one, discussed below, involves an optimization, and two others involve forecasting with Box-Jenkins models; but none of the other 20-odd projects represents classical OR. Mostly they are "what if?" simulations. The department is well equipped with terminals, formerly connected to a UNIVAC 1106 but now being switched over to an ICL 2972, which is a large mainframe computer. Interestingly, there is a mathematics group in the Research Division which utilizes classical

models—for example, modeling a gas reservoir by means of differential equations. The OR Group is in the economics planning division, and its members act as internal consultants. One measure of their utility is that the demand for their services exceeds their ability to supply them.

The optimization model was part of a strategic study aimed at determining how gas fields should be developed and depleted. If fields are developed too early, interest fees must be paid on excessively early capital expenditures, and some of the gas must be sold to less desirable customers, namely, those who are willing to pay only for its energy value and not for its convenience. On the other hand, if the fields are developed too slowly, the special facilities already described must be built, at considerable expense, to shave the peak demand. Supply, of course, is controlled by the rate of development, while demand is influenced by the pricing policy. Given various relevant parameters such as marginal revenues, marginal supply costs, discount rates, load factors, operating costs, and the like, this optimization was worked out as a linear programming problem. However, no one really believes the results, because of the uncertainty in the appropriate parameters, which must be predicted; and in any case, in a state-owned industry the ultimate decisions are often based on factors which are not easily modeled. Nevertheless these models have been of great value in helping to understand the problem, and they are utilized (if only for background) by top-level decision makers.

Another project which fascinated me because some of its results were nonintuitive related to security of supply. Suppose there is a town which relies for its gas supply on a single spur of the transmission line; should another spur be built? The OR Group works a cost/benefit analysis backwards; if the spur is built at a particular cost, say £100,000, and if one anticipates that it will be required once in 50 years, then depending on the discount rate one is imputing a cost of millions of pounds to the damage that would result from that spur failure. It frequently turns out that the actual damage cost clearly would be much lower, and therefore the spur should not be built. Conversely, the same type of analysis has often shown that a backup pump is an extremely worthwhile investment.

Because of the decentralized, regional structure of British Gas, it is difficult for headquarters to impose a solution that is satisfactory and that can be implemented in all the regions. What frequently has worked is for headquarters to develop a framework which can be modified by each region as necessary. These modifications are never easy, but headquarters has learned to be flexible. Typical of these solutions is one based on a model of vehicle replacement. This is a familiar OR problem, trading off the capital costs of replacement against the operational costs including repairs. British Gas has thousands of light vans used, for example, by fitters installing gas appliances. The model is very simple. It postulates, say, a five-year replacement cycle, calculates all the cash flows, works out the present net values of the vans, and then repeats the calculations for 4 years or 6 years until it finds an optimum. What is unique here is the consideration of individual vehicles, as distinguished from assuming that all vehicles are identical. This gives the analyst in the region the opportunity to decide to replace a car sooner than would usually be recommended if it has suffered collision damage or if it is a "lemon", or to keep one operating beyond the usual replacement age if there are good local reasons for doing so.

I was impressed by the fact that in the British Gas Corporation, as in other organizations where large OR groups are working in successful symbiosis with top management, the kinds of things they actually do have almost nothing in common with what is taught in the universities or published in the OR journals, especially in the US. At British Gas, OR seems to have its feet squarely on the ground and to be doing very well indeed. (Robert E. Machol)

OPERATIONS RESEARCH AT THE PUPIN INSTITUTE IN BELGRADE

Mihailo Pupin was a Serbian electrical engineer. Although he spent most of his professional life in the US (at Columbia University where a large building on the north end of the campus is named for him), Pupin is considered something of a hero in Yugoslavia. He was a friend of Theodore Roosevelt and an adviser to Woodrow Wilson, and he is rumored to have had something to do

with the formation of Yugoslavia as a state. So when a major research institute was developed in Belgrade shortly after WWII, it was named in his honor. The institute currently has some 900 employees, more than 300 of whom are engineers or comparable professionals. Like everything else in Yugoslavia, the institute is highly decentralized (such decentralization is specified in the country's constitution), and is organized into six research-oriented divisions, plus a support group and an administrative section. The divisions are: (1) Hydraulics and Pneumatics, (2) Measurement and Regulation, (3) Electronics and Technology, (4) Telecommunications Equipment, (5) Digital Equipment, and (6) Automatics.

The Operations Research (OR) Department is in the Automatics Division and consists of about 20 professionals plus support people. It is directed by Vlastimir Matejić, whose doctoral thesis at the University of Belgrade was entitled "One Method of Analyzing the Behavior of Organizational Systems." While this sounds sociological, it was, in fact, a highly technical mathematical thesis. In the academic year 1965-6 Matejić was at the University of California in Berkeley, where he worked with George Dantzig in the OR Department. Returning to Belgrade, he first taught electrical engineering at the university and then transferred to management science. He became director of the Management Development and Training Institute in Belgrade before coming to his present position at Pupin. Matejić holds professorships at both the University of Belgrade and the University of Kragujevac, 150 km from Belgrade, where he teaches an OR course once a week.

The OR Department at the Pupin Institute is divided into four groups. The largest, on reliability, is under the direction of Radivoj Petrović, who has been at Pupin since 1960, and who took his doctorate in electrical engineering at the University of Belgrade in the early 1960s. His business card shows him to be a "Scientific Advisor," which apparently is a rank somewhat like research fellow or senior research engineer. When I asked him how he happened to get interested in OR, Petrović said he went from electrical engineering to automatic control and from there to "controlling common sense," from which it was just a short jump to systems theory. He teaches an OR course in the Electrical Engineering Department at the University of Belgrade.

Petrović's group has seven professional people plus support personnel, and while the title of the group is "Reliability," their principal interest is in what he called the knapsack problem, although apparently he uses this term very broadly to cover all types of 0-1 programming, or even in reference to other types of combinatorial optimization. A typical problem is to determine the optimum number of spares in inventory at each level of a hierarchical organization, with the objective of maximizing the reliability of equipment over the entire organization, subject to a cost constraint. A considerable amount of their work is on reliability problems for the Yugoslav military and, since this was classified, he could not discuss it with me. Yet, it is interesting to note that I was not challenged when I came into the building nor asked to wear a badge, an indication of how much freer Yugoslavia tends to be than other socialist countries.

Petrović told me about a joint research project which his group is conducting with a Dr. Barber at the National Physical Laboratory at Teddington, UK (ESN 34-1:35[1980]), and which is sponsored by the European Economic Community (EEC) in Brussels. Yugoslavia is not a member of the EEC, but this does not prevent it from working on the EEC's "COST" projects. In particular, Yugoslavia is working on COST 11, the European Informatic Network. The reliability group's segment of the problem is reliability and availability; they are doing Monte Carlo simulations of failures of various arcs and nodes of the network; simulating traffic densities, repair times, and the like; and measuring the fraction of information packets which fail to be delivered.

The second group in the OR Department works on the application of OR and computers to traffic control. They have been studying city traffic control, with Belgrade as their laboratory—although the results should be universal. In particular, they are dealing, not with single intersections, but with a three-level hierarchy: the intersection, the zone, and the city as a whole. This group is especially interested in software (another department in Pupin deals with hardware), but they go beyond the simple writing of programs all the way to the selection of computer architecture. They are now beginning to expand to highway traffic.

The third group works on "problems of informatics." One such problem concerns medical information systems, but Matejić was somewhat pessimistic about the use of such systems even if they were developed; he felt that, in Yugoslavia at least, only the largest hospitals could afford such systems. Another problem concerns forecasting and planning for the Yugoslav electrical system. They are using a linear programming model developed by Pierre Massé in France for investment planning for the electric power industry. However, the electric power industry (like everything else in Yugoslavia) is highly decentralized, which makes it difficult to apply such planning tools. One problem which can surely be applied, if it is solved, concerns the optimal level of supply voltages. Typically, for example, power is transmitted over long distances at 400 kv and transformed down successively to 35 kv and 4 kv before finally being brought to the level of consumption—but is this optimal? Might it not be better to cut out one of the intermediate levels and go, say, from 400 kv to 10 kv, and then directly to the domestic-use voltage? Or might it be desirable to have more intermediate levels? This problem is still under intense study.

The fourth group works on research for more complex systems. One of these is a development and investment program for the Serbian railway company, which, again, is difficult to apply because of decentralization. They are trying to develop a long-range plan and decision-making aids for the large corporation manufacturing automobiles in Kragujevac (Yugoslavia builds many of its own autos in plants constructed by Fiat). A third problem concerns the development of science in Yugoslavia over the next 20 to 30 years; the group is trying to develop both a methodology and an implementation of this methodology to help the appropriate ministry in the central government.

Until recently, the Pupin Institute was the largest manufacturer of digital computers in Yugoslavia, and they are still manufacturing hybrid computers (such computers are exported to several countries in Eastern Europe). For parochial reasons, the Institute used its own computers, which were not really large enough or good enough for the kind of work the Institute was doing, and Matejić felt that this had hurt them. They expect soon to have a link into

a large mainframe computer in Belgrade which will enable them to do much more. This is particularly important because the major emphasis of Matejić's department is on software.

There is no national OR society, as such, in Yugoslavia. What contact there is with international OR groups is in the Pupin Institute, with Petrović as the focal point. Again, this is based on the decentralization of Yugoslavia. In the past OR has been organized largely through the economics societies, of which there is one in each of Yugoslavia's republics. But there is a "Yugoslavian Organization for Electronics, Telecommunications, Automatics and Nuclear Technology" (ETAN), which has contacts, through one of its sections with IFAC, the International Federation for Automatic Control. Working through ETAN, Petrović has made application to join the International Federation of Operations Research Societies.

There is no question that operations research is strong and continuing within Yugoslavia. It started there in 1960 with a postgraduate course on OR at the University of Belgrade, financed by the United Nations (Matejić was a student in that course). For some years there was discussion in Yugoslavia as to whether OR was capitalistic or communistic. About 1966 it was apparently decided that OR was acceptable, and it has grown rapidly since. However, there is very little government subsidy of OR, or, in fact, of most other kinds of research. Ninety percent of the financing of Matejić's department comes from customers, mostly industrial firms, while about 10% comes from the Yugoslav Council of Sciences. This makes it very difficult to do basic research. While it is possible to bootleg a little time out of a sponsored project, most fundamental research, Matejić told me, has to be done on one's own time. The result is that there is comparatively little material on OR by Yugoslavs in the international literature. The Pupin Institute has a large series of publications, but most of these are in the Serbo-Croatian language.

I conclude that competent applied research work is being done in the Pupin Institute in general, and in particular in Matejić's OR department. However, unless the government's approach to the subsidy of research changes, it seems unlikely that outstanding work of international interest will come from such institutes. (Robert E. Machol)

NEWS and NOTES

PUTTING ENGINEERS BACK AT THE TOP

The view that management boards of British industry are top-heavy with accountants and that this may be a factor in the country's poor economic performance is behind a training project being carried out by a university engineering production department and a local company in South Wales.

Prof. Denis R. Towill, of the University of Wales Institute of Science and Technology, Cardiff, believes that production management in home industry is troubled by the "generalist myth" which says that once people have risen above a certain level, they ought to have an instinctive understanding of all the processes of their trade.

"One result is that too many boardroom seats are occupied by accountants, thus concentrating skills on too narrow a part of the throughput process of every manufacturing enterprise." Continental boardrooms, on the other hand, are distinguished by a large number of top posts filled by engineers who still retain an active interest in the whole manufacturing process.

Towill said in a recent paper that with honorable exceptions the overwhelming picture of twentieth century United Kingdom industry is a weakness in production management plus a complacent resting of the laurels of Victorian engineers.

To help Britain to become product oriented again, Towill believes that work should be redefined in terms of the "outputs" and not "relationships," and "if education was aimed at doing something rather than being someone, so much the better."

The engineering production department of his institute and the company concerned, Zimmer Orthopedic of Bridgend, practice what they preach by taking advantage of the so-called teaching company scheme. This was initiated in 1975 by the Science Research Council and the Department of Industry as a means of establishing closer links between the academic and the industrial worlds.

The scheme enables high-caliber students, usually with postgraduate experience, to use a company as live laboratory in the hope that they will become expert managers or entrepreneurs of the future. In return, the company

hopes to benefit from their fresh ideas, and it also has the advantage of access to highly specialized university equipment.

Before the associates moved into the plant, the managing director and his staff "sold" the project to the workforce whose members were naturally suspicious that they might be expected to cooperate in a job-cutting exercise. Also, some senior management members had personal reservations, questioning whether they could learn anything of advantage from the fresh-faced young men.

But according to the managing director, the scheme has prospered and will benefit both the company and the university. He said that the prime objective must be to train in a practical environment the next generation of managers from engineering disciplines.

At present there are only about 25 such schemes in Britain, and financial constraints might make it difficult to expand that number significantly. Towill hopes that the success of the Zimmer project will help to concentrate the Government's mind on the importance of the engineering sector when it next examines education spending. (The Times)

UNDER 21s FARE BADLY AT THE OPEN UNIVERSITY

Editor's Note: The information in this article published on 27 June was not available to the author of the article on page 327 of this issue at the time he wrote.

New evidence that students under 21 fare badly at the Open University (OU) has led to a warning from the retiring vice chancellor, Lord Perry, that politicians should not regard the OU as a cheap alternative to traditional universities.

A report published on 27 June about five years of research into a group of under 21 given special permission to take OU courses disclosed that they did less well than full-time students in residential universities and older OU students.

Commenting on the results of the project Lord Perry said: "The experiment was vitally necessary, for it is all too easy, for political or economic reasons, to see the Open University as a potential substitute for the more expensive traditional university education of high school graduates.

It was necessary to prove what works well for mature students is not necessarily suitable for younger people, whether qualified for university or not."

The pilot project to admit under 21s attracted 1,400 students in three years from 1974. Few were 18 years old and even fewer were high school graduates. More than half were 20, and two out of three did not possess traditional degree course entry requirements.

The younger students were less likely to confirm their registration than older students—61 percent compared with 75 percent—or to gain a first-year course credit—63 percent compared with 81 percent.

The report said: "Broad comparisons would suggest that the wastage rate among younger Open University students was much greater than those found in other sectors of higher education. Their performance was particularly poor in comparison to full-time students elsewhere.

"However, while a relatively small proportion of the younger students are likely to graduate from the Open University, 4 out of 10 of all those admitted gained some course credit and many had used this qualification to gain entry to a full-time degree course."

The project, intended to find out how suitable the Open University was for younger students, discovered several reasons for their poor performance. These included the fact that most under 21s were entering an unstable period of their lives, as well as being unwilling to "play the system" and take short cuts which would make their studies less daunting.

Professor Naomi McIntosh, the project director, commented: "We can draw out three clear policy pointers from our study. Firstly, there are some younger students for whom a correspondence course is the only door to a degree. Secondly, our system was set up for mature adults. We would expect younger people to do better in a correspondence course which was specifically designed for them.

"Finally, we feel that combining face-to-face teaching with a correspondence course is an approach that needs more exploring. Only a few people have so far started looking seriously at this. For example, there have been suggestions recently about an Open Tech. Our research is another bit of evidence suggesting the idea should be explored further. (The Times)

ONRL STAFF CHANGES

In July we welcomed our new chief scientist, Dr. William J. Condell, who came to ONR London from the Office of Naval Research in Washington, DC.

We welcomed also Dr. Jerry A. Cooke formerly with the Nuclear Regulatory Commission, as the new director of the US Navy European Patent Program.

We said farewell to Dr. Willard D. Bascom, who returned to the Naval Research Laboratory in Washington, DC; to Dr. J. Dennis Frew, Dr. Cooke's predecessor, who went to the Office of Naval Research; and to Dr. Irving Kaufman who returned to Arizona State University in Tempe, Arizona.

CHAIRS

Professor Derek Atherton, professor in the Department of Electrical Engineering at the University of New Brunswick, Fredericton, Canada, has been appointed to the chair in the Electrical Electronic, Control Engineering, and Computing Science Subject Group at the University of Sussex as of September 1980.

Dr. Kumar Bhattacharyya, senior lecturer in engineering production and head of the Manufacturing System Research Unit at the University of Birmingham, has been appointed to a newly established chair of manufacturing system research at that University. He will take up his position on 1 October 1980.

Dr. Christopher Lance, visiting lecturer at the University of Pennsylvania, Philadelphia, PA, has been appointed to the chair of pure mathematics at the University of Leeds. He will take up his new appointment in October 1980.

Dr. John Mavor, lecturer in electronic engineering at the University of Edinburgh, has been appointed to the Lothian chair of microelectronics in the Department of Electrical Engineering at that university.

ONR COSPONSORED CONFERENCES

International Conference on Adhesion and Adhesives, Durham, England, 3-5 September 1980.

Conference on Physics of Dielectric Solids, University of Kent, Canterbury, England, 8-11 September 1980.

3rd International Symposium on Gas Flow and Chemical Lasers, Marseille, France, 8-12 September 1980.

IUTAM Symposium on Creep in Structures, Leicester, England, 8-12 September 1980.

International Symposium on Gallium Arsenide and Related Compounds, Vienna, Austria, 22-24 September 1980.

NATO Advanced Study Institute, "Singularities in Boundary Value Problems," Maratea, Italy, 22 September-3 October 1980.

NATO Advanced Study Institute, "Molecular Ions: Geometric and Electronic Structures," Isle of Kos, Greece, 30 September-10 October 1980.

International Workshop on "Ion Formation from Solids," Münster, West Germany, 6-8 October 1980.

ESN 34-8 (1980)

European Visitors to the US, Supported by ONR London

Name of Visitor	Affiliation	Navy Lab./Org. to be Visited
<u>SEPTEMBER</u>		
Dr. F.M. Harris	Royal Society Research Unit, University College of Swansea, UK	NRL, NSWC, DTNSRDC
Dr. A.P. Parker	Materials Branch, Royal Military College of Sci- ence, Shrivenham, UK	NRL, DTNSRDC, NSWC
Dr. D. Price	Dept. of Chemistry & Applied Chemistry, University of Salford, UK	NRL, DTNSRDC
<u>OCTOBER</u>		
Dr. K. Allen	Adhesion Science Group, City University, London, UK	NRL, NSWC
<u>DECEMBER</u>		
Dr. F. Durst	Sonderforschungsbereich 80 an der University Karlsruhe, West Germany	NRL, ONR, NOSC

ONAL REPORTS

C-8-79

Physics of Nonlinear Transport in Semiconductors by Irving Kaufman

This is a report on the NATO Advanced Study Institute of Nonlinear Transport in Semiconductors, held at the Sogesta Center near Urbino, Italy, during 16-27 July 1979. The Institute was held to "provide young researchers with the foundations of the principles of nonlinear transport behavior that will be encountered in work with ultra-fine-geometry or ultra-high-speed semiconductor devices. The topics that were treated included phenomenological aspects of hot carriers, electronic structure and band renormalization.

C-3-80

OCEANOEXPO '80; Bordeaux, France by C.H. Spikes

This is a report on the 4th International Exhibition and Symposium on the exploitation of the world's oceans, covering shipbuilding, offshore techniques, harbors, fishing and pollution control, held in Bordeaux, France 4-8 March 1980. The International Sponsoring Committee consisted of the President of the Republic of Senegal and the Chairman of the French National Assembly. Over 84 countries were represented, with emphasis on the African, Caribbean and Pacific (A.C.P.) States, and Arab countries, the Southeast Asian countries and Latin America. Primarily a glittering showcase for the opulent Arabian nations, conference discussions ranged from seabed mining techniques to high seas piracy. The well-attended exhibits covered fields as diverse as aqua culture and lightning research, while the Warsaw Pact was represented by both Poland and the USSR.

R-1-80

CLIMATE VARIATIONS AND VARIABILITY: Facts and Theories by Wayne V. Burt

A NATO-sponsored advanced study institute on climate variability was held in Erice, Italy (near Palermo, Sicily), 9-12 March 1980. Twenty-seven lecturers spoke to 76 other participants. Every facet of climate, its variability, and effects of variability on man were discussed. The majority of the papers presented were tutorial reviews based on published papers. Several of these papers are referenced in this report, while the body of this report concerns papers that were reporting unpublished research.