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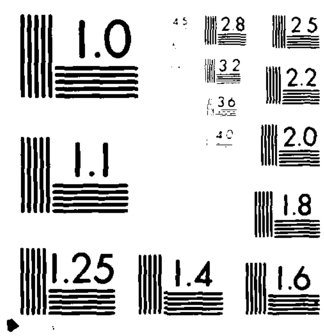

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EUROPEAN SCIENTIFIC NOTES

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This is a monthly publication presenting brief articles concerning recent developments in European Scientific Research. It is hoped that these articles (which do not constitute part of the scientific literature) may prove of value to American scientists by calling attention to current developments and to institutions and individuals engaged in these scientific efforts.

The articles are written primarily by members of the staff of ONRL and occasionally articles are prepared by, or in cooperation with, members of the

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NEWS & NOTES

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W.J. CONDELL
Chief Scientist

F.F. GIBBER
Captain, USN
Commanding Officer

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Dr. W.V. Burt	Oceanography & Meteorology
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AVIATION

INTERACTIVE ANALYSIS AT BRITISH AIR

The Operational Research (OR) Group of British Airways (BA) is located in South Ruislip, a suburb which can be reached by rapid transit from central London. The OR group of another comparable airline, Scandanavian Airlines (SAS), was described recently in these pages (*ESN* 33-12:523), but the two are as different as night and day. (Iberian Airlines will be described two months hence.) Many of the differences arise from the unusual style at BA, where most of the analysis is on the basis of interactive computer modeling. In this type of analysis, the computer model is used by an operator (not necessarily from the OR Group) working at the computer terminal and interacting on-line with a computer simulation until a desired solution is obtained, at which point the computer prints out the results. As will be seen below, this leads to a wide variety of other differences. For one thing, OR is much more successful at BA (the BA Group is more than 10 times as large as the group at SAS). They have major inputs on policy planning and the like, which is not true at SAS. And they have developed virtually all of their own models, because they are apparently ahead of all other airlines in this respect.

The OR Group has about 55 professionals, of whom about 1/3 are computer programmers, the remainder being analysts. The general manager is Norman R. Tobin, a distinguished member of the OR Society, and well known internationally. His formal education was in physics and he stopped at the bachelor's level. Tobin worked for several years as a physicist before getting into operations research in the 1950s. He came to a predecessor of BA 16 years ago to head a very small group.

It should be mentioned in passing that this OR Group does the conventional things; for example, like all airlines BA carries enormous inventories of spare parts and other supplies, and therefore has a major inventory control problem. This problem was computerized by the OR group a number of years ago and imbedded in the existing electronic data processing (EDP). It operates routinely, and no one from the OR group has had to look at it recently. The more interesting things, and what keeps most of the 55-person staff fully occupied, are the developments of the interactive computerized models. It is perhaps best to describe in detail a typical one which was demonstrated for me.

ALCOM (allocation and cost model) is used as an aid in the analysis and preparation of aircraft procurement and retirement, and in allied long-term planning problems. It was demonstrated to me by M. Jackson, a programmer, and his supervisor, S.M. Fletcher, who is in charge of the team (within Tobin's group) that looks after corporate planning and finance. Fletcher is professionally trained in OR, having taken his MA in this subject at Lancaster (*ESN* 32-12:431).

For aircraft-procurement purposes, long-haul and short-haul traffic are considered separately. Not only do they use different types of planes, but the ground rules are completely different. In long-haul traffic the plane, a 747 or comparable aircraft, may go to Australia, with several stops on the way, and not necessarily come back by the same route. In short haul on the other hand, a plane, such as a 737, will fly from London to some city such as Paris, and perhaps make as many as 4 or 5 round trips in a day. It follows that short-haul planning is more amenable to analysis; in fact, while the ALCOM model of short-haul traffic has been operational for some years, they are only now developing a comparable model for long haul.

In ALCOM the variables are the numbers of aircraft of each type (Boeing 737, Trident 2, Trident 3, Lockheed Tristar, etc.) which fly on each route (London/Paris, London/Rome, etc.) The computer uses a simple linear-programming (LP)routine to set those values of each of these variables which minimizes the total cost subject to a set of constraints. The network (of routes), the demand, and the fares are all assumed given (these must, of course, be supplied by the user of the program). The costs include direct operating costs such as the cost of crew and landing fees, load-variable costs such as cost of passenger meals, indirect operating costs, and overhead. For each route there are constraints that all demand must be met and that some upper limit on "load factor" not be exceeded. Load factor is the fraction of seats which are occupied on the average. Of course, all profit calculations on airlines are extremely sensitive to this factor. Very high load factors are possible in theory, but cannot be maintained in practice because of fluctuations in demand and for other reasons. This constraint prevents unrealistically optimistic assumptions about load factors. Futhermore, on many routes a criterion of a minimum frequency of aircraft is stipulated by the marketing people, even though the demand might not justify operating these aircraft at all times. Finally there is another set of constraints for the fleet as a whole which concerns the minimum and maximum number of aircraft of each type. These constraints are not used when the program is first run, but are brought in later, as described below. The minimum is set by the number presently available, and the maximum by a wide variety of considerations concerning the ability to purchase such aircraft.

After the computer has gone through the LP calculations, the operator examines the results on his display and compares the total number of aircraft of each type used with the minimum and maximum permissible. In general some of these latter constraints will have been violated. The operator then merely types "go" and the machine proceeds through another iteration which tends to reduce or eliminate the violation. If, for example, the number of 737s used exceeds the maximum permitted (which usually happens, because the 737 is an efficient aircraft and therefore not very costly), the computer automatically increases the cost of 737s in the objective function, thereby exacting a penalty for their use. If the number of Tristars is below the minimum, the computer may introduce a negative cost for them in order to force more of them to be used. The LP program is then run again and a new print-out is made.

The solutions, of course, do not in general come out in integers, but this not a significant disadvantage. Half a 737 on the London/Paris route simply means that it flies on that route half the day and on some other route the other half of the day. Of course, at the end, the total allocations must come out in whole airplanes, but this constraint can simply be typed in by the operator just before the final print-out. In the interim, all sorts of data can be printed out on revenues, costs, profits, passengers, load factors, landings, flying hours, and such cost breakdowns as fuel, flight crew, cabin crew, etc. All of this can be displayed as totals, by route or other aggregation. At any time the operator can divert the output to a printer to obtain hard copy.

At the end of any iteration the operator can display whatever information he likes. If he finds, for example, that on one route there are seven 737s, 5 Tridents, and 1 Tristar, he may decide that that is too many different types of aircraft for that route and too few Tristars for that route; and he would then type in that the number of Tristars for that route is equal to 0 and run the program again.

The ALCOM model is used very little by the OR Department, but mostly by the Planning Department, both in determining fleet size and in determining operating plans for the future. Furthermore, the model has been sold in its entirety to a number of other airlines, mostly to small ones, such as Botswana Airlines.

Digital Equipment Corporation hardware, consisting of 3 PDP-10s (1 KL, 2 KIs) and a great deal of peripheral equipment, is utilized for these systems. This represents an extremely powerful mainframe which, Tobin asserted, is much more suitable for interactive simulations (because it has been designed with that in mind) than comparable IBM hardware. There are now 20 terminals in the OR group, but much more impressive is the fact that the Planning Department, which is not primarily interested in programming or OR-type analysis, has 86 terminals. Most of these are in and around London, although one is as far away as Manchester. The point is that the operating people are using these terminals all the time. Another impressive example arises twice each year when BA goes to IATA conferences on international timetables. These are usually in Geneva, although the next one will be held in Singapore. At these conferences, landing and takeoff slots are arranged so as not to overcrowd any particular airport at any particular time. BA has special interest in this because it is responsible for assigning slots out of Heathrow to many airlines (*ESN* 33-4:135). BA routinely takes 6 terminals to these conferences! As Tobin said to me, "One terminal might indicate that it was a toy and that people were having fun with it, but when they take 6 of them, it's clear that they have a significant operational use."

Tobin's group believes strongly in the evolutionary approach to model development. In most airlines, he told me (and it is also true of most other large organizations that I am familiar with throughout the US and elsewhere), a client comes to the EDP group and they essentially negotiate a contract; detailed specifications are agreed on as to what the model will do and how it will operate and how much it will cost. In Tobin's group, quite to the contrary, they look for the smallest implementable subset, develop this tiny model, and get the customer using it before proceeding. There are a number of advantages to this approach, one of which is that it sometimes turns out that the model required is not as complex as was first thought.

Tobin assured me that some of the things they have done sound like EDP by the time they have finished, but could not have been obtained from a classical EDP organization. As an example, he told me of a model for aggregating and breaking down costs. Some of these costs vary with the number of flying hours, some with the number of landings and takeoffs, and some with the number of passengers, and not all of these costs are well understood. In several cases there is no agreement on the proper formula to be used. To solve this problem, they have developed a set of formulas which can be edited at the terminal. It is thus possible to implement the computerized system before agreement has been reached on the formulas, and actually to produce outputs for any one or more combinations of particular cost formulas desired.

The following trivial-sounding model has saved millions of pounds a year, and therefore has more than paid the cost of the OR group every year all by itself. And yet, identifiable savings such as this are the minor part of the benefits of these computerized models—intangible benefits, such as greater confidence in planning, can be much more important. This is a station-work-load model (station in this context means airport). It takes a proposed timetable and produces a profile, at 5-minute intervals throughout a week, of how many people are needed in every classification of labor—baggage handlers, checkout-counter clerks, cleaners, and the like. Not infrequently, a peak shows up which is simply not obvious from the timetable. This model is usually not run interactively but rather in an overnight batch mode. It is used interactively, however, for planning work forces (How much overtime will be needed next week? How many people must be hired for next summer?), and for rostering.

Another example is pilot scheduling. Because the textbooks have so many algorithms for scheduling, it sounds like a classical and easy problem. In practice, it is extremely difficult by classical methods but works very nicely in the interactive mode. The operator developing the schedule will note and instruct the computer that you cannot send this type of aircraft to that particular airport, or that this pilot has indicated that he will not fly with that particular crew member. These kinds of things lead to great complexity if they are programmed ahead of time, but they are comparatively easy in the interactive simulation.

The interactive mode can also handle uncertainties. At one time work had begun on a channel tunnel, and it seemed probable that such a tunnel would be completed within the decade, in which case the demand for aircraft on the London/Paris route would be drastically reduced. Again, 10 years ago when Brandt first developed his ostpolitik, it threatened drastic revision of the demand in internal German flights (according to the Four-Power treaty, Lufthansa cannot fly the internal German routes and these are supplied by the occupying powers). Interactively, these things are easy. The operator simply types in "internal German flights equal 0 for 1982-1985" or whatever. In general, the big unstructured data bases which are the bane of realistic computer models are avoided. The relevant information is in the planner's head and not in the computer.

The real test of such systems is, of course, how they are received by the users, and here the reception seems unprecedented. Tobin told me an anecdote about a request from the sched uling people to rationalize all of their programs. The OR staff decided it would take 8 more people 3 years to do it. BA, which has more employees than any other airline in the world, was under an absolute freeze, so that the slots could not be obtained. Then other departments in the airline responded to the crisis by volunteering one or two slots each to the OR group so that they could complete this chore.

It seems to me that there are some important lessons for operations research to be learned from British Airways. The time is past when the optimization models and mathematical formulas on OR taught in the textbooks can, by themselves, be of much use in industry. Whether or not it is called OR, the kinds of interactive computer models used by the OR group at BA seem to me to be a wave of the future. (Robert E. Machol)

CHEMISTRY

THE ROYAL RESEARCH UNIT AT THE UNIVERSITY COLLEGE OF SWANSEA

I spent George Washington's Birthday visiting an old friend, Prof. J. Beynon, FRS, Royal Society Research Professor at the University College of Swansea. Beynon previously worked 27 years in Imperial Chemical Industries' (ICI) Research Department, Dyestuffs Division, and in the head office of the Research Department at Millbank. During his tenure at ICI he also had a chair of chemistry at Purdue University for seven years, and was visiting professor at Swansea, Warwick, and Essex. He is one of the world's leading mass spectroscopists as evidenced by his election as a Fellow of the Royal Society and by his receipt of the 1979 Pittsburgh Conference Spectroscopy Award.

At Purdue, Beynon began his studies on MIKES (Mass-Analyzed Ion Kinetic Energy Spectrometry). This work, which he initiated with Prof. Graham Cooks, has opened a new field of mass spectrometry. By reversing the electrostatic and magnetic field sectors in a double-focusing mass spectrometer, Beynon produced an experimental system for the study of gas-phase chemistry by mass spectrometry that is similar to the classical wet-chemistry structure determination.

In his approach to the study of chemistry, Beynon uses the mass spectrometer ion chamber as the synthetic step for preparing a molecule as a synthetic chemist prepares molecules. In the next stage of his mass spectrometer, the magnetic sector, the ions are separated according to their mass-to-charge ratio. Beynon correlates this stage to the purification step in chemical studies. Following that, Beynon's chemistry scheme introduces a collision cell between the magnetic and electrostatic sectors. The mass-sorted ion beam is passed into this collision cell where the ions decompose and then exit from the other side. This is analogous to study of new compounds by the classical chemical reactions. The last step in Beynon's scheme is the mass analysis of the decomposed ions with the electrostatic sector. This corresponds to the chemical analysis of the products of the classical chemical reactions.

Beynon and his colleagues have been using this technique to investigate a series of simple molecules in an attempt to understand how an ion, once formed, breaks apart, or fragments, to give the characteristic mass spectral fragmentation pattern. This is a very complex step; many molecule ions fragment faster than they can be detected. Thus it is difficult to observe the first step in the decomposition. With Beynon's approach, the first steps of ion decompositions are much easier to observe because the ions are decomposed by thermal collisions in the collision cell rather than by high-energy electron impact collisions. In addition, other physical chemical measurements, e.g., the electron affinities of a variety of molecules, can be made. In the synthetic step, negative ions in high concentrations are formed in the ion chamber from resonance capture of secondary, thermal energy electrons produced from electron impact of argon. The negative ions are mass separated and passed into the collision chamber. In this chamber, the negative ion decomposes into two electrons and a positive ion of the same mass-to-charge ratio. The heat of reaction of this process is equal to the electron affinity plus the ionization energy of the neutral molecule. By measuring the energy release of the collision and knowing the ionization energy of the molecule, the researcher can deduce the electron affinity.

Another area that Beynon and his co-workers have investigated is that of consecutive reactions. They have shown that nitrophenol, for example, loses first a NO moiety, and then a CO moiety, whereas the well-known McLafferty rearrangement reaction from nitrophenol is not a consecutive but a concerted reaction.

Beynon and his collaborators have improved the energy resolution of their mass spectrometer. The Swansea scientists have introduced angular correlation slits behind the ion exit slit, the magnetic sector, and the electrostatic sector, and have thereby greatly improved the energy resolution. They find that the improved energy resolution is obtained with little loss in sensitivity. Theoretically, the decomposition of a doubly charged ion into two singly charged ions should have two distinct energy releases. However, with a conventional MIKES instrument, a "moon-shaped" distribution of energies is observed. Beynon and his collaborators tested their modified MIKES instruments on the reaction: HeH^+ decomposing into $H^+ + He$. They resolved four discrete energy levels in the peak decomposition and showed that the energy resolution depends on the angular correlation of the ion beam. Now they are using the improved instrument to study the decomposition of doubly-charged benzene.

Beynon's collaborator from the Physics Department, Dr. Frank Harris, described some of the group's laser mass-spectrometry work. In this investigation, they are using an argon ion laser, which emits 11 distinguishable wavelengths between 2.5 and 3.5 eV, to study the effects of promotional energy on ion decompositions.

Harris passed the laser beam through the ion source of the mass spectrometer, parallel to the ion flight path in a conventional double-focusing mass spectrometer (electrostatic analyzer before the magnetic sector). They have found that this arrangement is more successful for observing photo fragments from the ion beam than the crossed-beam approach.

In the study of nitrobenzene, Harris has discovered that the decomposition of the molecule ion can be changed from loss of NO to loss of NO_2 by activating the ion beam with 1.6 eV photons. When the loss of NO_2 from nitrobenzene is enhanced, the loss of NO becomes "negative"; that is, the ion current observed for the nitrophenol minus NO becomes negative. Harris and Beynon do not understand the meanings of these observations and so are pursuing this work.

As to the future, Beynon believes that the negative ion mass spectrometry and the laser mass spectrometry studies hold promise for providing a better understanding of very complex and fast chemical reactions and, perhaps, the determination of the structure of complex ions. (F.E. Saalfeld)

ELECTRONICS

IC'S AND ELECTRON BEAM LITHOGRAPHY—SOME IDEAS FROM BRITAIN

The quest toward higher packing densities, very-large-scale integration (VLSI), and greater speeds in handling and processing information has led to the fabrication of semiconductor-integrated-circuit (IC) devices requiring geometries of 1 μm, or submicron, size. Because IC components having such small dimensions cannot be produced by ordinary optical photographic reduction techniques, firms engaged in IC production are now using, or are considering for use, various other techniques, such as systems using x-rays or electron beams. In fact, there are already about 100 fully implemented electron-beam systems in the world at this time.

Because electron beam lithography (EBL) is currently of great importance, the Institution of Electrical Engineers (IEE) recently held a well-attended, one-day EBL colloquium, with 11 speakers participating. In this article I have paraphrased the opinions presented in two of the more general talks and sketched the subject material of two of the more technical papers of this colloquium. For completeness, the names, affiliations, and topics of the other speakers are listed at the end of the article.

D.H. Roberts (Director of Research, General Electric Company Ltd., Wembley, UK), in discussing EBL and the optimum scale of integration, pointed out the important fact that the major impact of Silicon Integrated Circuit (SIC) technology has resulted from its demonstrated capability to penetrate old markets and to create new ones by virtue of cost reductions. Roberts predicted that future developments in SIC technology will split into the three main groupings described in the following paragraphs.

(1) Products made in sufficiently large quantities for manufacturing costs to dominate. This is the area where improving circuit-packing density gives the most obvious cost benefits; and therefore it can be expected to be fertile ground for 1 μm linewidth. Roberts cautioned, however, of the possibility that with narrow linewidths, smaller defects might become significant, testing costs could become too high, and new reliability hazards resulting from smaller geometries might well become important.

(2) Customized products of modest performance, mainly digital, where design costs dominate. A primary consideration here is improvement of the design process, and this could be achieved by reduction of elapsed time, engineering content, and cost, as well as need for redesign. Computer-aided design, coupled to EBL for final metal delineation, here offers ideal turn-around time and flexibility. On the other hand, device modeling and process characterization, coupled with process control, may not be compatible with linewidth reduction.

(3) Very high performance devices. Here, where performance implies fast switching speed, high-frequency response,

or minimum-power operation, there are clear benefits for linewidth reduction through EBL. How far this can be pushed is not yet known, since there may be physical limits not yet discovered. (See *ESN* 33-11:448.)

Roberts concluded that, in general, EBL offers the SIC engineer a major opportunity to explore the total performance envelope in which he can work. He cautioned, however, that not all aspects of improved performance will imply the need for smaller line widths (and therefore EBL). It is therefore not yet obvious that all SIC processes and applications should jump on the submicron bandwagon.

Some thoughts relating to how technology will impact microelectronics were presented by I.A. Cruttwell, who leads the Electron Beam Microfabrication (EBMF) Division of Cambridge Scientific Instruments, (CSI), Melbourne near Royston, Herts, UK. CSI is a company that has been a pioneer in EBL technology. Its initial systems, manufactured in the 1960s, are still in operation in a number of laboratories. CSI presently markets its EBMF-2 system, an electron beam system that, according to Cruttwell, has been installed in all the major government VLSI programs in the world.

Cruttwell stated that EBL will impact microelectronics in the three major areas of direct writing (on wafers covered with photo-resist), mask making, and reticle fabrication.

Direct writing has been in progress since the beginning of EBL technology and can be expected to continue in use to accomplish several objectives:

(1) Ultrafine writing (0.2 μm lines), for research into device fundamentals. Here flexibility and systems stability are of greatest importance.

(2) The fabrication of devices requiring 2.0 to 1.0 μm geometry, such as microwave-gallium-arsenide-field-effect transistors. Again, this is a low throughput, speciality application.

(3) Making medium-geometry devices (5.0 to 1.0 μm) for which the critical parmeter is the time from the design data to the first wafer (sometimes the only wafer). An example is customization of a device such as a ROM.

(4) Producing medium-geometry devices (5.0 to 1.0 μm) for high-volume production. Cruttwell felt it unlikely that optical techniques would be replaced here until industry could no longer tolerate such techniques because of their relatively large size.

While EBL for direct writing is still limited to devices of low volume, it is well established for mask making. (Indeed, optical techniques for high-density systems are now possible because masks can be made by EBL techniques.) The commercial mask-making machines that dominate the market at the present time are US machines that incorporate ideas developed at Bell Laboratories. These machines raster scan over a small field (125 μm) to achieve high throughput at medium resolution (4-2 μm) and have been optimized to produce multichip masks. Cruttwell stated this is the largest use that is made of EBL and that he expects the use of masks to persist 10 years or more.

EBL is also being used to write reticles. These are images of a pattern that are 4 to 10 times the final size. Reticles were formerly used for mask making. They are now being used in direct-stepper systems, in which an image is projected a number of times onto a wafer in a stepwise manner. Cruttwell felt that this represented the last significant development of optical techniques. He then went on to describe the well-known CSI type EBMF-2 system, which can expose full 4" circuit arrays, as well as smaller arrays on 5" mask plates. He stated that this system, which has also been used to write ultrafine structures (0.05 μm), achieves an accuracy of registration (from one exposure to next) of from 0.03 μm to 0.07 μm. The chief problems with such an ultrahigh resolution system are noise level in the deflection electronics (or stage position), stray fields, and deflection induced aberrations.

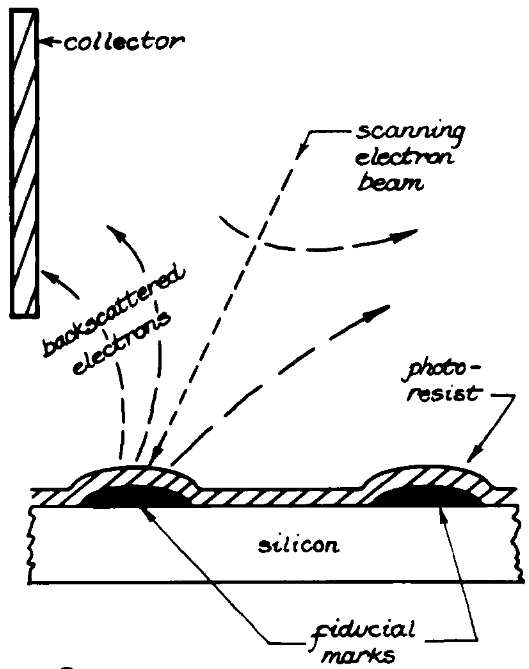
Roberts had stated that considerable improvements in photoresists are in order for ultrafine resolution work. Cruttwell stated that when EBL technologies are applied to direct writing, the subsequent processes that the wafer is subjected to require the use of a relatively robust resist. At present, the very sensitive resists are suitable only for medium resolution lithography mask plates; less-sensitive resists have to be used for direct writing. As a result, the writing time for fine lithography is rather long.

Commenting on his company's plans for the future, Cruttwell stated that, in the immediate future, CSI will direct its efforts at enhancing the performance of the existing system with regard to throughput, ease of use, flexibility and reliability. According to Cruttwell, the EBL systems that are to be introduced in the early 1980s will provide a throughput that, although much faster than at present, will still not be as fast as optical systems. However, they will be better able to accommodate in-plane distortion and will be inherently more flexible. As the 1980s progress, EBL techniques will start to displace optical systems in state-of-the-art production. Cruttwell also predicted that CSI will continue to make use of steered-beam systems in its future devices.

In contrast, P.J. Daniel (Philips Research Laboratories, Redhill, Surrey, UK) discussed his company's efforts of 1:1 electron-image projection through a mask onto a wafer. This system was discussed in a recent report on a visit to Philips at Redhill (*ESN* 33-10:401). Work of this type actually originated at Westinghouse in the 1960s. Developments at Philips have included the addition of an automatic alignment system, relying on x-ray emission from special markers on the silicon. The main advantages of such an electron image projector were said to be high speed (20 sec exposures even with an insensitive resist), high resolution (certainly submicron), large depth of focus (at least 50 μm for 0.1 μm edge movement in the image plane), fast automatic alignment to ±0.1 μm, and the potential to correct for wafer expansion or contraction.

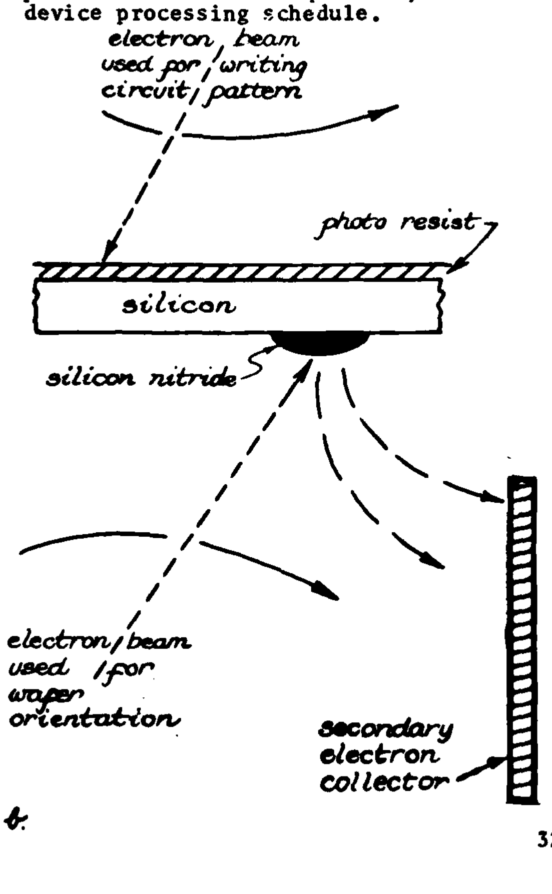
Daniel stated that there is some image distortion in this system which arises from the fact that the electric field cannot be perfectly uniform, since part of the positive electrode is the silicon wafer itself. A slight discontinuity at the edges was said to be inevitable, and any slice bowing would also result in some distortion of the image. But except for the fact that it would be impractical to use the electron projector in the extreme case of a mask with isolated small features on a clear background, the effects were said to be quite tolerable in the majority of circuits. Overall, therefore, there appeared to be no fundamental difficulties that would prevent the electron image projector from becoming the economic method for making large scale ICs with very-high packing density.

A typical process for fabricating ICs requires that a wafer be coated with resist and patterned 8-10 times (either by exposure to photons or electrons). A successful IC, therefore, must be aligned precisely (by the use of fiducial marks) before each exposure. Present commercial EBL systems use laser interferometric alignment. A number of individuals believe, however, that for the ultraprecise alignment required for ultrafine geometries, the use of light, i.e., a laser, will not provide sufficient accuracy. They maintain that inherently greater accuracy should be obtained with an electron beam which will locate the position of fiducial marks by sensing the different amount of electron back scattering from these fiducial marks (which could be metal, silicon nitride, etc.) as compared to that obtained from other areas (see Figure a).



a.

The EBL group at Cambridge University believes, however, that since the entire wafer will be covered by photoresist during the sensing alignment, the signal-to-noise ratio for backscattered electrons will be very poor, so that significant registration errors are very likely. In the colloquium, members of this group (H. Ahmed, G.A.C. Jones, H.C.H. Phang, and R.A. McMahon) discussed their CUMMS II dual-electron beam system, for which the principle is illustrated in Figure b (p. 322). Here both surfaces of a polished silicon wafer are initially free of all marks. The lower surface is covered with silicon nitride, followed by a photoresist. The lower beam then writes a set of registration marks, which, after development of the resist and subsequent etching of the nitride, may be, typically, four L-shapes for defining the dimensions of a chip, and subsidiary marks within the chip, to provide additional registration data points. The upper beam operating on the active wafer surface is used for writing the circuit pattern, as usual. No marks at all are needed for registration on this surface, so the whole chip area is available to the circuit designer. Once the wafer has been removed from the system and processed, so that it is ready for what would be a second masking stage in conventional practices, it is returned to CUMMS II. A second pattern is then written on the top face after the back face marks have been located by the lower beam by sensing the differential secondary emission from the bare silicon nitride marks and the bare silicon. The back face marks are then used to set the parameters of the upper beam, taking into account any changes that have occurred during processing. The procedure may be repeated as often as required by the device processing schedule.



b.

Some of the advantages of this new method of EBL were said to be that it compensates for many process-induced wafer distortions, that it detects the back wafer registration marks with greater precision than any method that detects front wafer registration marks, and that it is usable as a registration method with other means of lithography which require independent registration methods.

Ahmed also discussed some other studies members of group have carried out on EBL technology. They have examined, for example, a method of line-width control using a developer-dependent model, a method for correcting for the "proximity effect" for two lines very close together, an electron beam method for annealing ion implanted wafers in which the implant remains localized after activation so that better control of device dimensions may be achieved, and a novel fabrication technique using their "Superzap" electron beam system. With "Superzap," a heavily-implanted wafer surface is scanned over small separated areas, so that these are an annealed in a sea of relatively amorphous material and thus create arrays of conducting regions.

Additional material on the work at Cambridge will be found on p. 323 of this issue.

Authors and titles of the remaining papers presented at the colloquium were as follows: (1) P.A. Charman (Cambridge Consultants Ltd., a subsidiary of Arthur D. Little Co.), "Electron-beam equipment—Where Will It Fit;" (2) R.A. Lawes (Rutherford Laboratories), "The Manufacture of Precision Masks Using Electron-Beam Lithography"; (3) R.A. Beelaard (N.V. Philips, Eindhoven, The Netherlands), "The Philips Beam Writer"; (4) J.R. Earnshaw (Ferranti Electronics Ltd.), "Bipolar Transistors"; (5) R.H. Bennett, R.S. Butlin, A.J. Hughes, and D. Parker (Plessey Research Ltd., Caswell, UK), "Sub-Micron Fabrication Techniques"; (6) E.G.S. Paige (Univ. of Oxford), "SAW Devices"; (7) B.L.H. Wilson (Plessey Research Ltd., Caswell), "Physical Limitations to Semiconductor Device Size."

The active participation of a number of speakers from both industry and universities demonstrated that the UK has a great interest in improving IC technology, that there is no shortage of ideas, and that there is considerable activity in this field. The UK is no newcomer to EBL, for high-resolution electron-beam technology has been a field actively pursued in Britain for a number of years, especially at Cambridge University. A companion paper discusses the recent visit to Cambridge and, in particular, to the EBL facility there. (Irving Kaufman)

ELECTRON-BEAM SYSTEMS AT CAMBRIDGE

A standard line of a physics instructor I know is, "If you should ever visit Cambridge University, be sure to see the original electron at the Cavendish Laboratory"! When I did visit Cambridge and the old Cavendish Laboratory recently with a colleague, we did not see the original electron, but we did see much interesting activity in the Electron-Beam Systems Group of the Department of Engineering, where our host was Dr. H. Ahmed, the leader of the microcircuit engineering work of the group.

Engineering at Cambridge is unified; i.e., it is not split into the usual electrical, mechanical, and other engineering disciplines. The academic and research staff comprises approximately 100 professionals, including professors, lecturers, and research associates. There are about 800 undergraduates and 175 research students. Generally these students are very good since, as one of the top two universities in England, Cambridge virtually has its pick of undergraduate as well as of graduate students. Teaching is accomplished by lectures and by private tuition, i.e., tutoring of, say, two students at a time several times a week.

Engineering research at Cambridge is carried on in the areas of: Acoustics; Aerodynamics and Fluid Mechanics; Applied Thermodynamics; Control, Management Systems and Computer-aided Design; Electrical; Materials; Mechanics; Soil Mechanics; and Structures. While much could be said about each of these topics, this article is limited to a brief description of electron beam systems (EBS) activities in the Electrical Group.

At present, the EBS work at Cambridge deals with electron beams of very small dimensions. The group is continuing work that has been in progress at the university for a number of years; Cambridge was a pioneer in scanning electron microscopy (SEM). Ahmed and his colleagues proudly mentioned that Dr. T.E. Everhart, now dean of engineering at Cornell University, earned his PhD at Cambridge in electron-beam work before returning to the US and setting up SEM facilities at the University of California, Berkeley. Ahmed stated also that a considerable amount of electron-beam work at IBM (Yorktown Heights, NY) is being carried on by graduates of his group.

There are essentially three branches to the EBS Group: Ahmed heads the work in microcircuit engineering; Dr. W.C. Nixon is responsible for electron microscopy work and microcircuit inspection; Dr. K.C.A. Smith and his group work on computer processing of electron images and on problems of field emission and electron lenses.

Dr. G.A.C. Jones is a collaborator of Ahmed; they are assisted in their work by half a dozen research or postdoctoral students. Their work is funded by the Science Research Council, the British Ministry of Defence, the Post Office, and the Electric Board. There are also several industrial grants called "CASE studentships." A large portion of the effort deals with electron beam lithography (EBL), which involves both mask making and direct writing on wafers with line widths of the order of ½ to 1 μm. A number of scanning electron beam systems are in use for carrying out this work. The objective is to devise and perfect EBL techniques for ultimate use in the fabrication of very-large-scale integrated circuits (VLSI). Investigations are in progress for mask making as well as for direct writing with an electron beam on wafers covered with photoresist.

In mask making, one etches lines or areas into opaque films on glass or directly into a thin sheet of metal in accordance with a desired integrated circuit design. The principle of the technique is illustrated in Fig. 1.

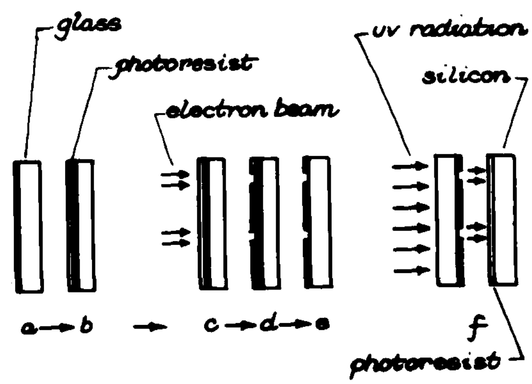


Figure 1

In direct writing on wafers, the electron beam "writes a pattern directly on the photo-resist covered wafer, as in Fig. 2. In both cases, the reason for using an electron beam instead of light is that much finer patterns are possible with electrons.

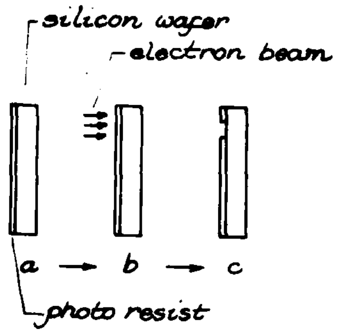


Figure 2

The electron beams originate from thermionic cathodes composed either of tungsten operating at 10^{-5} torr, or the new, and preferred, lanthanum hexaboride (LaB_6), which was said to be much brighter and very stable, with a lifetime of 100-200 hours. The LaB_6 cathode operates at 1600°C and requires a vacuum of 3×10^{-7} torr or better. The most popular photo-resist in use in the laboratory is PMMA which, although slow, has the best tolerance and achievable line width.

Following is a listing and a brief discussion of some recent and present research projects of Ahmed and Jones:

(1) 10 × 10 mm field scanning-electron-beam-microfabrication: A microfabrication instrument of 10,000 lines per field has been under development. With this instrument, masks for large devices can be exposed without requiring the "stitching together" of a number of small fields. Normal substrate incidence is incorporated in order to eliminate positional errors caused by electron-optical distortion and to maintain a high writing speed despite the large scan area. Positional errors are reduced by the application of a polynomial correction function containing terms corresponding to each of the possible deflection distortions.

(2) Reduction of beam writing time for EBL: Masks made by EBL techniques generally have 1000 Å chromium films on glass. When fabricated with a fine beam of constant radius, the fabrication time is on the order of 16 hours. Thanks to the work of this group, a large amount of evidence has now been accumulated indicating that the current density in their scanning-electron beam can be maintained at nearly the same value, no matter whether the beam is a small dot or a large rectangle as in Fig. 3 (up to a total current of 1 mA).

Figure 3
Beam shapes that can be maintained at nearly constant current density.

According to Jones, this development can reduce the writing time required for a mask or a wafer by a factor of from 5 to 100. He stated that progress on this problem has also been made by a group at IBM, Yorktown Heights, NY.

(3) A dual beam EBL system for direct writing on wafers: This is the CUMMS II system, discussed in a companion article. A wafer with both faces polished is used. Electron beams are incident on both top and bottom of the wafer. One beam is the writing beam; the other is for reading, writing or registering, depending on its role at any particular stage of the lithography process. The mode of operation is first to reference the beams with respect to each other with a set of alignment masks. After this procedure has set the relative positions and scales of the two beams, they are used to write on the two resist-coated surfaces of the wafer. (see p. 319 of this issue). The general objective is to obtain better alignment than is possible with just one beam.

(4) Line-width control: For direct writing on wafers it is necessary to expose resist which covers steps of varying heights on the wafer. Line-width control is difficult in these conditions. The interaction of the electron beam with thin resist layers has been modeled with a Monte Carlo method. This model predicts the threshold energy density which must be absorbed by the resist for high contrast development. For thick resist layers, a developer-dependent model has been proposed. Both models have been tested experimentally and the results have given good agreement with predictions.

(5) Proximity-effect correction: In complex circuits, there is often the problem of compensating the exposure at any point in the proximity of patterns already exposed. In the development of two adjacent lines, when each line is given the dose required for the line isolation, the wedge in the middle can break off at its base because of undercutting. One method of correcting for proximity effect is to vary the dose given to each pattern element, taking into account the dose of relevant near neighbors. To simplify the problem, a strategy that has been successfully implemented is to expose the inner part of any rectangle to the required threshold dose at a fixed-clock speed and to write the four sides with varying clock speeds which take into account the dose already delivered or to be delivered by near neighbors.

(6) Beam-pattern-distortion correction: To correct pincushion-type distortion, one can use software correction (as IBM has done) or hardware correction, i.e., correcting by use of the electron optics. Work on this problem as well as the measurement of beam pattern distortion is in progress.

(7) Electron-beam zapping: The furnace-annealing of wafers after ion implantation leads to significant problems in the microfabrication of submicron devices because of the diffusion of impurities. Work on annealing with electron beams instead of a furnace has been in progress. Here the implant remains localized both horizontally and vertically after its activation, so that better control of device dimensions may be achieved. In a typical experiment, a 2-3 mA, 30 keV beam has been focused into 25 μm spots. Impurities in silicon that have been annealed in this manner to date are boron and arsenic.

In a related technique, the so-called "superzap" system, small, separated areas of a heavily implanted wafer surface are electron-beam annealed so that arrays of conducting regions or of diodes isolated from each other are formed. Other applications of the technique are being explored.

It should be pointed out that a lot of this work requires equipment which is quite expensive. For example, in response to my question "How much would it cost to replace your good EBL setup?" the answer was £1/3M. Some of the reasons for this high cost are: the entire vacuum system rests on a cushion of air; most everything is of very high precision; there is a soft iron magnetic return path (which is a "must" of such systems); and the room temperature must be constant. A system of this nature therefore needs a special room for operation.

While the majority of our time was spent with Ahmed's group, we were able to talk also with Nixon. Among his projects in electron microscopy and micro circuit inspection are the following: (1) SEM inspection: Here a typical operation is to expose an array of 10,00 × 10,000 points in 40 seconds, with recording on a 5 cm × 5 cm film located in the vacuum system, and a recording range of 10 grey levels. (2) Identification of crystal structure by scanning electron diffraction. (3) Fabrication of Josephson-type devices with 100 Å resolution, using 10 Å beams over a 100 μm × 100 μm area. This work is performed in collaboration with others who will use the devices.

Nixon is also the principal investigator associated with a very large 600 keV electron microscope, whose resolution is approximately 2 Å. This instrument, which has been constructed in the old Cavendish Laboratory, is now being used for physics and biology studies. It is one of the world's outstanding instruments of this type.

We were unable to meet Dr. K.C.A. Smith, who, as mentioned above, deals with the processing of electron images as well as with electron beam associated problems.

In summary, on visiting the Electron-Beam Systems Group at Cambridge, one can readily conclude that this group is rich in highly sophisticated pieces of apparatus, in ideas, and in the capable personnel that can successfully combine the two. It is all in the Cambridge tradition of success in science. (Irving Kaufman)

ENGINEERING

COLLOQUIUM ON MILLIMETER-WAVE RADAR AND RADIOMETRIC SENSORS

A one-day colloquium with the above title was held at the IEE London headquarters on 22 April 1980. The chairman, Mr. S.E. Gibbs (Royal Signals and Radar Establishment [RSRE], Malvern), began the proceedings by pointing out that this was an auspicious time for such a meeting since the subject of millimeter waves is reaching a peak of popularity. There certainly is a flurry of activity in this area, also extending to continental Europe. Recent reports from this office reflect this activity, and millimeter-wave technology has been discussed in a European survey (R-12-1977), in recent notes on the propagation measurements at the Rutherford and Appleton Laboratories (*ESN* 34-5:216), in an article about work at the Imperial College (*ESN* 34-2:58), and in a report on Germany's FGAN (*ESN* 34-6:274). The meeting was well-attended, with contributions from many different British organizations. Some of the sessions were chaired by Dr. C.D. Watkins (RSRE).

The first paper, by F.L. Warner (RSRE), was titled "Early Work at TRE and RRE on Millimeter-Wave Radar and Radiometer Systems." (RSRE used to be called RRE and before that TRE.) Warner referred to the fundamental millimeter-wave research carried out at the end of the last century by Prof. Bose in Calcutta, India, using quasi-optical systems and spark transmitters. Near the end of WWII, he said, interest in millimeter waves was renewed, but the enthusiasm was short-lived as more information was gained on propagation losses. He attributed the present renewed interest to the need for narrow beams, small antennas, spectral crowding at centimeter wavelengths, availability of millimeter hardware, reduced susceptibility to jamming, complementary performance to optical and infrared systems, higher Doppler shift, wider bandwidth, and covertness. Warner started by describing th first TRE millimeter radar which w. built in 1945. Much later, in 195 it was followed by a single-channel airborne radiometer. Its noise figure was too high to allow scanning but it showed feasibility for a multi-channel system which was subsequently built and tested (1956-58), giving a good quality strip map. Warner referred to the considerable improvements made in recent years in components, particularly in wide-band and low-noise solid-state (GaAs FET) amplifiers. He concluded that single-channel side-scanning radiometers have now become quite feasible.

"The Use of Millimeter Wave Sensors In Air-to-Ground Weapons" was discussed by R.J. Orme from the British Aerospace (BAe) Dynamics Group (DG), Bristol Division. Orme examined the various missions and the associated technology for active or semiactive radars and active or passive radiometers in the millimeter band. He concluded by saying that although present work in the UK is centered mainly at 35 and 95 GHz, he believes that this is a time when component technology is undergoing rapid changes and that 140 to 220 GHz may well form the basis for future systems, using optical-microwave concepts.

Holography was the subject of an interesting paper, "Millimeter-Wave Systems for Holographic Investigations," by L.A. Cram, G.W. Newberry, and K.O. Rossiter from EMI Electronics Ltd, Systems and Weapons Division, Wells, Somerset (long known for their association with holography). The paper was presented by Cram, who briefly described millimeter wave holograms as the record of the interference pattern in an aperture obtained from the target-reflected waves and a reference wave. The record may be in the form of a scaled photographic slide which is illuminated with coherent light for a reconstruction of the 3-D picture. Scaling factors of 10^{-4} would be required if the hologram were made with millimeter waves, but errors as great as 50:1 appear acceptable.

Cram first detailed a 70 GHz holographic-recording apparatus that was built by EMI in 1966 as a pilot experiment to prove feasibility. It contained a transmitter that illuminated the targets, a small receiving antenna that mechanically scanned across the receiving aperture, and a reference illuminator that was fed with some of the transmitted signal. The received (beat) signal was amplified and used to intensity-modulate a light that was attached to the receiving antenna and traveled with it as it scanned. The light was then photographed by a camera with an open shutter giving a small-scale record. Cram then discussed the second EMI system that was built using 35 GHz radiation, which contained many improvements, but which showed the need for more details in the display. The present system was then constructed operating at 140 GHz and containing further refinements. Both transmitter and receiver were sufficiently small to be mounted together on the scanning platform as a monostatic system, equivalent to a bistatic system at 280 GHz, i.e., at double the frequency. The reference signal was introduced directly from the transmitter into the receiver channel which, Cram explained, unfortunately simulated a far-field broadside reference signal which obscured the field of view at broadside. To avoid this, the system interrogated a field of view that was offset by 45° from broadside and the scanned aperture was increased in the horizontal plane to maintain the same angular resolution. (In the previous 35 GHz system the reference signal was phase-shifted between horizontal scans, which simulated an offset reference, but at 140 GHz phase shifters were not available.)

Details of the system were given: the transmitter was a 100 mW Klystron, the transmitting and receiving antennas were horns giving a 30° beam width, and the scanned aperture was 1 m high and 1.5 m wide, scanned in a raster. The signal from the mixer, after amplification, energized a light-emitting diode (LED). The variations of light intensity were recorded on film by a camera that was connected to the LED by a telescopic pivoted tube which provided a light-tight enclosure. Holograms were subsequently reduced to 5 mm × 7.5 mm, resulting in an acceptable low scaling error of 9:1. Pictures of a small truck at a distance of 13 m were shown and were found to be quite recognizable. Cram's concluding remarks were about future developments which will, perhaps most importantly, include a search for low-cost real-time systems.

"Target and Terrain Measurements Using Millimetric Radiometers" was the title of a paper by M.W. Hosking and C. Felix (BAe-DG). The paper was presented by Hosking who listed equipment available for tests at BAe as: 35 GHz radiometer, 94 GHz radiometer, pulse radar and FM or pulse coherent radar, and 149 GHz radiometer. The radiometric work only was discussed and some of the trial results from extensive measurements were given, obtained from land, sea, and an experimental platform supported by a barrage balloon. Particularly striking were results showing drastic reduction in radiometric ocean temperature by changing from vertical to horizontal polarization.

N.F. Kington from Marconi Space and Defense Systems Ltd. presented a paper, "Measured Target Characteristics at 94 GHz." Radar target sections (σ) were measured in m^2. For distributed targets that uniformly filled the beam, the reflectivity was defined as σ/A where A is the illuminated area in m^2. Typical values for σ were: single-dense tree, 0.4; wet asphalt, 0.4; solid tree trunk, 18. Typical values for σ/A were: dry/short field grass, 0.12; trees and foliage, 0.33; dense tree foliage, 2.2.

The next two papers were from the Rutherford and Appleton Laboratories in Slough. (The laboratory in Slough is in the process of being moved to Chilton, the home of the original Rutherford Laboratory [see *ESN* 34-5:216]). In the first, "Propagation Factors in Relation to Millimetric Systems," by J.A. Lane and J.R. Norbury, Dr. Lane examined present capabilities to predict the attenuation of millimeter wave radiation by rain. In clear air, he said, there was very little absorption below 100 GHz with the exception of the 60 GHz oxygen absorption band. From 100-300 GHz, the absorption is less than 10 dB/km except near the strong absorption lines of 119 and 183 GHz. Low attenuation exists in windows at 90 and 150 GHz giving a loss of less than 1 dB/km. Moderate rain (5 mm/hour) would give some 4 dB/km attenuation at 90 GHz rising to 20 dB/km in very heavy rain (50 mm/hour), the drop size distribution having an important effect. At 35 GHz the corresponding values would be about 1-3 dB/km and 12 dB/km. Curves were shown giving the estimated upper and lower values of attenuation due to rain as a function of path length which would occur for 1% or 10% of an average year. The second paper from Slough, "Millimeter Radiometry at the Appleton Laboratory " by A.R. Burkes, C.L. Rench, D.R. Vizard, and D.L. Croom was presented by Dr. Burkes who summarized their radiometry work. Radiometry measurements were, he said, carried out to determine the atmospheric attenuation. This was calculated from the gas emission temperature which, in turn, was measured with a radiometer beam pointing upwards towards the zenith so that the gas could be observed against a cold background. The attenuation measurements were plotted as a function of precipitable water prevailing at the time of measurement and estimated from radiosonde data.

Burkes then described attempts to monitor the distribution of ozone and water vapor at high altitudes, in the range of 50-90 km, using the molecular spectral lines of water (22.235 GHz) and ozone (110.836 GHz). The predominant mechanism that determines the shape of the spectral lines is pressure or collision broadening, which therefore varies with the altitude. The spectrum of the line shows the variation of the emission level as a function of frequency. At any given frequency the linewidth corresponds to a specific altitude and the level to all emission from below that altitute. Burkes pointed out that useful results were limited to altitudes of 50-90 km because at higher altitudes collisions are no longer the dominant mechanism that gives rise to line broadening and lower altitudes required a receiver bandwidth greater than was available. High frequency stability is required and obtained from a Klystron phase locked to a stable frequency standard. High sensitivity is needed and was achieved with the development of a very low-noise, front-end mixer using GaAs Schottky barrier diodes. Noise figures of 5-5.5 dB at 100 GHz, 7 dB at 170 GHz, and 8 dB at 230 GHz were achieved together with low local oscillator power requirements.

NASA and the UK Science Research Council support another remote sensing program. It was presented by Dr. D.A. Flower (Heriot-Watt University, Edinburgh). The paper, "An Active Millimeter Wave System for Remotely Sensing Pressure" was written jointly with G.E. Peckham from JPL (Jet Propulsion Laboratory, Pasadena, CA). Flower argued that pressure charts are the most important basis for predicting the weather and could be supplied on a global scale for ocean coverage from a remote satellite-borne sensor. The principle of the measurement, said Flower, was simply to compare the two-way transmission loss of an earthward-looking radar at two frequencies, one of which is lying in the oxygen absorption band. The difference in the loss would be due to absorption which in turn is due to the total number of oxygen molecules present, i.e., it is a function of pressure. In the proposed system, six frequencies would be used (30-70 GHz) and would yield atmospheric pressure data almost independent of extraneous effects such as temperature, water vapor, and dispersive characteristics of the ocean. Equipment has been specified and system errors were analyzed. About 80% of the measurements are expected to have an rms error of less than 1.5 mbar. With clouds or heavy sea state, the rms error could reach, or exceed, an unacceptable level of 3 mbar. Flower reported that a two-frequency microwave pressure sounder is presently being constructed to demonstrate feasibility by trial from an aircraft.

S.J. Nightingale (Philips Research Laboratories, Red Hill, Surrey), presented a paper, "A Potential Low-Cost Millimetric Sensor" in which he described a search for the most effective way of reducing the costs of radiometers. His first conclusion was to aim for a wide bandwidth and achieve it with cheap IC amplifiers rather than with slightly superior, expensive, conventional FET amplifiers. He suggested a bandwidth of 1 GHz for a 35 GHz receiver, 2 GHz for an 80 GHz receiver. Secondly, he suggested that mechanical components be made accurately but cheaply from molded metalized plastics, rather than being machined from solid brass. His RF components were "E" plane circuits mounted in the center of a standard rectangular waveguide. A 35 GHz radiometer had been built, said Nightingale, and was presently being evaluated. The components' performance at 35 GHz was: mixer, 4 dB; PIN-diode switch, 1.5 dB; isolator, 0.5 dB; and at 85 GHz: mixer, 7 dB; pin switch, 3 dB; isolator, 1 dB. He is expecting improvements of 2-3 dB in future mixer designs.

"System Requirements for the Precision Guided Munition" was a paper presented by D. Tipping (BAe, Stevenage). He noted that ground- or air-launched weapons require a range of at least 40 km to be able to attack enemy supporting forces and he examined the guidance control and configuration options.

The last paper, "Millimeter-Wave Intruder Alarm" was given by P.H. Walker, who is a consultant engineer. He described a number of his concepts to build intruder detection fences.

The state of the art is advancing rapidly in this field. The feasibility of various millimetric remote sensing techniques is being established and needs full implementation and exploitation. Radars and radiometers and associated components are quite available, perhaps up to 95 GHz. For higher frequencies further developments are still required and this may be where great strides will be made using quasi-optical techniques. In holography the cry is still for better and faster processing, ultimately giving real-time displays. (T.C. Cheston)

MICROWAVE OPTICS AT THE UNIVERSITY OF SURREY

The Polytechnic of Surrey expanded and achieved university status by royal charter in 1966. It is a modern university situated in Guildford about an hour's drive south of London. It has a total of about 3,000 students. My reason for visiting the polytechnic was to see Dr. Sidney Cornbleet, who has been most actively conducting theoretical studies of antennas and who has come up with many novel design methods and ideas. Cornbleet is reader (which is the equivalent of associate professor) in the Microwave Physics Group in the Physics Department and heads the antenna studies. The Physics Department has a staff of 26, about 8 postdoctoral fellows, and a total of some 180 students, approximately 70 of whom are doing research or are taking postgraduate courses. Research is supported by the University and by contracts from the Science Research Council, government establishments (MOD), and industrial research laboratories.

Cornbleet has been commissioned by the Focal Press to write a book, *Optical Geometry*, on his new geometrical methods for designing optical antennas. Hopefully it will be published in 1981. Cornbleet makes use of the concept of zero-distance phase fronts and of a little-known inversion theorem of Damien, as explained below, and uses the properties of rays without resorting to ray tracing as such.

To obtain the zero-distance phase front of a source and dielectric interface, the rays from the source are viewed after refraction, from within the dielectric medium. Each ray is extended back to the point of its apparent origin, beyond the interface, as if all space were filled with the medium. The locus of all these points defines a new surface, the zero-distance phase front. Its shape is a function of the source position, the *interface surface*, and the dielectric constant. It is normal to the extended rays and is the wave front that, in a continuous medium, would have produced the existing field.

In designing a dielectric lens, one may choose the first surface arbitrarily. The zero-surface phase front is then obtained, derived for the given source position. For a focus at some desired point, the second surface is chosen such that its zero-surface phase front is coincident with that of the first surface. Zero-surface phase fronts may be constructed point by point for a number of fundamental surfaces, however, a whole surface analytical procedure becomes possible by the use of Damien's theorem whereby phase fronts and refracting surfaces can be obtained geometrically with inversion theorems. Damien has shown that after inversion a phase front becomes a refracting surface and vice versa. Cornbleet uses this method to design lenses and extends the theory to reflectors by making the dielectric constant equal to minus one.

To design complex systems of mirrors or mirrors and lenses Cornbleet uses an extension of the well-known method of drawing an ellipse with string that is attached to the two foci and kept taut by a pencil that traces out the shape. About 275 years ago Leibnitz pointed out that if two caustics are interposed as obstacles about which the string winds or unwinds, then the pencil will trace out the shape of a reflector which converts one caustic into the other. Cornbleet uses this conversion to design, for example, a corrector for a spherical mirror. He shows that other taut-string techniques can generate virtual foci (hyperbola) as used in a Cassegrainian antenna system.

There is much enjoyable, elegant neatness in these geometrical methods and I am looking forward with pleasure to the publication of his book.

Cornbleet has also investigated dielectric media with variable dielectric constants. He has derived a design for a short-focus microwave lens made from a flat sheet of dielectric, with a dielectric constant that varies as a function of the radius. As an approximation and for convenience, these variations can be discontinuous, in steps, and, in most cases, a very small number of steps were found to give acceptable small errors. Another dielectric lens was designed for millimeter waves and is in the form of a flat disc illuminated from its rim. The dielectric constant is effectively varied by changing the thickness of the disc as a function of radius. The study extends to fiber optics. He calculates the variations in dielectric constants that are necessary such that a ray will be confined within an arbitrary cylindrical contour. It is possible to have all rays in phase to give a transmission line with exact coherence.

Other studies that Cornbleet or his team started or are about to start include investigations of the scattering of electromagnetic waves by irregular bodies, with application to the radiation from aircraft communication antennas, and measurements of the millimeter wave radiation of the sun as part of a cooperative international effort.

Cornbleet's present most absorbing interest is a search for a four-dimensional conformal mapping of the wave equation, using quaternions (4-D complex numbers). He has outlined the problem but at this time has questions rather than answers.

Cornbleet's ideas and theories bring new light and understanding to the theory of microwave optics and offer new tools to the designer. (T.C. Cheston)

MATERIALS SCIENCE

COMPOSITES II

National Engineering Laboratory

The first of these articles on composite materials (*ESN* 34-3:125) ended with a description of work at the UK National Physical Laboratory (NPL) and so it is appropriate to begin the second in the series with a description of NPL's sister laboratory, the National Engineering Laboratory (NEL). NEL began as the Mechanical Engineering Research Organization (later Laboratory) at NPL, but in 1948 it was made a separate engineering laboratory of the Department of Industry. NEL is situated in East Kilbride, Scotland, just south of Glasgow. The work performed there is essentially engineering research and development, and the funding is shared equally by the Department of Industry, private industry (short-term), and government requirement boards (long-term, basic studies).

The Composite Group at NEL, headed by Dr. William Paton, was organized about 10 years ago and has a tradition of studying fatigue and creep behavior of organic-matrix composites with both short and continuous fiber reinforcements. One of their latest efforts is on the fatigue failure of glass-reinforced plastic (GRP) pipe. This work is part of a program sponsored by a consortium of 22 industrial firms which include GRP fabricators, suppliers, and users who are concerned about the lack of engineering data and design parameters for GRP pipe. NPL and the Rubber and Plastics Research Association (RAPRA) are also involved in this program (*ESN* 34-4:183). NEL is testing bends and T-sections and RAPRA is testing straight pipe sections. The bends and Ts are fabricated from short chopped strand glass fiber, but the straight sections are filament wound. Paton explained that in service GRP pipe exhibits a rather specific type of failure, brittle cracking with no evidence of fiber pullout. This suggests that the reinforcement is not inhibiting crack growth significantly. However, according to Paton, this failure cannot be duplicated in laboratory tests except in the presence of acids. Although GRP pipe is used to convey acids, brittle failure in service is not limited to these applications. At NEL, researchers are trying to duplicate this brittle crack growth by tensile fatigue tests of commercial pipe but as yet they have been unsuccessful.

Other efforts in connection with GRP pipe at NEL include multiaxial fatigue testing of GRP flat plate attempting to determine failure mechanisms, investigating ways of filament winding bend and T pipe sections, and developing finite element stress analyses of defects and drilled holes in GRP. The analyses indicate that stress distribution is strongly influenced by pipe geometry, wall thickness, and variations in the wall stiffness. Attempts to correlate the results of the analysis with measured stress levels have given only qualitative agreement.

Another major part of the composite work at NEL is concerned with the wear of filled polymers. These include dental restoratives, filled polytetrafluorethylene (PTFE) sliders for food canning machinery, and seals for oil-line valves on oil tankers. The work on filled PTFE is being done with Dr. J. Lancaster at the Royal Aircraft Establishment, Farnborough (*ESN* 34-7:334). The wear rate of the filled PTFE sliders is unusually fast and the mechanisms involved are unclear. The high speed at which these sliders operate causes heat buildup and accelerated wear but water cooling does not help to prevent this. The NEL people think that a lubricant-exuding polymer may be the answer.

The line valves on oil tankers frequently lock after they have been closed for extended periods as a result of creep or thermal expansion of the polymer seals. In search of a solution to this problems the NEL people are investigating PTFE filled with rigid fillers, like graphite.

They are also working on oscillating-wave energy devices. The bearing surfaces against which the oscillating arms rotate are made of self-lubricating bronze which corrodes and is expensive (these bearings may be up to 3 m in diameter). NEL is investigating filled epoxies as alternatives to bronze. They are especially interested in the role of water as a bearing lubricant and are exploring the possibility of injecting surfactants into the bearing to lower the friction. Actually, they find that sea water is a better lubricant than pure water and they suspect that the sea salts form a deposit on the bearing surface that acts as a lubricating film.

Atomic Energy Research Establishment

Another center of research on organic-matrix composites in the UK is at the Atomic Energy Research Establishment in Harwell, which is about halfway between London and Bath. Harwell is the largest of the Atomic Energy Authority (AEA) laboratories and is considered the Agency's corporate laboratory. Fifty per cent of the funding comes from the AEA but the staff must solicit the remainder, mostly from the Ministry of Defence, British Nuclear Fuels Organization, Central Electricity, British industry, and non-British industry and governments. A large part of the work, about 40%, is unrelated to nuclear energy. There is a professional staff of 1200 working in 16 divisions. Three of these divisions are devoted to materials science and, in fact, there is more research and development in materials science than in nuclear science at Harwell.

I visited the Advanced Engineering Materials Section in the Materials Development Division. My hosts were Dr. D.C. Phillips, H. Wells, and Dr. N.L. Hancox, who are the principal investigators in polymers and composite materials. Phillips, with a staff of 5, is working on the failure mechanisms of polymers and composites. With R.J. Lee, Phillips is conducting a fracture-mechanics study of composites aimed at determining crack-tip damage. The reinforcement is continuous and is either composed of carbon fiber alone or includes mixtures of carbon and glass fibers, and the specimens are center notched. Depending on fiber orientation and the type of surface treatment the fibers had been given, they find these types of behavior: (1) the fracture is independent of notch length; (2) fracture depends on notch length and the stress intensity factor (K_c); (3) fracture is notch sensitive but independent of K_c. This diversity of behavior disallows a simple linear elastic-fracture-mechanics (LEFM) analysis. As alternatives to LEFM, Phillips and Lee are investigating the inherent flaw model (Waddups, Tsai, S.W. Halpin, J.C. and Pagano, N.S., in *Composite Materials Workshop*, Technomie Pub., Inc., 1968, p. 254) and the point and average stress failure criteria (Whitney and Nuismer, ASTM STP 593). In the latter, the failure criteria are based on the damage zone either reaching a critical stress at point d_o or reaching an average stress over the distance a_o (Figure 1).

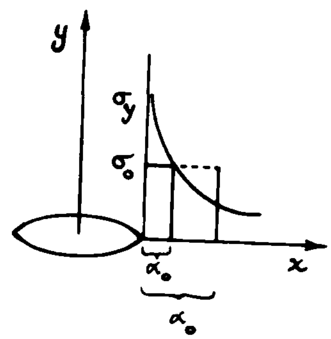


Figure 1

Phillips plans to subject notched composites to stresses below the failure load and then to examine the notch-tip region by means of scanning electron microscopy, x-ray radiography, and acoustic emission to determine the physical significance of d_o and a_o. In discussing the effect of fiber surface treatment on fracture behavior, Phillips expressed the belief that it is related to the proportion that different failure mechanisms, i.e., fiber pullout, debonding, and delamination, contribute to the fracture energy.

Phillips and G.M. Wells are conducting multiaxial stress tests using GRP biaxially loaded tubes. The tubes are loaded internally by hydrostatic pressure and externally by tensile and compressive loading along the tube length. Plots of their data can be fit using classical laminate theory (Fig. 2) except at the high axial tensile loads where internal cracking causes leaking (weeping) of the pressurizing fluid. Phillips and Wells think that raw internal cracking can be eliminated by use of a tougher matrix resin and that the theory will then describe the data in both the tensile and compression regions. Dr. R. Davidson is working with Phillips and Wells on elastomer-matrix, carbon-fiber composites; the elastomer is a polyether-urethane. They expect that the elastomer-matrix will give the composite high torsional flexibility but recognize that the fiber length must be long to avoid low buckling strengths. One application for these materials is containers for magnetic equipment used in nuclear fusion experiments. In this application the elastomeric CRP is coated with copper and a small amount of epoxy resin is added to the urethane to improve both the adhesion to the Cu cladding and the adhesion between the C-fiber and the resin matrix. Phillips expects that elastomeric-matrix compo- sites will also find use as mooring ropes for wave energy equipment, in which Harwell has a large program. The reinforcement will be oriented uniax- ially along the length of the rope and will probably be a polyaramid (e.g., KEVLAR) instead of carbon.

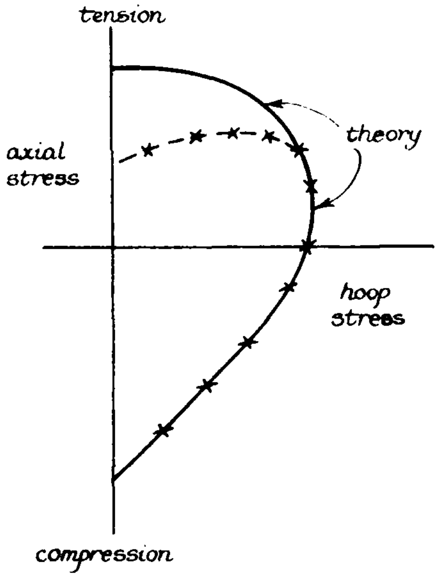


Figure 2

Mr. H. Wells has been developing composites in which the reinforcement is jute fiber. This work was initiated by the Commonwealth Secretary in coop- eration with the Indian Jute Industries Research Association (IJIRA) in Calcutta. A large part of the world market in jute as bag material has been lost to plastics. To find alternative markets, the IJIRA contracted Wells to determine the potential of jute fiber in reinforced plastics. Working with I. MacPhail and Pranab K. Pal (on leave from IJIRA), Wells has found jute to be a surprisingly good reinforcement. Jute-reinforced plastic (JRP) has a modulus equal to GRP but the density of the JRP is about half that of glass-reinforced composites so the specific modulus of JRP is nearly 50% higher. The reason that jute and glass have similar reinforcing behaviors is that both have low elongation to break. This would not be the case for most other natural fibers like cotton. Jute fiber has a better packing factor than glass, and therefore it is possible to obtain higher fiber loadings with jute (>70 vol.%) than with glass. On the negative side, the flexural strength of JRP is only half that of GRP.

Unfortunately, jute is supplied as yarn and woven material and when it is used as reinforcement in these forms it does not reflect the poten- tial indicated by unidirectional JRP. The problem is that the fibers in the yarn are not long enough and are not longitudinal, i.e., they twist along the length of the yarn. Wells thinks that there are solutions to these and other problems that could make jute a viable reinforcement. He finds that JRP made from untwisted yarn has 90% of the property values shown by uni- directional JRP. Felts of short jute fiber are another possibility as are glass/jute hybrids which Wells has prepared and has found to have mechan- ical properties equal to all-glass GRP.

Other workers, principally in the US, have looked at jute as a reinforce- ment and have concluded that although JRP properties are good, the cost of resin in India and other jute-producing countries is too high to make the venture profitable. Wells counters by suggesting that the jute be sold in the West, where resin costs are low, to make JRP. While the composite might still be too expensive for developing countries, this would at least create a new market for jute.

Hancox introduced me to continuous carbon-fiber-reinforced, plastic (CFRP)- reinforced aluminum. The material comes in a variety of shapes including sheet stock and rods of both circular and rectangular cross section. Hancox is working with I-beam aluminum in which the channels are filled with CFRP as shown in Figure 3.

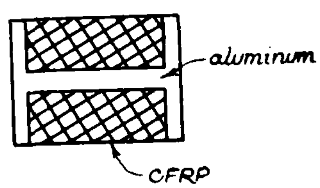


Figure 3

He is using these composite rods as the structural members in leg braces (which in the UK are called callipers). The Al-CFRP replaces the steel bars in braces which are heavy and suffer from fatigue failure. One of Hancox's prob- lems was to overcome the inability of the people who fit braces to adapt to organic-resin-composite technology. Having always worked with metals, they could not adapt to wet resin layup and complex curing cycles. Hancox used a resin, stable at room temperature, which could be partially cured to give a structure that would support the patient during the fitting, but which could still be bent 90° without delaminating the composite or debonding the composite from the aluminum. Once fitted, the braces are put in an oven to complete the resin cure. The resulting structure has better properties than steel and weighs a good deal less, and the fatigue resistance is better than steel or aluminum alone.

Hancox also described a project on which he is working to develop artificial limbs (knee to ankle replacement) using CFRP. Since the work is funded by private industry he could not go into great detail. He did say, however, that the artificial limb was designed to compression, torsional, and fatigue loads which are quite formidable for the human leg. Unidirectional layup was too difficult, so he went to woven carbon fiber cloth. He developed the fabrication process, and a prototype limb is now being tested. Static testing has been satisfactory and torsion fatigue tests are under way.

Royal Aircraft Establishment

The principal center for composite research and development for the Royal Air Force is at the Royal Aircraft Establishment (RAE) at Farnborough. Most of the work is done in the Materials Department but research on carbon fiber is also in progress in the Physics Department. My host was Dr. David Thomas, who heads the Materials Department.

The emphasis at RAE is on high-performance composites—materials that can meet the extremes in strength, stiffness, and temperature required for military hardware. These materials are usually too expensive to find extensive commercial markets, although there are some exceptions; e.g., expensive sporting equipment.

Work on organic-matrix composites (mostly continuous fiber reinforcement) has been going on at RAE since WWII, which makes RAE one of the oldest composite research groups in the UK and probably in the world. It was involved very early in the development and production of carbon fiber from synthetic organic fiber and in developing filament-winding techniques for CFRP.

Dr. J. Sturgeon told me about the current work on CFRP. (Sturgeon was probably not even born when research and development of composites materials began at Farnborough.) Today, as at many other laboratories, the emphasis at RAE is on fatigue, the effect of moisture on mechanical properties, and creep behavior. In the fatigue work; different reinforcing fibers (including glass-carbon hybrids) and different thermosetting resins are studied. Some of the fatigue work Sturgeon has under way includes the effect of fiber orientation, the behavior when the reinforcement is woven carbon fiber fabric, and the effect of moisture (he finds none at room temperature). All specimens are unnotched although the effect of drill holes is being examined. The fatigue-loading cycle is a so-called "Falstaff" pattern developed in Europe which simulates loads on an airplane wing close to the fuselage. Although the room-temperature effect of moisture on the fatigue of composites is negligible, there is a loss in strength at elevated temperatures. Sturgeon is doing three-point bend tests on exposed specimens and is looking at the morphology of the failed surfaces to determine what the water does. Most carbon-fiber reinforcements are given a surface treatment, usually an exposure to oxidizing agents to introduce surface polar groups. These treatments generally have a beneficial effect on static mechanical properties, but Sturgeon is attempting to determine whether these treatments have any effect, beneficial or otherwise, on fatigue resistance.

Sturgeon has a number of studies being done under contract. One of these is with RAPRA, which is determining the effects that aging prepreg at various storage temperatures and humidities produces on the mechanical properties of the fabricated composites. (Prepreg refers to unprocessed composite material with the reinforcement impregnated with uncured or partially-cured resin.) RAPRA researchers have found that any aging effects are lost in the data scatter; the same conclusion has been reached by other laboratories in the US and Europe. Sturgeon is also supporting research on fatigue under biaxial, inplane loads at the University of Cambridge (Dr. K.J. Pascoe), and on the effect of moisture on fatigue at the University of Bath (Prof. B. Harris). In addition he is sponsoring the correlation of literature data on composite fatigue at the University of Nottingham (Prof. M. Owens).

In the Physics Division, Dr. G. Dorey is doing an in-depth study on carbon fibers, in particular, their structure and surface properties. He hopes that this work will eventually lead to improved fibers with a higher strain-to-failure which should lead to higher composite toughness. This investigation is a continuation of the work in the Materials Division at RAE by W. Johnson who believes that the graphitic structure of carbon fibers is significantly different from what has been proposed in the past (*Nature* 279, 142 [1979]). Using polarized light microscopy, Johnson observed an inner core and an outer sheath in polished longitudinal sections of carbon fibers. Similar observations had been reported by others but the explanation given was that the graphite crystals were oriented radially in the core and circumferentially in the sheath. Johnson presented evidence that there is no difference in the orientation of the crystals in the two regions, and that the observed polarization interference is due to stress in the fiber resulting from differential shrinkage between sheath and core during the thermal graphitization of the polyacrylonitriie precursor fiber. Dorey is continuing this work by etching single graphite fibers to determine the crystal structure.

The major part of Dorey's work is related to the effect of surface treatment on the chemical composition and crystal structure of carbon fiber surfaces. He pointed out that depending on the manufacturer there are 6 different surface treatments in use, each differing in the level of surface damage. The effect on the mechanical properties is equally varied and not always beneficial. As the severity of the treatment is increased, the notch tensile strength of the composite decreases by about 50%. The impact strength of multidirectional laminates (but not unidirectional ones) goes through a maximum with increasingly severe surface treatment. Dorey is trying to optimize this effect on impact strength.

Part of the study of the condition of carbon fiber surfaces as a result of pretreatment is being done in-house and part is being done under contract. In-house, Dorey is measuring surface area, surface polarity (using dye adsorption), water absorption, and the mechanical properties of single fibers. Heats of adsorption are being measured at the University of Oxford and surface analysis by means of photoelectron spectroscopy is being done at the University of Newcastle. At the University of Surrey, gas desorption as a function of temperature is being determined by means of mass spectroscopy.

The use of load-bearing structural adhesives has become a key factor in military aircraft construction, indeed, in aerospace in general. Adhesive bonding is a method of choice when one is joining composites since composite materials are too notch sensitive to tolerate drillholes without some elaborate reinforcement to prevent cracking. Adhesive bonding is not without its problems, however, especially when composites are being bonded to metals such as aluminum and titanium; the adhesive/metal interface is especially sensitive to stress corrosion. Dr. J. Cotter, who heads the Adhesive Group in the Materials Division at RAE, has an extensive field testing program for adhesive joints, mostly metal/metal joints which are weathered in Australia and the UK. He has developed a surface treatment for titanium based on an alkaline-hydrogen peroxide etch. Adhesive bonds to the etched titanium show good stress corrosion resistance. This is a radical departure from the acid-chromate and acid-phosphate etches widely used in the US aerospace industry. However, despite this difference in the etch chemistry, Cotter's treatment produces a thick (approximately 200 nm) amorphous surface oxide similar to that produced by the acid chromate and acid phosphate treatments.

Cotter's other activities include examining acrylate adhesives and cold-setting epoxies for making battle-damage repairs of composites. Conventional adhesive bonding requires dry and clean conditions and time-consuming surface preparation, both of which are impossible when making repairs in the field.

The Polymer Chemistry Section, headed by Dr. W. Wright, is working on the thermostability of polymers, differential scanning calorimetry (DCS), chemical characterization of polymers, and the synthesis of novel epoxies. They are studying the kinetics and mechanisms of the thermodegradation of polymers (mostly elastomers) and the development of antioxidants having a high molecular weight and thus low volatility. DSC is being used in connection with the thermodegradation work and also to determine the kinetics of polymer cure. Wright and his co-workers are cooperating with ONERA (Office National d'Etudes et de Recherches Aerospatiales) in a program to chemically characterize commercial polymers. One of the polymer systems they are examining that is especially interesting is a tetrafunctional epoxy based on bis (N,N-di [2,3-epoxypropyl]-4-aminophenylmethane). This resin is very popular as a matrix in advanced aerospace construction because it cures to a very stiff, high-temperature stable polymer. Unfortunately, it is very brittle. A version of this resin that RAE and ONERA are investigating has a thermoplastic additive to improve toughness. It is suspected that the thermoplastic is present as a dispersed phase and so Wright is having the Cranfield Institute of Technology (Dr. C. Buchnell) examine the morphology of this polymer.

This series on composite materials will continue and the next article will deal with composites found in nature and how by imitating nature it is possible to develop materials with remarkable mechanical properties. (Willard D. Bascom)

SOME PRACTITIONERS OF TRIBOLOGY

The study of the friction, wear, and lubrication of solids has come to be known as tribology. The term was coined in the UK and first appeared in the Jost Report prepared by a working group (headed by Dr. H. Peter Jost) of the Department of Education and Science. This group documented the great importance of tribological phenomena to all aspects of industry (especially the cost of machinery failure) and their report and subsequent action stimulated considerable research in tribology in the UK which has spilled over into the rest of Europe and the US. The impact of the Jost Report 10 years after it appeared was documented in a report from this Office (ONRL Report R-7-76). A more recent report reviews the current state of the art of tribology in the UK and Europe (ONRL R-4-78).

This article makes no attempt at such thorough coverage of the subject but instead takes a look at a few people working in the field.

Dr. J.K. Lancaster is at the Royal Aircraft Establishment (RAE) in Farnborough, Hampshire, where he has conducted research since 1963 in nearly all phases of tribology, but he is perhaps best known for his work on solid lubricants and the friction and wear of polymers. He is currently concerned with aircraft bearings and oil debris analysis in his research at Farnborough and with elastohydrodynamic lubrication and the wear of carbon-carbon composites under contract to the University of Reading.

The bearings in aircraft are, for the most part, dry bearings of polytetrafluoroethylene (PTFE) fibers and glass fibers in a resin matrix, usually a phenolic resin. They function by the formation of a thin, so-called "third-body" layer of PTFE on the counterface. The introduction of more rigorous operating conditions in new generation aircraft has made it necessary to develop dry bearings that have better thermal resistance and can take higher loads than the conventional PTFE/glass/phenolic materials. Much of Lancaster's work over the past decade has involved evaluating these new dry-bearing materials, developing accelerated test methods, and looking into the friction and wear mechanisms of dry bearings in general. Presently, he is determining the effects of temperature, counterface roughness and environment on bearing wear. RAF field reports on these bearings often conflict in the amount of wear reported. Lancaster points out that the bearings are usually swimming in hydraulic fluid and/or water. He finds that these fluids inhibit the formation of a stable PTFE film and enter surface cracks which they extend under stress and hydrostatic pressure. The severity of the effect produced by the contaminating fluid is very dependent on the stress on the bearing, and Lancaster suspects that differences in stress level and how well the bearings are protected from oil and water explain the conflicting field reports.

Diagnosis of engine wear by examining the engine oil for the amount and type of wear debris is used in machinery maintenance in the US and Europe both by industry and by the military. However, there are those who question the scientific basis and engineering relevancy of the analysis. Lancaster has his reservations but is involved nonetheless in the RAE Machinery Health Monitoring Program to evaluate oil debris analysis as a diagnostic tool. He is determining the types of debris created by different types of wear situations and is generating an atlas of debris which catalogues the amount, shape, and composition of the microscopic particles that can be separated from the oil.

Rain erosion, especially as it affects aircraft cockpit canopies, has been studied on and off at Farnborough for many years. Lancaster indicated that their in-house work is coming to an end largely because their whirling-arm equipment, which drives a test plate through simulated rain, is too antiquated. It has a 1918 London Transport motor which is about to be "pensioned off." The RAE has a contract, monitored by Lancaster, with Dr. John Field (Cavendish Laboratories, Univ. of Cambridge, UK) to study erosion-protection coatings and the rain erosion of ir transparent materials. Field studies erosion using techniques in which a small slug of water impacts the substrate at very high speeds (*ESN* 33-6:231).

At the University of Reading, Lancaster is working with Prof. W. Hirst on the elastohydrodynamics of lubricating films and on the friction and wear of carbon/carbon (C/C) composites. Before going to Reading, Hirst had worked with Lancaster at Farnborough. The lubricating-film work is aimed at finding the optimum shape for piston rings during engine break-in.

The C/C composites are brake-lining material; their friction characteristics are being examined under controlled environmental conditions. The wear of the composite against metals is less than that of the composite against itself simply because the metal acts as a heat sink and so the contact temperature is lower than for composite against composite. An oddity has turned up in Hirst's work. Contrary to previous experience with other materials, in friction tests with C/C composites and also with graphite the wear rate increases with gas pressure. Lancaster suggests that the pressure of the gas opens up surface cracks in these materials and that this would not be a problem in the wear of metals which are much more ductile than the composite or graphite.

The next tribologist I visited was Dr. M. Godet at the Institut National des Sciences Appliqués (INSA) in Lyon, France. Godet heads the Laboratoire de Mécanique des Contacts (LMC) and, in the words of Lancaster, "Godet has a good-size group of energetic people." I did not get to meet many of Godet's people but Godet himself impressed me with his enthusiasm and energy. The Laboratoire is one of 40 at INSA and also one of the largest. INSA is the largest engineering school in France and is unique in that after two years of a fixed curriculum, the student has an option of choosing from 8 different departments (specialities). Most French engineering schools offer only two or three choices.

The research budget of LMC is about 1.8 million francs per year, most of which comes from industry. The research is related to defense, power, petroleum refining, automobiles, and mining. Most of the work is applied research but with some room for basic investigations. Godet divides the research into three catagories: Hertzian contact (high pressure, low area), bearing contact (low pressure, high area), and dry friction.

The lubrication of Hertzian contacts has come to be known as elastohydrodynamic lubrication (EHL); under high contact pressures the contacting solids undergo elastic deformation and the viscosity of the lubricant cannot be assumed to be independent of pressure. There has been considerable development in the theory of EHL to which Dr. D. Berthe at LMC has contributed significantly. Much of his work has been on the rheological behavior of lubricants under the high-speed and high-pressure conditions of EHL. Berthe, Godet, Dr. L. Flamand, and Dr. G. Dalmaz have examined a number of fluids by means of a rotating disc machine and are currently evaluating nonflammable lubricants for coal-mining machinery.

The high cyclic stresses associated with repeated Hertzian contact during rolling or sliding result in surface fatigue and damage (surface distress). Surface roughness influences the type and degree of surface damage, especially when the ratio of surface roughness amplitude/film thickness is less than 5. Flamand and Godet are investigating the effects of surface roughness on EHL fatigue damage and find that under rolling friction two types of damage occur: large pits about 200 μm in diameter and about 50 μm in depth and micropits 20 μm in diameter and 20 μm deep. A network of the 20 μm pits develops first followed by the formation of the 200 μm pits. The larger pits have been observed by others and are attributed to Hertzian shear stresses. The observation of the 20 μm micropits is new and EHL theory would indicate that the two types of damage are independent. However, the LMC workers think that the micropits are precursors to the formation of the 200 μm pits. Part of this work relating to the effect of surface roughness on surface damage is being done in cooperation with Lancaster. Godet and Flamand are using oil debris analysis to correlate debris formation with surface damage. The friction tests are run at LMC, while the oil analysis is done in England.

Certain chemical additives to lubricants reduce the amount and rate of EHL surface damage, probably by modifying the viscosity or viscoelastic response of the lubricant. However, Godet thinks that these additives are also adsorbed onto the metal surface and affect the surface plasticity of the metal; i.e., the Rehbinder effect. Because he is not a surface chemist and does not have access to instrumentation for surface chemical analysis, Godet is looking for help to investigate his idea.

When the relative surface velocities of rolling or sliding contacts are different, tractive forces develop which can adversely affect the thickness of the lubricating film and the level of surface fatigue damage. Godet and Flamand are studying traction by means of a ball-bearing-type test device in which the inner race moves at a fixed speed and the outer race is stationary. Force is transmitted via the oil film and causes the balls to rotate about their own axis. Theory predicts a much higher force on the balls than is actually observed from their rotational speed. The theory assumes that only viscous forces are important in the oil film. Godet thinks there may be an elastic response by the oil which causes the balls to slide as well as to roll. He plans to test this hypothesis by using an oil which has a dominantly viscous behavior.

In the area of bearing contacts, the LMC is working on high-speed bearings, specifically, the conditions under which flow instabilities (Taylor vortices) develop in the lubricating oil film. They have produced a general theory that predicts instabilities over a wide range of conditions. Currently, Dr. J. Frene and Dr. D. Nicholas are investigating the effects of polymeric lubricant additives which delay the onset of instabilities to higher bearing speeds. Unfortunately, the additives suffer shear degradation and for this reason Frene and Nicholas would like to find less-shear-sensitive polymers.

Two other areas of bearing lubrication related to connecting rods and clutches are being investigated by Dr. B. Fantino. In the work on connecting rods, it has been determined that the shape of the bearing end of the rod has a large effect on the pressure distribution in the contact area, and Fantino is working on optimizing the shape of the bearing for minimum wear The function of wet clutches is the subject of a new program at LMC in which the role of the facing paper is being studied. The paper is porous, and the questions being asked are, first, whether the oil flows in the porosity during the operation of the clutch, and, second, whether the oil undergoes an elastic response while the paper is simply a vehicle for holding the oil.

Godet, Dr. D. Play, and Dr. A. Floquet are doing dry-friction studies. Much of the work, part of it in cooperation with Lancaster, is on polymeric materials. The thrust of the effort is on the third body layer of particles that develops between the bearing surfaces. The lubricating action may be the rolling of particles, the shear deformation of an interfacial layer, or some combination of the two. Godet suggests that there are three aspects of the third body layer that must be understood. First, its transport behavior as the bearing slides, i.e., is it continuously formed and expelled or is it retained? Second, what is its load carrying capacity? Finally, what is its ability to fill surface roughness? The group is investigating all three aspects.

Again in the dry friction area, Godet and co-workers are studying the high-temperature behavior of a CrNi steel pin sliding on a CrNi alloy. At 950°C they have observed a luminous dust that suggests particle formation. With continuous running there is a build-up of material on the bearing face of the pin and on its leading edge. This material has a different composition from that of the pin or disc, and Godet thinks it may be an eutectic that forms at the leading edge and flows plastically under the pin.

Prof. J. Blouet heads the Laboratoire de Tribologie at the Institut Supérieur des Materiaux et de la Construction Mécanique (ISMCM) in Paris. The Laboratoire is one of five physics and engineering laboratories at ISMCM which, being an engineering school, gets the bulk of its financing from the Ministère des Universités but also receives support from other government agencies such as the Delegation Generale a la Recherche Scientifique et Technique as well as from private industry.

Blouet has a staff of eight engineers and about a dozen research students. He showed me through an impressive array of test equipment which included sophisticated apparatus for high-temperature friction and wear studies in controlled atmospheres.

The work of Blouet's group is divided into fundamental research, applied research, and technical assistance to industry. The fundamental work is mainly on two topics: adhesion and friction of metals and ceramics at high temperatures, and the impact sliding of solids. In the high-temperature work they are investigating the self-welding of nickel at temperatures up to 950°C. When two spheres of nickel are pressed together in a high vacuum, interdiffusion occurs at the point of contact and a weld is formed. Blouet is determining the activation energy of the diffusion process and his results indicate that at temperatures above 850° the process is one of bulk diffusion, but that between 750° and 850° the predominate mechanism is surface diffusion. In another part of its high-temperature work, the group is studying the friction and wear of ceramics at high temperatures and in different gases.

The purpose of the impact-sliding studies is to characterize the damage that occurs as two contacts successively slide and impact against each other. This type of wear is encountered when sliding components are subjected to vibration and is usually more severe than the wear inflicted by sliding alone. Blouet finds that the fracture toughness of the contacting materials is a critical factor in the amount and type of wear and is trying to model the processes involved.

A specific instance of impact sliding occurs between metal and bone at the joint of artificial bone replacements. Body motions cause the metal implant both to slide and to impact against the bone. Blouet is doing both *in vivo* and *in vitro* studies of the impact sliding of various metals against human bone to determine the mechanisms of wear and also to determine if there are any changes in the mechanical properties of the bone.

In the applied work, Blouet has three programs. One involves the friction and wear of glass-reinforced composites against metals and he is finding that the viscoelastic response of the polymer matrix plays a role. In another study he is evaluating the frictional behavior of commercial polymer coatings on wire and cable. Finally, he is doing some friction and wear studies for the nuclear industry.

Lancaster, Godet, and Blouet are internationally known for their contributions to tribology. I close this article by describing the work of Dr. B.J. Briscoe, a relative newcomer who is fast developing a well-deserved reputation in tribology and surface science in general. Briscoe was a student of Prof. D. Tabor (Cavendish Laboratories, Cambridge Univ.) and then a lecturer at Cambridge before going to the Interface Science Group, headed by Prof. A.I. Bailey, in the Department of Chemical Engineering and Chemical Technology of Imperial College (Univ. of London).

Briscoe has several projects underway but the one he chose to describe in detail was a study of the wear mechanisms of filled polymers, specifically, the curious fact that polymers containing particulate fillers—like carbon-filled PTFE—wear at rates orders of magnitude lower than the unfilled polymer. Intuitively, one would think that hard particles would assist wear by a grinding action in the contact area. Besides the fact that there is only limited understanding of why the wear rate is so low, Briscoe indicated that the wear rate is difficult to predict. Then too, there are problems in fabrication—difficulties in getting a uniform distribution of the filler and uncontrolled variations in the quality of the filler. In the field, moisture causes a serious increase in wear rate.

Briscoe has made a systematic study of the wear of PTFE containing three different types of fillers: graphite, glass spheres, and metal oxides (CuO, PbO). He is using a polar graphite and an oleophilic graphite; the polar material is formed by milling in air which exposes highly oxidized crystal edges, and the particle-aspect ratio is 5. The oleophilic graphite is milled in a hydrocarbon liquid which causes the crystals to weld together to form platelets that have an aspect ratio of 200. The metal-oxide fillers are chemically active in that in the contact area they degrade the PTFE to form low molecular weight PTFE. Briscoe examined the effect on wear rate of the following factors: particle size and aspect ratio, the load on the sliding polymer, the coefficient of friction, and the presence of water. The counterface was cast iron which has a slightly porous surface.

The following are some of Briscoe's observations pertinent to understanding wear mechanisms. (1) Taking the wear rate of unfilled PTFE as one, the relative wear rate of PTFE filled with polar graphite is 10^{-4} and that of PTFE filled with oleophilic graphite is 10^{-2} (one would have thought that the platelets of graphite would inhibit wear relative to the low aspect ratio, polar graphite particles). (2) Consistent with (1) is the fact that the wear of unfilled PTFE increases linearly with the load (W) on the slider, whereas the wear of PTFE filled with oleophilic graphite increases with the square root of W, but the wear of PTFE with polar graphite increases to only the cube root of W. (3) The wear rate of PTFE filled with glass spheres decreases with decreasing particle size. The volume % of the particles was kept constant so that the actual number increased as the size was decreased. (4) Mixtures of PTFE with CuO or PbO exhibit evidence of a low-temperature chemical reaction in differential-scanning calorimetry experiments at about the same ratio of oxide to PTFE at which the wear rate is minimal.

The process by which unfilled PTFE wears against metals is reasonably well understood. A film about 10 nm is transferred during the first traverse, but because this film is only loosely held by the counterface, the polymer continues to wear at the same rate. On the other hand, PTFE containing hard fillers transfers about 1 nm on the first traverse and deposits an average of only 0.1 nm for each subsequent slide. Briscoe suggests that local heating around a filler particle in the contact region softens the PTFE which allows the transfer film to conform and thus adhere to the topography of the counterface. The adhesion of the transfer film will be even greater if, besides local softening, the molecular weight of some of the polymer is being reduced by chemical reaction. Briscoe thinks that occurs when the filler is a metal oxide and that it may also occur with a polar (chemically active) graphite filler. On the question of why water increases the wear rate of filled PTFE, Briscoe essentially agrees with Lancaster that the water chemically displaces the transfer film from the counterface.

Looking to the future, Briscoe will continue investigating filled PTFE but will also begin looking into the sliding wear of other polymers, specifically those that do not form transfer films. Many such materials, like PMMA, polyvinylchloride and the epoxies, have the strength to be used as bearings which could be manufactured inexpensively by injection molding. However, they wear rather rapidly and need to be modified by adding an elastomer which can form a transfer film or a high molecular weight liquid which slowly exudes to act as a lubricant. Briscoe pointed out the need for low-cost pumps in developing countries; these pumps would best be made from plastic but will need inexpensive, rugged polymer bearings.

The four tribologists mentioned here represent but a sampling of the people working in the field. However, their activities give some picture of the state of the art of research on lubrication, friction, and wear in Europe. (Willard D. Bascom)

MEDICAL PHYSICS

SAVE AN EYE WITH DIAGNOSTIC X-RAY SPECTROMETRY—A DEVELOPMENT IN ISRAEL

The International Radiation Protection Association held its fifth international conference recently in Jerusalem. This writer attended and had the opportunity to meet Prof. Arye Weinreb of the Racah Institute of Physics, Hebrew University. Weinreb works in the field of molecular structure, but some years ago he became intrigued with the possibilities of applying the methods and approaches of the physicist to solve problems in medical science. He and his colleagues have developed a successful method for measuring trabecular bone density in the distal portion of the radius, a valuable adjunct in the study and diagnosis of osteoporosis (*ESN* 34-5:233).

Another problem area that caught his attention, and the subject of this report, was the detection and analysis of metals in the eye by x-ray spectrometry. He got into this work as the result of a conversation with an Israeli army physician, an ophthalmologist, who told Weinreb that if a very sensitive method to detect minute bits or pieces of nonmagnetic metals in the eye had been available at the time of the Yom Kippur War (1973), he could have saved 60 pairs of eyes. Weinreb joined forces with Dr. Michael Belkin of the Department of Ophthalmology at Hadassah Hospital, University of Jerusalem, to develop a noninvasive method of detecting metallic foreign bodies in the eye.

The Problem

The presence of metallic nonmagnetic foreign bodies in the eye is a serious problem for the patient, and constitutes a difficult management problem for the ophthalmologist. The retention of such metallic foreign bodies in the eye can be disastrous if the metal is toxic, especially copper. On the other hand an operation for their removal is extremely hazardous. In fact, at the present time there is no widely accepted approach to the management of nonmagnetic intraocular foreign bodies (IOFB). Both "active" and "conservative" approaches have their difficulties. The active approach calls for the removal of foreign bodies that in fact may not endanger the eye, since some foreign bodies of innocuous chemical elements are tolerated in the eye for a long period of time. Even if the foreign body is of a hazardous nature, but becomes encapsulated, it may not dissolve and will be tolerated. The difficulty with a "conservative" approach (no surgical removal plus "wait and see") has been the lack of a reliable and sensitive test capable of signalling trouble before irreversible damage has taken place. The key element of danger of a retained nonmagnetic IOFB is the development of chalcosis (irreversible damage associated with copper in tissues) due to the dissolution of the foreign body. It is the dissolution of the metal which creates the hazard. Until recently the dissolution could not be detected reliably and with sufficient sensitivity. The contribution made by Weinreb and his co-workers was the demonstration that the use of diagnostic x-ray spectrometry (DXS) could detect trace elements in human tissues reliably, with great sensitivity, and noninvasively.

The most common nonmagnetic IOFB contain copper or its alloys. Copper is highly destructive to the eye when it dissolves to form the Cu^{+2} ion, unless it becomes encapsulated and does not dissolve. Copper concentrations of the order of 4 to 10 parts per million (ppm) were found on analysis of the aspirated vitreous of injured eyes. In the aqueous humor of injured eyes concentrations of 4 to 6 ppm of copper have been found. Thus a method of detection is required that is able to measure changes in concentration of this order *in vivo*.

Method of Detection

The vitreous of the eye is irradiated through the sclera by a monoenergetic beam of x-rays, and the characteristic fluorescence of the elements present is detected. Figure 1 shows the relative position of the eye, the primary beam of radiation, and the scattered and fluorescent x-rays.

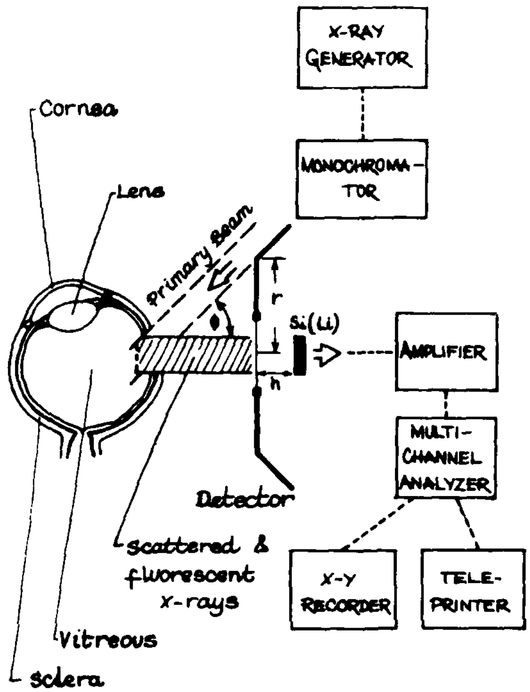


FIG 1. MEASURING SYSTEM & THE EYE

It also indicates the block diagram of the instrumentation that is used. Since the greatest interest was in the detection of copper, the L_β characteristic radiation of gold, which is strongly absorbed by copper, was chosen to excite the fluorescence. [note: the L_β characteristic radiation of gold has an energy of 11.4 keV, whereas the K-absorption edge of copper is at 8.98 keV; thus the gold radiation moderately exceeds the energy required to ionize the K electron of copper, a good condition for copper to absorb the radiation.] A homogeneous intense beam of 11.4 keV photons is obtained by monochromatization and focusing with a curved quartz crystal. The x-ray generator is operated at 45 kilovolts peak (kVp) and 3 milliamperes (mA). The primary beam measures 5 × 5 sq mm in cross section at the eye, and is directed onto the temporal sclera. The beam's location is monitored by a parallel beam of white light. The 11.4 keV photons are capable of exciting the fluorescence radiation of the atoms in its path. Each element is capable of emitting fluorescence radiation with an energy which is characteristic for that element. For copper this energy is slightly above 8.0 keV. The detection of the fluorescent radiation is performed by a Si(Li) solid-state type of detector with an 100 mm^2 effective area. The information is received by the multichannel analyzer, recorded and displayed as an energy spectrum (see Figure 2).

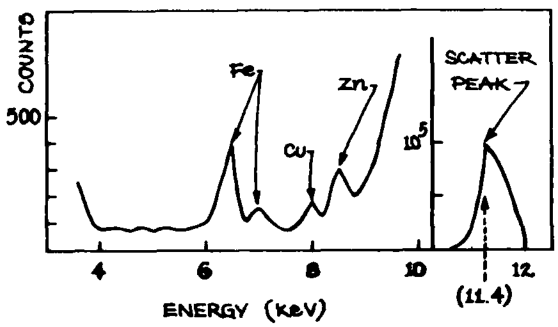


FIG. 2. ENERGY SPECTRUM OF A RABBIT'S EYE CONTAINING A DISSOLVING COPPER IOFB

The abscissa is the energy and the ordinate is the number of counts accumulated. Each element present in the path of the monochromatic 11.4 keV photons is represented by a peak at a definite position. Note the position for copper (Cu) at 8.0 keV. The net peak (total peak integral minus background integral) is proportional to the quantity of copper present. The foreign body can also be analyzed, if it is visible, by exposing it directly to the 11.4 keV photon beam. Elements with atomic numbers between 26 and 30 (iron, cobalt, nickel, copper, and zinc) can just be detected in solution at concentrations below 1 ppm. The absorbed radiation dose is approximately 7 rads delivered to an area of 25 sq mm. Since the absorption coefficient for 8.0 keV photons in water is relatively high, the copper is detected only to a depth of 4 mm from the surface of the eye. Figure 2 also shows the "scatter" peak at 11.4 keV due to the coherently scattered and Compton scattered photons of the primary beam which interacts with the eye tissues in the pathway. This peak integral depends only on the eye tissues that are in the beam pathway. Thus a good measure for the concentration of copper is the ratio of the net peak for the copper to that of the scatter peak. This measure is independent of the intensity of the x-ray generator.

Subjects and Methods

Thirty-two male patients with nonmagnetic IOFB were referred to Drs. Belkin and Weinreb from Israel and abroad from October 1973 through December 1977. The patients' ages ranged from 9 to 48 years, and they were mostly military casualties. Twenty-nine of these patients were followed for periods ranging from 1 month to 4 years. Three did not return after the first examination.

For these 32 male patients a 5 × 5 sq mm photon beam in cross section was directed onto the temporal sclera (see Figure 1). The test requires 6 minutes, with an absorbed dose of 7 rads delivered to 3% of the eye surface. The lens, which is the most radiosensitive ocular structure is not struck by the direct beam. The scattered radiation reaching the lens is less by two orders of magnitude. With this magnitude of dose it is possible to detect 0.26 ppm in a copper solution. Since copper is normally present in the eye at low concentrations (about 1 ppm), readings of the injured and healthy eyes are compared. A pathological copper content was considered to be present when the reading of the injured eye exceeded that of the healthy one by two standard deviations (SD). The SD is obtained from the readings of the patients in whom copper dissolution was not detected. On this basis it was determined that the fluorescent peak of copper obtained from healthy eyes is equivalent to that obtained under the same conditions from a standard copper solution of 1.0 ppm with an SD of 0.3 ppm.

Comments

Nine of the patients had evidence of dissolving copper IOFB. The time elapsed from injury until the first positive diagnostic x-ray spectrometry result varied from 2 weeks to 26 months. Some of these patients were referred a long time after the original injury. In 7 of these 9 cases a standard opthalmological examination (electroretinography—ERG) was not able to show the characteristic signs of chalcosis. The surgeons decided to operate on 5 of the 9 patients. Two of these interventions were successful, while three were not.

In 23 of the original 32 patients no positive diagnostic x-ray spectrometry results were obtained. Twenty-one of these had retained an IOFB for periods ranging from 5 months to 28 years. Of the 21 some 17 patients had retained an IOFB for two years or more. In this group there was no evidence of damage due to dissolution. The remaining group of four patients was too small in number to permit any classification. In the group of 17 patients who retained a foreign body for more than 2 years, the visual acuity and the ophthalmological findings were very satisfactory. For this group it is likely that an operation would have been performed for the great majority in centers using an "active" approach. Belkin and Weinreb do not believe that results as good as they reported would have been achieved had surgeries been performed on this group.

Returning to the group of 9 patients with evidence of dissolution, it is useful to divide them into 2 groups: those operated on and those not. The results for the 5 surgical efforts for the extraction of the IOFB were typical of such operations. Of the 4 patients who did not have the operation 3 patients were followed for periods of 2 to 3 years. The dissolution first observed disappeared later. Also they enjoyed good vision and normal ERGs. In these cases it is believed the temporary character of the dissolution is related to an encapsulation built up around the foreign body.

Conclusion

It appears that diagnostic x-ray spectrometry (DXS) is the only method currently available with the requisite sensitivity, reliability, and noninvasiveness for the early detection of chemical dissolution of a foreign body. An important contribution of DXS in management of nonmagnetic IOFB is its reliability in ruling out chemical activity (dissolution), enabling the physician to avoid intervention (operation), and still preserve good visual ability in most cases. Of course copper concentrations below the present limit of detection could have a slow damaging effect. More work is needed to study the consequences of very low concentrations. (*Moses A. Greenfield*)

MEDICINE

EDUCATIONAL TRENDS IN THE RADIOLOGICAL SCIENCES IN ISRAEL

Education in Medical Physics

The Fifth International Conference of the International Radiation Protection Association was held in mid-March 1980 in Jerusalem. This writer attended the week-long conference, and remained an additional week to visit universities and major hospitals in both Jerusalem and Tel Aviv. The visit provided the basis for this report on some educational and research trends in the radiological sciences in these two cities.

In Israel, the training of health physicists and medical physicists on the whole does not occur in structured, organized programs leading to degrees in medical physics. This is unlike the US which has a large number of organized university-centered programs leading to the MS and PhD degrees in medical physics or biophysics. Most of the health and medical physicists working in Israel received their original education and training in physics. Their hospital training or training in radiation health usually occurred through "on-the-job" experience. This is also how most health and medical physicists are trained in the UK. A good collective case history in Israel is provided by Prof. Arye Weinreb of the Racah Institute of Physics in Hebrew University, Jerusalem, and his students. In physics, Weinreb works on problems in molecular structure. Some years ago he became interested in what physics might accomplish to help solve some medical problems that were important to Israel. One of the problem areas was osteoporosis, a bone ailment afflicting older people. A long-range study of osteoporosis in Israel has been underway for more than 10 years. Weinreb made a significant contribution to this study by providing a measurement of a physical index for each subject in addition to the clinical and biochemical data that were being obtained (*ESN* 34-5:233). The physical index is the mass density of trabecular bone tissue in the distal part of the radius. He demonstrated a good correlation between the measured trabecular bone density and the clinically evaluated status of osteoporosis in the subject. Another problem area that caught Weinreb's attention was the danger presented to the eye which had been impacted by tiny pieces of metal (copper, iron). These fragments can ultimately cause blindness if they are not detected and removed. Weinreb and his students have developed a successful technique for detecting minute fragments by using fluorescence radiation. This is the subject of a separate report (*ESN* 34-7:339).

The point that Weinreb makes about training in medical physics is that first one has to be a good, well-trained physicist. Secondly, one must have some insight into what medical physics is all about and what problems are worth tackling. This can occur to some extent as a consequence of on-the-job training in a hospital where medical physics is an ongoing activity. It also calls for close cooperation and teamwork between the physicist and the physician. Certainly formal course work is also helpful at the postgraduate level, with an MS degree as the usual terminus. Weinreb and his students attended biology and biochemistry courses, with the professor insisting on taking the final examinations himself. He has also spent a sabbatical year at well-known medical physics centers in the UK and the Netherlands (Laboratory for Medical Physics, Univ. of Amsterdam).

It has been suggested to Weinreb that an institute of medical physics should be established at Hebrew University; in fact, he has been invited to do so. He believes, however, that this would be an ill-advised move, and would simply create an expensive and awkward bureaucracy. Weinreb and several of his students are now turning their attention to the possibility of studying blood flow in humans by analyzing the sound production that accompanies blood flow and turbulence. One is mindful, respectfully so, of the vast amount of information that can be gained by a skillful clinician using the simplest of tools: a stethoscope, a tapping set of fingers and the ability to relate and synthesize the sounds heard into a meaningful pattern for diagnostic purposes. I believe Weinreb has made a credible case for how to work in medical physics just by establishing his own good track record. It will be well worth waiting for exciting new developments from this small but quite active group of medical scientists.

Radioisotope Training Center

To satisfy Israel's need for persons trained in the safe use of ionizing radiation, a training center was established at the Soreq Nuclear Center at Yavne in the early 1970s. This center is administered by the Radiation Safety Department headed by Dr. Tuvia Schlesinger. The Soreq Center was a natural choice for this activity because of the ready availability of experienced personnel and an abundance of high-quality radiation detection and recording equipment. However, funds were needed to build a classroom and to provide some start-up facilities suitable for teaching. The training center was initially supported by a United Nations Development Program grant. Now it is financed in part by the Ministry of Education. The center trains a variety of categories of professionals including high school teachers, teachers in technician schools, physicians working in nuclear medicine, and radiation safety officers (health physicists). The course is brief but rather concentrated and is taught in a 2 to 4 week period. This arrangement allows "working" people to enroll without leaving their jobs or professions for an overly long period of time. In the past 5 to 6 years some 600 students have been trained.

Medical Education (Radiology)

This writer previously visited Israel 15 years ago, and was fortunate enough to be able to see some of the same persons in both visits. This permits a "now" and "then" view of matters. One of the leaders in medical education, particularly in the radiological sciences, is Prof. Samuel Schorr, chairman of the Diagnostic Radiology Department, at the Municipal-Government Medical Center, Ichilov Hospital, an affiliate of the Sackler Medical School of Tel Aviv University. Schorr is the source of much of the information in this section. During the past 15 years there has been a significant increase, from 1 to 4, in the number of medical schools. In addition to the original school at the Hebrew University in Jerusalem there are now medical schools at universities in Tel Aviv, Haifa and Beersheva. It is interesting to note this expansion in the face of stringent budgets occasioned by enormous and continuing outlays for defense. It is also somewhat the reverse of the mood in the UK, where a sentiment is growing for cutbacks, consolidations, and even the elimination of medical schools (February 1980 report from the Univ. of London by a committee chaired by Lord Flowers). In the past some of the spaces in the Israeli medical schools were allocated to students from a number of African countries. Middle east politics has largely stopped that. At the present time students from Europe and the US are attending Israeli medical schools. The Israeli educators hope and expect that one day the students from black African countries will return. From this point of view what appears at first to be an excess capacity for training medical students may well be an important long-range investment. In this context it is worth noting that radiologists from Latin America are now coming to Israel to obtain subspecialty training.

At the postgraduate level, medical training has expanded and has become more formal and structured. Following the patterns in the US and the UK, formal residency programs exist for specialty training in the radiological sciences. This includes diagnostic radiology, radiation oncology, and nuclear medicine, which are organized into separate and independent departments. Each discipline has its own examining board for all of Israel. Candidates are given written, oral, and practical examinations in basic sciences and in clinical areas. After the MD degree is earned, an additional 5 years of training are required for the graduate to qualify as a diagnostic radiologist. One of these years is spent in research training (6 months in a clinical area and 6 months in basic sciences), and 4 are devoted to training in the so-called subspecialties of diagnostic radiology (pulmonary, cardio-vascular, neuroradiology, pediatrics, gastro-intestinal, genito-urinary, bone diseases, ultrasound, and computerized tomography [CT]). Unlike the US, however, where a large university-centered medical school radiology department may have 20 diagnosticians, each virtually practicing a subspecialty, the much smaller Israeli departments (typically 5 or 6 persons) require each radiologist to cover most of the subspecialty fields.

Another important avenue that the Israelis have developed to maintain contact with the outside medical world is the holding of international conferences, something they do rather well. The Israeli radiologists established an annual lecture series in 1961 in honor of Prof. Leo G. Rigler. Rigler (who died in October 1979) was a world-renowned radiologist whose specialties were chest diseases and the understanding of pathology through a knowledge of physiology and anatomy as applied to the interpretation of radiographs. The 19th Annual Rigler Lecture and Convention to be held in 1980 will be devoted to abdominal CT and ultrasonography, currently very important areas of work. In addition to the Rigler Lecture, which is delivered by a recognized authority, the 2-day convention is attended by invited faculty from many countries. While the large majority of speakers are from the US or Israel, the 1979 convention had invited participants from South Africa, Germany, France, Belgium, and Australia. The theme of the 1979 conference was Pediatric Radiology. I noted with interest that one presentation was on the subject, "The Battered Children Syndrome," based on a study of 254 children admitted to the Royal Alexandria Hospital for Children in Sydney, Australia. This is a topic of current concern in the UK. The Australian report stated that 51 of the 254 children appeared with fractures requiring orthopedic attention. It is important for the radiologist to be able to distinguish between non-accidental post-traumatic deformity, when the history of trauma is denied, and congenital anomaly. The report formulated a practical radiological classification in order to assist in the diagnosis.

In Israel, the problem physicians face in maintaining clinical skills and keeping up with the latest in a field that has been revolutionized in the past 10 years (CT and ultrasound) is met by a formal program of continuing medical education. Weekly and monthly meetings are arranged which include the presentation of short refresher courses. These programs cover all the medical specialties, not just radiology. This is deemed to be a sufficiently important activity that a full-time dean is responsible for the administration of the program at the Sackler Medical School in Tel Aviv University.

Research Trends in Nuclear Medicine at Beilinson Hospital

One of the larger general hospitals associated with the Sackler School of Medicine is the Beilinson Medical Center. The Department of Nuclear Medicine has been chaired for the past 15 years by Dr. Zygmunt Lewitus, who retired recently. Dr. Ernesto Lubin, his associate for many years in clinical work and research, has replaced Lewitus as the new department head. Much of the research over the years, until very recently, has centered on both basic science and clinical aspects of the thyroid gland: how it functions and malfunctions. In a series of excellent papers dating back to 1961, the Department of Nuclear Medicine published studies of the thyroid gland's basic trapping mechanism for iodine, a study of a similar mechanism (concentration of iodine against a gradient) in certain marine algae, early studies of coronary heart disease using I-131 labelled material, and studies of endemic goiter in parts of Israel (Upper Galillee). Other parts in the series included a comparison of surgery vs I-131 in the treatment of toxic goiter, a clinical study comparing the efficacies of treatment of thyrotoxicosis with I-125 and I-131, and a follow-up, basic-science radiobiological investigation of the same problem using Wistar rats. More recently, the studies have shifted from the thyroid gland to other organ systems as more sophisticated equipment and newer radiopharmaceuticals became available. Some of these later papers describe studies of patients with myeloma by examining bone marrow cells using autoradiographic techniques, and a study of the role of thymus-dependent lymphocytes in thyroid diseases. Areas of work now underway include hypertension, kidney function, hepato-biliary systems and cardiac studies. While some of the sophisticated equipment used comes from abroad, more and more is being manufactured by an Israeli firm, ELSCINT, based in Haifa.

Conclusion

While the emigration of trained scientists and physicians remains a serious problem, it was interesting to note that some of the younger research physicians in the Nuclear Medicine Department have recently returned from the US. (This was also true of the Hadassah Hospital in Jerusalem where the new chief of radiation oncology had been trained at Stanford University.) It is also clear that Israel's most important scientific resource must be the dedicated people who work diligently, with enthusiasm, and with considerable success.
(Moses A. Greenfield)

METEOROLOGY

FRONTIERS IN SHORT-PERIOD RAINFALL FORECASTS

The UK Meteorological Office Radar Research Laboratory is on the grounds of the Royal Signals and Radar Establishment at Great Malvern, Herefordshire. Dr. K.A. Browning, FRS, is in charge of the laboratory. In 1978 the laboratory began a pilot project called FRONTIERS (Forecasting Rain Optimized using New Techniques of Interacting Enhanced Radar and Satellite). The principal goal was to develop and perfect a method for making short-period (0-6 hour), detailed forecasts of rainfall over the United Kingdom based on rainfall rates as observed by radar and cloud cover observations from satellites. The forecasts were to be of use to the fresh-water authorities, the building and construction industry, and in the management of agriculture. Secondary goals were to use the forecasts in place of some of the many rain gauges now in use for inventorying the fresh water supply and to learn more about the mechanics of meso-scale meteorological events that are usually short lived and are sometimes missed by the coarse grid of weather reporting stations. The concept of using interactive video display of radar data and satellite data had been pioneered by Prof. V. Suomi at the University of Wisconsin.

Four radar stations with overlapping coverage are used in the FRONTIERS project. They are located in such a way as to cover all of Wales and England except the southern part, east of London. Each of the radar sets scans 360° in azimuth at 4 low-level elevation angles. The complete set of 4 scans takes under 5 minutes. A method was developed based on minicomputers at each site that transmits the data to the laboratory and composites the data automatically to give a single large image of the distribution of rainfall as depicted by the radar sets. Calibration of radar-echo strength into rainfall rate is done with rain gauges. Typically three clusters of telemetering rain gauges are used with each radar set. Most of the data is transmitted by telephone lines, but in one case a microwave link is used.

The principal format is a rectangular Cartesian matrix of rainfall averaged over 5 km squares. The final rainfall-rate picture is displayed on a color TV screen that employs eight colors to depict eight different densities of rainfall. Presently a picture is made each 15 minutes and is stored in a computer for future study. The display can be sped up and subsequent 15-minute rainfall patterns can be shown as a moving picture. If 2 of the 4 scanning elevations were eliminated, the system would produce a picture each 2½ minutes.

Prior to my visit, the Midlands had suffered a long dry spell which was broken by a heavy rainstorm during the night I arrived in Great Malvern. While I was interviewing Mr. Patrick Menmuir of the laboratory staff, a nearby TV station called and asked if they could make a movie of the rainstorm from the stored data and show it on TV that evening. While Menmuir and his people were assembling the tapes for the broadcast, I was shown the whole sequence of the rainstorm as a moving picture. One could see the individual showers as they moved in a circular path around the storm center and the translation of the storm as it moved from west to east over central Wales and England.

The interpretation of radar data is still somewhat subjective. Refraction causes some backscatter of false echoes from the ground and there are blanks on the screen caused by mountains or other objects in the way of the radar beams.

Data from the European geosynchronous satellite METEOSAT was used in conjunction with radar data until METEOSAT stopped broadcasting on 23 November 1979. The satellite gave infrared images each half hour on a 5 km E-W by 10 km N-S grid over England. The heights of the cloudtops were inferred from their temperature as measured by the infrared sensor on the satellite. Up to eight cloud heights were displayed on the TV screen as different colors.

The video system can be switched back and forth to alternately display radar-rain images and satellite cloud-height pictures as a synchronous moving picture. The sets of data complement each other and help in the subjective interpretation of the combined data set.

The most interesting thing that I saw during my visit was a re-run of the storm which caused such great and tragic havoc during the Fastnet race in August 1979. Seventeen sailboats were lost and many others damaged during the race. The movie alternately showed rainfall rates and cloud heights in the storm. It displayed the storm as a living, writhing thing. The small storm moved very rapidly across the water near Lands End where the race was taking place. The twirling clouds could be followed in detail and the relationship between clouds and rainfall could be clearly seen.

A next step is to blend in some information on wind from synoptic charts to aid in the interpretation of the cloud and rainfall patterns. When the system becomes operational, forecasting will be done on a persistance basis. That is, if a rain storm is seen approaching the forecast area its rate and direction of movement over the water or land can be accurately determined and its path predicted. The laboratory is now working on methods for getting their short-range predictions into the forecasting system and to the public.

The beauty of the whole FRONTIERS system is the speed with which one can move from raw data to a finished forecast. Presently meteorological office forecasts take about three hours from the time observations are taken until the completed forecast is ready to send out (vs a few minutes using the FRONTIERS method), and have a grid size of about 100 km (vs 5 km using the FRONTIERS method). Mesoscale features may have a lifetime of the order of a few hours. Thus the features may change in the time it takes to make the standard forecast, as well as often slipping through the course grid unnoticed. With the FRONTIERS system, in addition to making frequent and rapid forecasts, one can study mesoscale features in great detail. (Wayne V. Burt)

OCEANOGRAPHY

MARINE RESEARCH IN GREEK GOVERNMENT LABORATORIES

Institute of Oceanography and Fisheries Research

The Institute of Oceanography and Fisheries Research is located on the coast of Greece at Ellinikos, about 10 km southeast of the center of Athens. Prof. C. Vambakas, who also teaches zoology at the University of Athens, is the director general of the Institute. Vambakas is a tall, charming "geopolitician" who is quite successful at promoting his establishment.

The Institute has a staff of 70 which has been housed in a new, two-story building since 1977. At the time of my visit in March 1980, they were awaiting the delivery of a new, 40-m-long, well-equipped research ship. The vessel will carry 15 scientists and a crew of 12.

In my conversations with the staff, I learned that a new law that will broaden the charter of the Institute to cover most of the aspects of marine science and will create a number of new programs and positions was well on the way to passage in the Greek Parliament. The present three departments will be increased to ten: Administration, Finance, Nautical Services, Technical Services (Engineering), Fisheries Biology, Physical Oceanography, Biological Oceanography, Marine Geology, Aquaculture, and Inland Waters.

From time to time consultants are brought to the Institute to help with various programs. While I was there I saw Dr. R. Chester, a chemical oceanographer from the University of Liverpool, Department of Oceanography (*ESN* 33-10: 425). Chester was spending several months working with and advising the marine chemistry group.

Three or four stdents from the University of Athens are usually in residence at the Institute doing research for their MS degree; when I was there, five students were working on their PhD theses. Although the Institute does not conduct any in-house training courses, it maintains a technical advice service similar to the services offered by the sea grant college system in the US.

The Institute comes under the Ministry of Coordination which seems to be a catch-all activity that funds and supervises a number of small programs. About 90% of the salaries, 10% of the equipment, and 50% of other expenses are paid by the Public Investment Service, a branch of the Ministry of Coordination. A small amount of funding comes from private companies that need oceanographic data for engineering purposes; and the remainder comes from other government ministries. The Ministry of Public Works, for example, pays for sewage outfall studies, while the Ministry of Agriculture funds fisheries and aquaculture research.

The Physical Oceanography Group is making a systematic survey of bays and gulfs in Greece. These surveys include the distribution of temperature and salinity, tides, current meter studies, and in some cases the distribution of nutrients. In each study the marine geologists take closely spaced bottom samples.

Studies of Thermaikos Gulf, the large gulf located in northeastern Greece near Thessalonike, and of Pagassitikosk Gulf on the east coast NE of Athens have been completed. The group is now preparing to study the coastal area of Patraikos Gulf west of Athens that is due for the introduction of many heavy industries, as well as the smaller Evoikos Gulf due east of Athens.

This year, from 1 May until the end of September, the physical oceanographers will survey Saronikos Gulf once each seven days as part of a study of the upwelling that occurs there. The Institute and the city of Piraeus (the port of Athens) are located on this gulf. They have 16 sampling stations in four lines running to the shore. Each line has 1 current meter station with an Aanderaa meter at a depth of 15 m and another near the sea bottom. Temperature and salinity are measured continuously near the shore at the end of each line of stations; and three weather stations record windspeed and direction.

The marine geologists take 1-2 m-long gravity cores on 1- or 2-mile grids in each gulf (Patraikos and Saronikos). These core samples are studied for size distribution of the sediments, organic content, clay minerals (x-ray), and heavy metals. Seismic sub-bottom profiles at 3.5 to 7 kHz are also routinely carried out. Nanson bottle seawater samples are filtered to determine the amount and kind of material that is in suspension.

Mr. George Chronis of the marine geology group has done cooperative reearch on Greek deltas with Prof. J.C. Kraft of the University of Delaware as well as a study of marine archeology with Prof. G.R. Rapp of the University of Minnesota, Duluth.

Aside from the study of the distribution of nutrients in Greek waters, the chemistry group has three ongoing research projects and a new project about to start. In the projects already underway, they are determining the products of decomposition of organic matter with an autonalyzer; they are investigating the distribution of trace elements in marine organisms and sediments using atomic absorption (zinc, copper, iron, manganese, and cadmium); and they are using gas chromotography to identify chlorinated hydrocarbons from pesticides. For the new project, they are ready to begin sampling for evidence of pollutants originating from petroleum using a fluorescent spectrophotometer to identify materials.

The Greek Hydrographic Office

Mr. B. Roufozalis, a chemical oceanographer, is the head of the oceanography section of the Greek Navy Hydrographic Office in Athens. The section has 15 civilian employees, all with university degrees. This includes three with PhD degrees in oceanography. During the past five years they have increased their laboratory facilities and inventory of instruments. While their main thrust is in the military applications of oceanography, they are expanding more and more into programs that are of major economic interest to other agencies of the Greek government, such as pollution studies near sewer outfalls from major cities. When Dr. M.J. Scoullos (*ESN* 33-10:425) was carrying out his momumental study of Elevsis Bay near Athens, the Navy made most of the salinity measurements for him.

Because the Navy has been, up to now, the only organization in Greece with ships available for oceanographic research, it has done and is still doing a number of things outside its main scope that other organizations cannot do. Scientists from other organizations are invited on all navy oceanographic cruises and are allowed to use navy-owned instruments. Persons from the Institute of Oceanography and Fisheries Research, the Ministry of Coordination, the Ministry of Public Health, and the University of Athens make use of Navy research ships.

All Navy research is restricted to Greek waters in the Ionian and Aegean seas, bays, gulf, and straits with particular emphasis on the Aegean Sea.

The Greek Navy is fortunate in having two oceanographic ships. The larger ship, *R.V. NAFLILOS*, which is 70 m long, was designed and built especially for oceanographic research. It was launched in 1975. It has an all-civilian crew, mostly from the Greek Merchant Marine. It carries two 9-m-long launches for inshore work. The launches as well as the ship have automatic computer-controlled continuous Decca navigating systems. They also have precise echo-sounding systems duplicating those on the larger ship. A smaller ship, the 30 m *R.V. MALIOPOULOS*, is used in gulfs and straits.

Roufozalis schedules three major seasonal cruises each year. The research is mainly in physical oceanography including studies of temperature, salinity, dissolved oxygen, pH, and sound velocity. In addition, bottom samples are taken and side-scanning sonar and sub-bottom profiling systems are used to study the sea floor. Although the Navy does very little biological research, it owns the necessary biological sampling gear for use by biologists who come from other organizations.

The Greek Navy operates 70 meteorological stations in ports and harbors and on lighthouses. Data from these stations are used by the Navy for operational purposes. These data are also sent to the national weather service. In addition, the Navy maintains 34 tide stations and 54 stations that record and report water temperatures every 4 hours. I was shown a very impressive array of books and charts summarizing the above data showing means, extremes, annual variations, and other statistical parameters.

Plans are underway to double the size of the Navy's oceanographic division in the next two years, largely with funds from the Ministry of Public Works, to do studies related to sewer outfalls from major Greek cities.

Radio Chemistry at the Democritos Nuclear Research Center

The Radio Analytical Chemistry Laboratory of the Democritos Nuclear Research Center in Athens carries out a program in chemical oceanography and marine biology. It was started in 1963 by Dr. A. Grimanis, who began studying trace elements including bromine, arsenic, zinc, and copper in Greek lakes. Now his group monitors heavy metals and other trace elements in marine sediments, sea water, and marine organisms using neutron activation techniques to determine the concentration of about a dozen elements. This laboratory also monitors some pesticides in the marine environment.

The laboratory appears to be a "gung-ho" place. I met a number of students from the University of Athens who were carrying out thesis research projects. Each one wanted to tell me about his research. I also met two of Grimanis' stars, Dr. T. Becacos-Kontos and R.L. Ignatiadis. They are relatively young ladies with impressive lists of publications. Both work in marine chemistry and marine biology.

It was a pleasant surprise to view the quality and quantity of Marine Research that was under way in Greek government laboratories after reading the gloomy forecasts that were made in previous articles in *ESN*. (Wayne V. Burt)

MARINE SCIENCE AT THE UNIVERSITY OF ATHENS

The University of Athens has active programs in marine science in the departments of chemistry, geology, zoology, and botany, and an interdepartmental program leading to the MS in marine science. This article discusses the activities in each of the programs as observed by the author during a recent visit.

MS Program: The interdepartmental MS program in marine science at the University of Athens is similar to that in the US. It normally takes 2 1/2 years. Students may enter with bachelor's degrees in biology, chemistry, geology, or physics. During the first year they take courses in biological, chemical, geological, and physical oceanography unless they have taken one or more of the courses during their final undergraduate year. All students also must take a course in advanced marine chemistry, probably because of the intense interest in marine pollution. Other advanced courses in oceanography are offered as electives. During the final year each student is required to do a thesis based on the results of original research. About 25 students were enrolled in this program at the time I visited the university. I was told that a significant proportion of these, including most of the best students, were women.

Students may also elect to work towards a PhD by writing a doctoral dissertation which takes about 3 years and is passed on by all of the professors (department chairmen) in the school of physical and mathematical sciences.

Chemistry: My host in Athens was Dr. M. Scoullos from the Department of Inorganic Chemistry. Scoullos is a very active, energetic young man with a tremendous record of achievement for a man of his age. He has a PhD in chemistry from the University of Athens and a second PhD, in oceanography, which he earned under Prof. J.P. Riley at the University of Liverpool (*ESN* 33-10:425). Scoullos has recently published two books in Greek. One is a textbook in chemical oceanography and the other a 325-page book on the chemistry of Elevsis Bay (see ONRL R-1-79). He supervises the thesis research programs of six graduate students and carries an enormous teaching load of 28 contact hours. Besides his personal research effort, he finds time to be active in the politics of developing marine science programs in Greece. On the side, Scoullos is a well-versed scholar of archeology and an avid collector of ancient Greek and Roman coins. He comes from a long line of professional men and politicians and traces his ancestry back almost a thousand years to a French knight who, on his return from an early Crusade to the Holy Land, stopped and spent the rest of his life on one of the Greek islands.

Scoullos' present program includes research into the partitioning of dissolved metals by sediments, humic acid, and other organic complexes with metals; continuing the study of Elevsis Bay with emphasis on pollution of sediments; and a new project to study the Gulf of Patras, in western Greece, which is surrounded by a newly established industrial area. The last-named will be a base-line study to determine nutrient levels, dissolved metal content, and other chemical properties prior to the construction of the large heavy industry complex. In addition to the above he is engaged in a joint project with Dr. R. Chester of the University of Liverpool in which they are studying fossil nodules in old beach deposits on the island of Corfu.

Geology: In the Department of Geology, Dr. A. Zamani teaches descriptive physical oceanography and marine geology in the interdepartmental program leading to the MS in marine science; she also teaches geology. Zamani also heads a group of four who are working in marine geology. The group's current research includes studies of the delta of the Sperkhios River in central Greece northwest of Athens, Pleistocene marine deposits on the northwest coast of Greece, bottom sediments of the western portion of the Gulf of Corinth, and evidence of tectonic movements on the southern coast of Peloponnesus.

Zoology: The Zoology Department has three professors, two of whom are marine biologists and four others with PhDs, out of a total staff of 25. Prof. V. Kiortsis, the head of the department, is a marine biologist. His main interests are in embriology and marine ecology as related to marine pollution. (For details on the development of his marine program and early research see two earlier reports on marine science in Greece

[ONRL R-30-63, ONRL R-9-73].) Kiortsis appears to be the leader in the development of marine science programs and projects in Greece. He is president of the board of the governmental Institute of Oceanography and Fisheries Research.

At the present time there are no graduate students in residence in the Zoology Department; this is primarily due to lack of space for them to carry out their research. It is a situation that will be corrected shortly when the department moves into large, spacious quarters that are located at a new campus just north of Athens. About 50 of the 350 undergraduates in the department specialize in an optional marine biology major and spend most of their senior year working on the marine biology program.

Despite the formidable language barrier (they must know both English and Greek) some foreign students are studying in the Zoology Department.

Kiortsis indicated that the number of marine biology PhD candidates will be somewhat limited because of the limited job market for them. However, Kiortsis is lobbying to require some government agencies interested in environmental problems or fisheries to establish positions for marine biologists. At present the environmental agency staff is composed mostly of engineers, while inspectors dominate the fisheries agency. By law, the fisheries agency is increasing its present staff from 15 to 70. Kiortsis is confident that some members of the enlarged staff will be marine biologists.

Kiortsis collaborates with Dr. Maris Moraitou-Apostolopoulou, a reader (equivalent of associate professor). She is a very charming and disarming young lady in her early thirties. Her pleasant personality and chic attire tend to disguise a mind of prodigious determination and discipline. When I asked her for copies of a few of her recent publications, she handed me 42! She received her PhD just 5 years ago but despite having a growing family she has published, or has in press, 30 papers in the last 4 years. Most of these she wrote alone, and only one has more than two authors.

She began her research by identifying and cataloguing copepods and cladocera in various places around Greece. Most of her recent work has been on three species of copepods, some mysids, and the effects of pollutants on whole planktonic populations.

She conducts field studies to determine the physiological effects of pollutants on planktonic organisms. Her favorite laboratory animal is the copepod *Acartia clausi* which she exposes to various concentrations of heavy metals (copper, cadmium, chromium, and zinc) to determine their effects. Her studies also show lower thermal tolerance when they are exposed to low concentrations of heavy metals. Her laboratory consists of three large walk-in constant-temperature rooms.

Moraitou-Apostolopoulou carries on a very active collaboration with workers at the Arago Laboratory at Banyuls sur Mer, France (*ESN* 34-4:187), and has visited there many times.

I was impressed by the breadth, depth, and sheer volume of her research. She would be an asset to any laboratory.

Botany: Prof. K. Anagnostidis of the Department of Botany and his pleasant lady collaborator, Dr. Ithina Economou-Amilli, work together on joint research projects. Much of their research is on sulfur bacteria that have the ability to reduce sulfur compounds. They have completed a monumental monograph, which is soon to be translated and published in English, on the sulfur bacteria in the fresh and salt waters of Greece.

Three PhD candidates are doing research in the Botany Laboratory. The laboratory itself is neat and spacious. I was assured that it contained all the very latest equipment including an electron microscope built by the Japan Electron Optics Laboratory Company (JEOL). While I was viewing the scope, Economou-Amilli started with a fairly large sample which was viewed on a scope at low magnification. Through a shadow technique one obtains a three-dimensional effect. Selecting one organism to study, she zeroed in on this organism and blew up the picture on the display scope until the organism filled the scope. She repeated this process until the scope showed a small fraction of a single organ of the animal under examination at a magnification of 2×10^5. Although nothing shows on the scope, the magnification can be increased to 10^6 and a negative made. The entire procedure, from original scanning to making the negative, can be done in a very short time.

The research of Anagnostidis and Economou-Amilli shows that each polluted area has its own assemblage of diatoms which is particular to the mix of pollutants present. They started with fresh water species but now work with salt water species. Some species can pass from fresh water to salt water and survive. They are studying the mechanisms that allow this adaptation in such simple organisms. They also specialize in systematics and taxonomy of blue-green algae.

The Department studies red tides which used to be rare in Greek waters. However, they are now beginning to show up in heavily polluted bays.

In summary, I was pleased with the quality, breadth, and depth of the marine research programs under way in the University of Athens.

The program of Professor D. Lalas, head of the Department of Meteorology, will be discussed in a future issue of this publication. His programs contain some marine research and he teaches dynamic oceanography to MS candidates in marine science. (Wayne V. Burt)

OPERATIONS RESEARCH

OPERATIONS RESEARCH AT A COUPLE OF YUGOSLAV UNIVERSITIES

The overwhelming difference between Yugoslavia and the other Communist countries in Europe is freedom. This is apparent in the availability of all sorts of foreign goods, including publications; in the stylishness and good design of the clothing available in the stores; in the familiarity with foreign countries displayed by all the people one talks to; and in the general attitudes, which are more like those of Western Europe than those of Eastern Europe. Nonetheless this is a Communist country. All university students take several required courses in ideology and in Marxism; Yugoslavia's constitution decrees (with some exceptions) that one may not hire another for profit; the country itself is decentralized, as is every organization within it; every organization has a self-management structure, which is supposed to take care of planning, while a parallel administrative structure takes care of implementation.

The fact that such structures work well in most cases is somewhat suprising to Americans. The fact that the country works at all is rather remarkable. It consists of 6 republics plus two autonomous regions, many of which have a long history of independence, or at least separate existence. Furthermore, the country has 3 quite different languages (Serbo-Croatian, Slovenian, and Macedonian) written in two different alphabets (ours and the Cyrillic). There are three different religions (Roman Catholic, Eastern Orthodox, and Moslem), and great economic strains between the affluent North and the impoverished South.

There are some 20 universities in Yugoslavia, and operations research (OR) is taught in all of them, often in more than one faculty. I visited the Faculty of Organizational Sciences at the Univ. of Belgrade (Belgrade is the largest city in the country and the capital of the Republic of Serbia); and the Faculties of Economics and of Mechanical Engineering at the Univ. of Ljubljana (Ljubljana is the third largest city in Yugoslavia and the capital of the Republic of Slovenia).

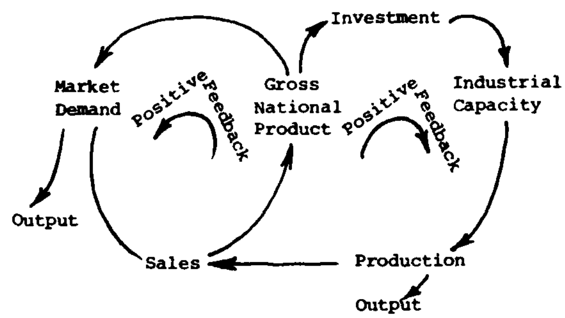
Students enter university at the age of 19 or 20. If they successfully complete the first 2 years, they have the right to the title of "Engineer" (or "Economist", or whatever). If they complete 4 years they receive a diploma (equivalent to a BS) and can use the title "Diploma Engineer" or whatever. If they complete 6 years they obtain the degree of magister (equivalent to MS). Large numbers of students start university, but there is tremendous attrition. For example, in the Faculty of Mechanical Engineering at the Univ. of Ljubljana, I was told that there are about 1,200 new freshmen each year, of whom about 2/3 are full-time and 1/3 part-time students, plus several hundred additional freshmen, who having started in previous years, failed, and were now starting over. Of these, 400 to 500 start the second year, only about 150 receive the diploma, and only about 20 the magister. A few doctorates are awarded each year.

Both of the universities that I visited are very large, with faculties scattered all over the city, frequently many kilometers apart. This separation is feasible because a student in one faculty rarely takes courses in another. The Univ. of Belgrade is the largest in the country, with some 30 faculties and a total of nearly 100,000 students.

The students graduating from high school in Yugoslavia are a bit older and generally better educated than high school graduates in the US. For example, they invariably have had a calculus course and courses in the sciences. At this point, their general education is completed. In the university they generally receive only professional education in the faculty in which they are enrolled.

The Faculty of Organizational Sciences at the Univ. of Belgrade is perhaps most nearly equivilent to a management school in the US. Prof. Jovan Petrić took a bachelor's degree in mathematics, another in electrical engineering, and then a PhD in mechanical engineering before deciding that his principal interest was in OR. He is in charge of postgraduate instruction in OR, and has written some of the most successful books on OR in Yugoslavia. Most of the postgraduate students have their undergraduate degrees in fields other than organizational science. However, this program is not large, only about 35 MS and 14 PhD degrees having been granted since the program was started a few years ago. The MS is based largely on classroom work, although a thesis is required. No class work at all is required for the doctorate. The thesis topics tend to be interdisciplinary; for example, a computer application to some real case which has not been studied previously. The kind of thesis work which is common in the US for the doctoral degree in OR involving the development of new mathematics could not lead to a doctorate in this faculty, although it could in other faculties of the university.

Prof. Miloš Rajkov took a master's degree in mathematical statistics and a doctorate in organizational sciences, writing a thesis on system dynamics after having spent a year working with Jay Forrester at MIT. He now teaches courses in system dynamics, and showed me the system dynamics laboratory where students study systems through simulation on both analog (EAI) and digital (DEC) computers, as well as by analytic solution of the equations representing the mathematical models of systems. For example, on the analog computer they simulate various different policies in stock management which demonstrate systems stability and instability. On the digital computer they use a modification, developed by Rajkov, of Forrester's dynamo language, which Rajkov feels makes easier interactive work with the computer possible. He showed me a digital simulation of a meat-production system, with positive feedback loops as indicated in the diagram, plus a negative feedback loop between market demand, production, and investment. The students can change such parameters as the investment level or the delays between the start of building capacity and the realization of production; they can even change the sensitivity of the system. And they discover the effects of such things on stability. While these are standard system-dynamics-type models, they certainly have very general application. Rajkov also showed me some computerized models, developed from Harvard Business School cases, on which the students work, including a general integrated model of a production firm with material flow, cash flow, capacity flow, profit, and the like. There are numerous terminals on the DEC computer, and all students get practice in hands-on simulation.



Another OR instructor in this faculty is Milutin Čupić, who recently spent a year at UCLA under Morley English, and who will shortly receive a PhD in OR from the Mechanical Engineering Faculty at the Univ. of Belgrade. His thesis is on job-shop scheduling problems and branch-and-bound methods of solving them.

The curriculum for the BS degree in this faculty includes no electives at all, although in the final year a student may select one of four sets of required courses. As stated above, there is no general education; the amount of professional education is remarkable. It includes a great deal of mathematics, foreign languages (English and Russian are usually chosen, although French and German are available as alternatives), economics, computers and information systems, time and motion studies, psychology, sociology, marketing, transportation, finance, system theory (meaning system dynamics), decision making, business law, research and development, design of the organization, etc., etc. Many of these courses are especially thorough; e.g., in the computer course they learn several different computer languages. The four streams available in the fourth year are production management, personnel management, business management, and cybernetics and the use of computerized information systems.

The University of Ljubljana, which officially started in 1919 (they recently celebrated their 60th anniversary), has, in fact, had some schools, such as the divinity school, in continuous operation since the year 1700. There are almost 30 faculties. The Faculty of Economics is located in a research park about 3 km from the center of the city; a few other faculties of the university are in the same park, but most of them are elsewhere. The United Nations Research Organization for Underdeveloped Countries, an institute for economic research, an institute for testing materials, and a number of industrial research organizations are also situated in the park. The buildings of the faculty, which have only recently been completed, represent some of the most beautiful and functional facilities that I have seen at any university anywhere in the world.

The dean of this faculty is Ivo Fabinc, whose doctorate in international economics was obtained at this university. His appointment as dean is for a period of two years and can be renewed for an additional two years, but then he must revert to being a professor again. His research areas are foreign trade and foreign economic relations. Fabinc assured me that he was most anxious to return to teaching and research, and while I have heard this frequently from deans, I really believe it in this case, because here, apparently, the dean is not relieved of his teaching duties while he carries on these additional duties of administration. Administration apparently never becomes a way of life for such people.

There are four departments of this faculty, OR being taught in the Department of Mathematics, Informatics and Statistics, headed by Viljem Rupnik. Rupnik is a remarkable man who received PhDs in mathematics and in economics many years ago from the University of Ljubljana and now is getting a third PhD in systems theory from the Faculty of Technology at the University of Zagreb. He spent a year in the United States, working half of that time with R. Ackoff at the Univ. of Pennsylvania and the other half with R. Bellman at UCLA. For a couple of years, he was dean of the faculty.

Rupnik told me that through teaching alone he receives some $900 per month in salary, but that he more than doubles his salary through research and consulting (all of which is funneled through the university), so he takes home some $25,000 to $30,000 per year after taxes. He adds that he could make more if he wanted to, if he were not working on his third PhD. This is an extraordinary level of affluence in a country where such things as medicine and education are free and one does not have to save money for one's old age. He has two cars and three houses, and he travels extensively out of the country. Not all Yugoslav professors do this well, and, in fact, some parts of Yugoslavia are very poor (large numbers of Yugoslav workers do many of the menial tasks in the countries of Northern Europe), but Rupnik is clearly an unusual person.

His department is divided into three basic groups; the first has 5 people, with 2 more to be hired, in the area of informatics. They are creating a management information system for ISKRA, the large electrical equipment company of Yugoslavia. They are also doing research in accounting, and feel that by appropriate computerization, double-entry bookkeeping can be eliminated—not just the paper records, but the actual idea of the accounts; since debits are the columns of a matrix and credits are the rows, each transaction requires only a single entry.

A second group is mathematical and has 7 people with 2 still to be hired. Rupnik recruits for this group only mathematicians who are well trained in mathematics and who are willing to study economics. A major effort in the group is a large project on national economic planning, which is also being worked on by other departments of this faculty.

The third group in the department, statistics, has 6 people, with 2 yet to be hired. It consists of both theoretical statistics staffed by mathematicians and applied statistics staffed by economists and econometricians.

OR appears in all three of the above groups, according to Rupnik, as "a kind of intersection between them." As regards the educational program, the student may choose from 11 specializations during the first 2 years and 8 in the second 2 years, although once a specialization has been chosen there are no elective courses other than language (in addition to the local language, Slovenian, and the national language, Serbo-Croatian, the student must select 2 from among English, Russian, German, and French. The specializations include such diverse subjects as domestic trade, international trade, tourism, banking, insurance, transportation, information technology, statistics, and accounting. A student planning to take the MS in OR would normally major in statistics in both biennia. There are five different MS areas; OR is the most popular of these, and 6 to 10 master's degrees are given per year in this field.

Rupnik's research is on what he calls mathematical systems theory, although he includes in this phrase such things as topology and functional analysis. His third doctoral thesis is on modeling the technological process of a chemical factory. This is a systems process which can be imbedded in a larger economic process. He is also looking at what he calls "nonterminal control theory." Unlike the standard problem in optimal control, which attempts to find a trajectory to maximize some functional at the end of a given time period, he is trying to obtain an optimum in some sense at each point along the trajectory. This is related to what he calls a continuous dynamic linear programming problem, essentially a compromise between long-term and short-term optimization. Rupnik has a number of graduate students (MS and PhD) working on this problem, and hopes to go beyond the continuous dynamic linear programming to continuous dynamic quadratic programming, and perhaps to more general forms of continuous dynamic nonlinear programming. As an example, he told me of a sponsored project of reaching certain goals for Yugoslavia at the year 2000, subject to numerous disturbances and with a wide variety of constraints on the situation in Yugoslavia in the interim.

Rupnik is also interested in a wide variety of bottleneck problems and in n-dimensional assignment problems (he has very successful algorithms where $n=3$ or $n=4$). These are used, for example, in the control theory for a firm involving portfolio concepts. Thus, the first dimension might be types of capital, the second types of production, the third types of workers, and so on. At time $t=0$ it is necessary to solve this n-dimensional assignment problem; and then as t increases beyond 0 to solve it again and again. Another group of his students is working on combining continuous dynamic linear programming with the Wolfe problem of generalized linear programming.

Four of the faculties of the University of Ljubljana are devoted to engineering, and OR is taught in two of these, namely, in electrical engineering and mechanical engineering. In mechanical engineering I talked to Prof. Janez Dekleva, who took his doctorate in applied physics at this university, then spent 5 years at Harvard in the late 1950s, working on the Cambridge Electronic Accelerator. He also spent a sabbatical year at Harvard in the late-1960s. His doctoral thesis involved theoretical and experimental radio-frequency mass spectrometry, and at that time he became interested in optimization, which brought him eventually to OR. He was at one time the director of the Institute of Transportation in Ljubljana, a large organization with over 100 people. For the past many years he has been teaching OR in the ME faculty. Dekleva's research is mostly in production systems, but he has also published in the areas of forecasting and scheduling. He and his group (consisting of one assistant professor, 3 assistants, and several candidates for MS and PhD degrees) have recently developed "non-delay scheduling" algorithms which work very well indeed (the conventional wisdom had been that such algorithms could not be useful). They have solved an applied problem, determining the optimal size of a ship in a tanker fleet based on the demands of the Yugoslav refineries. In the energy field they have developed descriptions of the kinds of data bases needed for decisions at all levels in energy policy. They also have done some logistics work, specifically, trying to optimize the transportation system for petroleum products in Slovenia, based on the existing refineries, one of which is in Slovenia, while the remainder are in other Yugoslav republics but near Slovenian borders.

Dekleva's principal current research interests are in what he calls GT (for Group Technological) cells. At one extreme in production systems are the functional types of production characteristic of job shops, where each machine has a specific function and work travels from one machine to another. Opposed to this in large-scale production systems are "line-flow" systems, where each machine is dedicated. Between these is something called group technology, where one isolates jobs which are similar and use the same technological processes, and then assigns each family of jobs to a particular group of machines, these groups being called "cells." Most production experts in the US and UK say that cell systems are particularly efficient, but Dekleva is quite pessimistic about this. In job-shop systems one has the mathematical equivalent of a queuing system with multiple parallel queues, in which the waiting time is necessarily less than that of the single-queue system which is characteristic of cells; or to put the same assertion equivalently, the foreman in a job-shop system can always juggle things to avoid unnecessarily long waiting times, whereas in a GT cell, with only one type of machine, there is no such flexibility. In any case, Dekleva feels that within a year he will have proof one way or the other about the efficiency of GT cells. These results will be published in English (the international language), since publication in Serbo-Croatian (the national language) has little professional value.

Education in OR at this mechanical engineering faculty is suprisingly similar to that at the economics faculty. In the BS degree the first five semesters are common for all students, consisting entirely of required courses. During the last 3 semesters the student is permitted to choose one of twelve fields of specialization. One of these is called industrial engineering, and is quite popular, getting 20-25 students each year. While there is considerable OR in this course, it is not so much a specialty in OR as it is in classical industrial engineering; it includes courses in marketing, economics, and other subjects not usual in an OR curriculum. Each student is required to do a thesis during his last 3 months, after completing all his examinations. Many of these theses are based on practical industrial problems, and the student then goes on to take a permanent job with the firm whose problem he has worked on. In any case, graduates in this program rarely have any difficulty in finding employment—which may be no trivial problem for other Yugoslav graduates.

Dekleva feels very strongly that while economists are very powerful in Yugoslavia at this time, they do not make as good managers as do engineers, and he cites articles in the *Harvard Business Review* stating that the best manager is one who has first been trained as an engineer and then has gone to a management school. At one time engineers had no training in economics, which was a great weakness; but now all the students in Dekleva's school receive such training.

Operations research in Yugoslavia operates under a number of handicaps. Decentralization makes it very difficult to apply optimizations, which must necessarily be specified at a central level and may be resisted at lower levels of authority. Any OR plans developed by the administration must be approved by the self-management structure. Furthermore, it is not clear that the personality of these people is amenable to this kind of efficiency and optimization. As an example, in my hotel in Belgrade there was some crossover between the hot-water and cold-water systems. I suggested to the man on the desk that in the long run it might save money to repair this rather than flush the toilets with hot water; and he indicated that he agreed with this, and had been so telling the management for a number of years! Nonetheless, Yugoslavia is determined to increase the efficiency and productivity of its organizations, and OR will doubtless continue to be taught at all the universities and applied in most of the major organizations. Because of the way in which research is financed in Yugoslovia, little may be expected in the way of development of new OR science; but with that country's excellent contacts with both West and East, Yugoslav OR workers may be expected to stay abreast with the best of what is being done elsewhere and to continue to do competent applied OR work. (Robert E. Machol).

PHYSICS

A RARE (EARTH) MEETING

Through the intervention of Prof. B.R. Coles I was invited to the Annual Rare-Earth Meeting held at the University of Birmingham on 16-18 April 1980. There the host and organizer, Dr. D.W. Jones, explained some of the history of this unique event to me.

In the mid-50s a group of UK solid-state scientists banded together in order to obtain sufficient funds to purchase rare-earth specimens for research. A meeting of the group was organized at Oxford University in 1964 by Dr. D.M.S. Bagguley for the purpose of discussing progress and results of the rare-earth research. Subsequently, the meeting became an annual event and continued at Oxford under Bagguley's sponsorship until 1973, at which time the meeting site was transferred to the University of Birmingham. The meeting is funded by a grant from the Scientific Research Council of the UK and is free to all invitees from the UK. A nominal fee is charged to foreigners who participate. Attendance is by invitation and is limited to research workers using the rare-earths, with the exception of an occasional guest. I was the token American. Two other foreigners were also in attendance.

Jones is the director of the Centre for Materials Science at the University of Birmingham and is responsible for the purification of rare-earth metals which takes place there. Many of the attendees obtained their samples from the Centre. Since the production of rare earths is limited, Mr. K. Davies of Rare Earth Products Ltd. was an important attendee. On the evening before the presentation of the papers, he participated in a special meeting given to discussion of the availibility of rare earths. While these business activities of the supply industry form an important concomitant of the annual meeting, the main purpose of the meeting is to present research results on rare earths. The papers presented ranged from progress reports to final results. Attendees varied in academic rank from professors through graduate students and in fact, the number of graduate students invited each year varies so as to keep the total number of attendees constant at approximately 80. In addition to presenting results achieved in rare earth research, the meeting serves as a useful forum for these young scientists. It should be emphasized that this is a workers' meeting, and its product, which is not formally published or cited, is a simple report about 12 pages long containing an abstract of every paper and a list of participants.

Those elements commonly called the rare earths are misnamed for at least two reasons: first, the term, "earth", applies to a metallic oxide, and secondly, they are not particularly rare. (Cerium is thought to be more abundant than tin in the earth's crust.) Current terminology is to label the members of Group IIIb of the periodic table of the elements, other than the actinides, as the rare-earth elements or metals. They include scandium, yttrium, and the elements 57 through 71, making a total of seventeen. Since their external electron configurations are similar, so are their chemical properties, which makes them difficult to separate.

The lanthanide series 57-71 are usually consigned to one box in the periodic table. Except for lanthanum, they are characterized by incomplete 4f electron shells. In the solid, the 5d and 6s valence electrons form the conduction electrons while the 4f electrons lie well within the ion core and are relatively well shielded by the 5s and 5p electrons.

Since this was a rare-earth meeting, magnetism was predominant, appearing in almost every paper. Prof. A.R. Mackintosh of the University of Copenhagen began by presenting a review of the information which has been obtained on the magnetic excitations in rare-earth systems by inelastic-neutron scatterings. This paper was a finished research product, essentially the same as "Magnetic Excitations in Rare Earth Systems," (*J. of Magnetism and Magnetic Materials*, 15-18, 326 [1980]). Mackintosh noted that the 4f electrons experience their surroundings through several different mechanisms: the indirect exchange, the crystal field, and magnetoelastic interactions. In indirect exchange, two localized spins interact through the medium of a conduction electron. A conduction electron passing near a localized spin experiences a force and thus carries information on the orientation of the localized spin which is transmitted to other ions by direct exchange.

Crystal-field effects can be important because the magnetic 4f electrons have highly anisotropic charge clouds. Therefore, in the inhomogeneous electric field of the neighboring ions the magnetic 4f electrons are subjected to a torque which tends to align them along a particular crystallographic direction. When the 4f charge clouds rotate, the lattice may spontaneously distort due to the magnetoelastic coupling. This effect is of particular importance in hexagonal systems in which the moments lie in the base plane. Terbium and praseodymium are good examples in which the distortion in the base plane changes the symmetry from hexagonal to orthorhombic. The excited states of the system may be calculated by starting with a molecular-field approximation of the ion-ion interactions. Excitations of the individual ions are found and then coupled by the exchange to form the collective excitations of the system.

Mackintosh continued with examples in which one energy term was dominant: exchange only—ferromagnetic gadolinium; exchange dominated—planar ferromagnetic terbium; crystal field dominated—paramagnetic praseodymium; and instances of only the crystal field such as rare earths in nonmagnetic hosts, thulium in yttrium or europium in magnesium. He concluded by noting that the shape of the excitation spectrum in the rare earths has been sketched out, but that there is considerable work remaining. The anisotropy of the exchange in gadolinium and the magnon dispersion relations for europium in an applied field are two problems requiring magnetic measurements. Growth of a face-centered cubic (fcc) cerium single crystal would allow the performance of neutron experiments which could test various theories of a mixed-valence system. In the heavy rare earths (those to the right in the lanthanide series) higher-resolution neutron-scattering experiments would clarify the anisotropy of exchange in these exchange-dominated elements.

Discussion of crystal-field-dominated systems was continued by Dr. K.A. McEwan of the University of Salford, UK, who said that in praseodymium, exchange between ionic spins is too small to produce ordering, but that coupling between the electronic and nuclear spins helps to produce order in a bootstrap-type operation. He pointed out that magnetic ordering in praseodymium at temperatures below 1 K has been observed by neutron scattering, and that this ordering of the moments in the base plane is driven by the enhancement of the exchange via the hyperfine interaction. McEwan also reported upon the inducement of magnetic ordering by application of stress. He studied ordering along [1010] by the application of the uniaxial stress along [1210] up to stresses of 120 MPa (1.20 Kbar). The spatial period of the ordering may be commensurable or incommensurable with the lattice structure. In the incommensurable type of ordering the excitations originate from both amplitude and phase fluctuations. McEwan claims to have evidence for the first observation of phase excitations in praseodymium at 120 MPa.

Reports on the results of neutron experiments were continued by Dr. D.G. Lord, also of the University of Salford, who presented data from elastic neutron scattering studies of the stoichemetric compounds HoCu, $HoCu_2$, and $HoCu_5$. Both body-centered cubic (bcc) HoCu and orthorhombic $HoCu_2$ were found to order antiferromagnetically at $T_N = 27$ K and $T_N = 11.4$ K respectively. A probable ferrimagnetic structure was postulated for fcc $HoCu_5$ in the ordered state below the transition temperature of $T_N = 10.5$ K. The results for HoCu and $HoCu_2$ are in agreement with previous experiments on the magnetoresistance of these compounds.

Results of other solid-state measurements were also reported: ESR in $GdAl_2$ and of Gd in LaTh respectively by Dr. R.W. Teale (Univ. of Sheffield) and Mr. C. Larcia (Imperial College); saturation magnetization by Dr. A.G. Clegg (Sunderland Polytechnic), magnetostriction in GbTb by Dr. W.D. Corner and Mr. A.A. Joraide, and in Tb by Mr. G.F. Clark and Dr. B.K. Tanner, all of the University of Durham; heat capacity of Pr below 20 mK by Mr. M. Eriksen; and heat capacity of Nd below 20 K and 4.5 T by Dr. E.M. Forgan and Dr. C.M. Muirhead, both of the University of Birmingham.

In addition to these presentations, third order effects were also discussed in several papers. Dr. D. Melville and Mr. W.I. Kahn of the University of Southampton presented "Third Order Anisotropy Constants of Rare Earth Compounds." Melville reported on work in conjunction with collaborators at the University of Parma, Italy. He noted that the equilibrium magnetization (M) for a uniaxial material in the external field B_0, applied along a symmetry direction, can be expressed as $B_0/M = p + qM^2 + rM^4$ where p,q, and r are functions of the magnetic anisotropy constants k_1, k_2, k_3. A plot of B_0/M against M^2 has an intercept, p, and a straight line portion with slope, q. The curve will bend up or down depending upon the sign of r. Applying this technique to data on the alloy $Nd_{0.35}Sm_{0.65}Co_5$ enabled the temperature dependence of k_1, k_2, and k_3 to be determined. The results showed that below 80 K the ratios k_2/k_1 and k_3/k_1 become very large and indicate the occurrence of rotations of the magnetization below 40 K. They believe it is thus possible to account for the sharp magnetization transitions observed experimentally at 40 and 40.2 K.

Third-order elastic constants of rare earth metals were discussed by Dr. S.B. Palmer of the University of Hull, UK. The ordinary (second-order) constants are the second derivatives of the internal energy with respect to the appropriate strain and describe the elastic behavior of a material. The third-order derivatives are a result of asymmetry of curvature of the internal energy (anharmonicity) and can be determined by studying the hydrostatic and uniaxial pressure dependence of the ordinary second-order constants. Using such measurements, Palmer was able to determine several of the third-order constants corresponding to the pressure dependence of the main diagonal, ordinary elastic constants of europium. Some difficulties were encountered because the pressure dependence of the second-order constants was not linear. This nonlinearity is also present in terbium and dysprosium and implies large fourth-order constants.

The study of these and other higher order effects as well as the problems enunciated by Mackintosh will give life to his prediction. Much has been learned since the first neutron-scattering experiments on terbium fifteen years ago. Much work remains before the rare earths are completely understood. (John R. Neighbours)

SYSTEMS ANALYSIS

SYSTEMS ANALYSIS IN ISRAEL'S DEFENSE DEPARTMENT

Imagine that you are charged with the defense of the State of Connecticut. Imagine further that all of your immediate neighbors (New York, Massachusetts, and Rhode Island) are so hostile that they may be expected to attack whenever they believe such an attack has a chance of success; and that several other states, more distant but also larger, richer, and more powerful (including one, say Texas, with lots of oil) are equally hostile and continually urging your neighbors to make war on you. This analogy gives some feeling for the difficulty of the problem of defending Israel, although the analogy is imperfect (the width of the country, from the West Bank to the Mediterranean Sea, is less than the distance from New Haven to Hartford).

In spite of their difficulties, the Israelis have been notably successful in the several wars they have fought during their 30-year existence, and at least some small portion of the credit for this success must go to their planning. Some of this planning, with emphasis on quantitative analysis, is done in CEMA, the Central Military Analysis group of RAFAEL, this last being (in Hebrew) an acronym for Armament Development Authority. The head of this group during my visit was Itzhak Ravid, who was replaced in this (rotating) position by Ilan Amit in January 1980. But Uri Reychav, Deputy Director of RAPHAEL, the parent organization, seems to control CEMA. He told me that while Ravid was father to CEMA, he was its uncle!

Reychav explained to me that weapons systems development in Israel may be very different from what it is in the US. In particular, they sometimes develop hardware without having set specifications—the specs being set only immediately prior to production. This is more flexible, but also riskier. People like Reychav have strong inputs to such decisions. The CEMA people tend to rely on formal methods, while Reychav tends to rely more on experience; as an example of this, Reychav told me of a controversy between himself and the well-known Prof. P. Morrison of MIT. Morrison had published a conclusion, based on formal analysis (i.e., theoretical methods) to the effect that precision-guided munitions could effect a significant cut in the defense budget of any nation, large or small (i.e., either the US or Israel). Reychav published a refutation of this claim, based on his experience with the Israeli military budget, indicating that the reduction in budget, while worthwhile, was only a tiny fraction of what Morrison had claimed.

Ravid is interested in the application to reliability testing of the classical problem of converting prior probabilities to posterior probabilities and the implications for hypothesis testing. In the usual reliability tests, it is only possible rigorously to deduce the probability of accepting an item given that it is bad; what is required, of course, is the probability that it will be bad given that it has been accepted. Ravid is interested in Bayesian approaches to this problem, with all that that implies regarding prior and subjective probabilities.

Amit, who took his doctorate in pure mathematics at the Technion, has worked for many years in operations research (OR) and applications, the last years in the military. He learned his English in Israel, but apparently from British people, since he speaks with a strong British accent despite the fact that he has never spent appreciable time there. He is presently interested primarily in software and especially in gaming. He has traveled extensively in Europe, Canada, and the US visiting war games, especially those designed for training purposes, and has reached several conclusions: (1) It is desirable to start with a manual game and computerize it; starting with a computerized model leads to inflexibility. (2) The game should reflect current doctrine as taught at the War College (of the country in question). This implies biases in the game, and these are proper (and in fact probably inevitable), the point being that they should be explicit. (3) It should be kept simple. In particular, simulations of lower levels should not be used as subroutines in a game involving higher levels; rather, the results of simulations or other analyses of the decisions made at the lower levels should be incorporated in tables or functions for use in such higher-level simulations. This is not easy to do. If the trainee is a one-star general, and the pieces which he controls are brigades, then he is only maneuvering 3-5 pieces, and it is too simple; but if the simulation goes down to battalions, he has 15-20 pieces, and that is too many. It is necessary to have something in the game to represent the colonels who are not present—a function which is performed poorly or not at all in most games; i.e., the colonels are all really there, and the staff is excessively massive. In a wide-ranging discussion of simulation and games with most of CEMA's senior staff, a number of other points were brought out, including a further discussion of biases in models, and whether or not they are (a) good, (b) removable, and (c) legitimate; the importance of the distinction between the functions of training and research, and the distinction between different types of training; the likelihood that a particular game cannot be useful for all functions; and the question of whether every game must be special-purpose, or whether general games have any value.

Amit also told me of work which he and colleagues had done for the foreign ministry. (In Israel, the military consumes 50% of the budget and 30% of the GNP, so they are likely to have the best people; from time to time, they use these people for service to other government departments.) They had set up a sophisticated information retrieval system of an exceedingly unconventional nature (they had to use three computers with different sets of existing software). It appears to be working well, even though its cost has been less than that of comparable systems elsewhere.

Haim Eldor, who has a PhD in Chemical Engineering from Purdue University, is more or less in charge of Naval OR. He told me of the extraordinary successes of the Israeli Navy in the most recent (1973) war. There were missile battles between Israeli ships and those of the Egyptian and Syrian navies almost every night. The latter two had 15 ships sunk, and the first-named none. That set of hardware and tactics is now obsolete, and there will be something new and different if and when there is another war. While they could not, of course, tell me about much of their work, they did describe some interesting analysis being done by Eldor and Prof. Arnon Boneh of the Technion (Israel Institute of Technology) in connection with some extensions of the theory of search and screening (originally developed by B. Koopman of Columbia University). The scenario has two opposing ships, each with over-the-horizon targeting capability (that is, the range of the weapons exceeds the visual range), but only one has acquisition capability over the horizon by means of an aerial platform. The deterministic assumption is also made: detection is with probability one inside a critical range R^* and with probability zero outside it. The problem for the ship with the aerial observer is to design a trajectory which keeps the enemy always at a distance $R>R^*$ even though the observer is airborne only some fraction of the time. They have a number of analytic conclusions; for example, the most dangerous angle between the paths of the two vessels is the arcsine of the ratio of speeds (if the speeds are equal, then clearly the most dangerous path direction is perpendicular). Boneh has also developed a simulation which he has converted into motion pictures (after the fashion described in *ESN* 33-4:133).

An analysis which to me was more interesting, because it came up with counterintuitive conclusions, was done by Eldor and Ze'ey Barzily, who has his PhD from the Technion in stochastic processes and has taught at George Washington University. The problem is to determine the position of a target when its direction is known, subject to some stochastic angular error, from two or more stations. In the case of two stations, the maximum likelihood estimator of the position is the intersection of the two given lines of direction, but the isoprobability contours around this point are <u>not</u> circular; they are egg shaped, being larger on the far side of the intersection. The more interesting case arises when there are three stations, all on a line (e.g., three direction finders on a straight shore). In general, the three lines of direction will intersect to form a triangle; but where in this triangle is the maximum likelihood target location? The unexpected answer: at one of the vertices, namely the intersection of the lines from the extreme stations. In other words, the observation from the middle station appears to add no useful information. However, this is true only insofar as the maximum likelihood estimator is concerned. Information from this intermediate station doubtless modifies the isoprobabily contours; it presumably modifies the unbiased estimator of the target location, and is of use to Bayesians; and it is invaluable in practice in indicating the possible presence of gross error in the other two observations.

Israel has, probably more than any other country, used systems-analytic techniques in military practice—e.g., mathematical programming for allocating military forces to sectors. They apparently aim to continue doing so. And the competence of the group charged with developing this effort, the CEMA group at RAFAEL, is, in my opinion, unsurpassed. (Robert E. Machol)

TELECOMMUNICATIONS

CSELT—BELL LABS ITALIAN STYLE

The STET Group of companies includes, among its many constituents, three organizations that provide a large part of Italy's telecommunication services. The acronym STET is widely used in both formal documents and informal discussions to denote the organization's name despite the fact that its full name is Società Finanziaria Telefonica p.A.; the predecessor company's full name, Società Telefonica Torinese, provided the basis for the acronym. (Società Italiana per l'Esercizio Telefonica [SIP] provides all local distribution and much of the intercity trunk services, Italcable provides intercontinental longline services, and Telespazio operates the ground stations for communication satellite systems.) STET also includes three companies that manufacture telecommunications equipment, a company that provides installation and maintenance services for that equipment, and a semiconductor device manufacturer.

The central research facility for this AT&T-like complex is called Centro Studi e Laboratori Telecomunicazioni S.p.A. (CSELT). It was organized 15 years ago and has since grown to be an impressively-instrumented facility in Turin, employing approximately 600 people. The staff is made up of an almost equal number of university graduates, technicians, and general support staff. Dott. Ing. Basilio Catania, CSELT's director, was a most gracious host for my visit to the facility. He and Dott. Ing. Augusto de Flammineis, one of the four members of a Technical Coordination Directorate within CSELT, provided guidance through a 2-day series of conferences and demonstrations which covered most of CSELT's activities.

The laboratory is organized into three divisions (Transmission, Switching, and Technology), a separate Systems Group that studies problems which overlap the transmission and switching aspects of the systems, and a Scientific Secretariat which is responsible for operation of their Documentation Center and, through that activity, is responsible for maintaining contacts with universities, other laboratories, and industry in general.

The Documentation Center provides two types of publications: for external distribution, the quarterly *CSELT-Rapporti Tecnici* (a partly-Italian, but mostly-English-language counterpart of the *Bell System Technical Journal*); and for internal, STET distribution, the monthly *INFOTEL*, an extensive bibliographic reference listing of articles published in approximately 150 sources in the telecommunications and electronics fields.

The Transmission Division is responsible for studies and prototype developments in electroacoustics; telephone terminal equipment; antennas; microwave devices; signal modulation and demodulation techniques; microwave radio facilities; and cable systems, both conventional and those employing optical fibers.

Hardware and software developments in electronic switching systems are the responsibility of the Switching Division. This activity is carried out in cooperation with Società Italiana Telecomunicazioni (SIT)-Siemens, a STET company which, among other things, has the responsibility for developing and manufacturing PROTEO, the electronic switching system now being introduced into Italy's telecommunication system.

The Systems Group is engaged in studies relating to network management (traffic analyses, quality control, plant supervision, etc.) and to signal processing (in particular, digital filter design, automatic recognition of typewritten characters, speech synthesis, and bandwidth reduction techniques for speech and image signals).

In support of all of the design teams, the Technology Division provides component development and prototype production services in micro-strip, thick- and thin-film hybrid circuit configurations. This latter activity is sometimes carried out in conjunction with Società Generale Semicondutori S.p.A.—ATES Componenti Elettronici S.p.A. (SGS-ATES), a STET-owned company whose own research laboratory is located near Milan. The Technology Division also operates a set of chemistry, physics, spectroscopic-analysis, and environmental-test laboratories. In addition, this division supplies mechanical engineering and general instrumentation support to all of CSELT, operates the computer center and maintains their computer-aided circuit-design facility.

Within the Switching Division's laboratories, I was shown through a software development laboratory wherein a system specification language is being developed. This activity supports a Europe-wide program to develop such a common language for use by cooperating telecommunication complexes. I was also shown an experimental electronic switching system which is being assembled. Its primary (first-level) controller is based upon American (AMD bit-slice) devices; its second-level (peripheral) controller uses a SGS-ATES-produced version of the American (Zilog) Z-80 microprocessor. The switching system architecture, for use up to a complexity of 64,000 subscriber lines, is based upon a 256-line modular unit. Studies, in conjunction with SGS-ATES, have not yet resolved the question of the number of custom LSI chips (one or a few) which will form the most economic configuration for that module, but Dott. Ing. G. Perucca, head of the Division, indicated that they expect to complete that phase of the study and produce a prototype of that module by the end of the year.

In the Transmission Division's area of interest, two antenna-related projects and a variety of activities related to fiber-optic cable systems were discussed. Dott. Ing. R. Bielli, head of the Antenna Section, described an experimentally-derived relationship which predicts, with greater accuracy than any available analytic method does, the radiation patterns for a family of corrugated conical horn antennas whose critical physical characteristics are a convex flare angle (i.e., half-flare angle greater than 90°) and a small overall aperture. Such a horn could be used as the feed to provide well-controlled illumination of a very deep reflector or, in pairs or quads, as elements of a signal-tracking system.

Ing. D. Savini then described a new signal-tracking system which might be used in conjunction with the beacon signals from communication satellites. The system maintains tracking in the presence of elliptically-polarized signals of arbitrary polarization orientation with respect to the antenna's boresight. The development, especially the compact mode coupler used, will be described by Savini at the 10th European Microwave Conference to be held in September in Warsaw.

In the fiber-optics area, CSELT has been at the forefront of field experimental activities in Italy. I was shown a recently produced film which described the early (1973-77) system experiment which used a 1-km-long cable that was laid in specially prepared trenches adjacent to the CSELT buildings and then a second experiment (begun in 1977) which uses cables laid over a 4-km route between two exchanges in Turin's local network. Both of these experiments used cables fabricated by Industrie Pirelli, the Italian cable and auto tire manufacturer, using Corning's glass fibers. The second experiment also used glass fibers made by CSELT themselves. These original fibers exhibited poorer characteristics than the Corning fibers in their dispersive effects. (Dispersion limits the data rate of the transmission.)

After seeing the film, I was introduced to Dott. Pietro Di Vita, assistant head of the Fiber Section, and three other members of the section: Drs. Giacomo Roba, Bruno Sordo, and Emilio Vezzoni. Roba showed me the original fiber-drawing mechanism in the laboratory and also the system which has replaced it. Closer controls over the take-up drum's speed and other production parameters have resulted in improvements in their fibers' transmission loss and dispersion characteristics. The new fibers have a loss characteristic of less than 2 dB/km at a 0.85 μm wavelength, compared to almost 4 dB/km for those CSELT-supplied fibers used in the Turin field experiment.

Presently, the only measurement made on the fiber *during* the drawing process is its diameter. This is done by causing the shadow of the fiber's profile to fall on to a photodiode array. With the old system, the diameter was maintained uniform within a 2% tolerance by open-loop methods. The new system has not yet been evaluated in this regard; whether or not a feedback-control system will be implemented to control the fiber's geometric and other characteristics has yet to be determined. Off-line methods for measuring the quality of the fibers are being developed by Sordo; if necessary in the future, these techniques might be modified to become production-line tests which could conceivably be incorporated into a feedback-loop-controlled fiber-production system. Sordo's fiber characterization scheme measures the variation of refractive index across the fiber's cross section (at 1-μm intervals across the up-to-100 μm diameter), and also the optical backscatter within the fiber. The former measurement affects the fiber's dispersion while the latter (an optical equivalent to the microwave system engineer's time-domain reflectometry measurement) senses non-uniformities along the fiber's length. Vezzoni demonstrated an automatic system that was developed at CSELT for performing measurements and plotting the dc electrical characteristics and certain geometric characteristics of the optoelectronic sources and detectors being considered for use in their newest system. That system will use a cable now being installed along a 16-km route in Rome. Tests on the second experiment's cable have been conducted at rates up to 565 Mbits/sec with a regenerative repeater spacing of 6 km (at a bit error rate of 10^{-9} with an operating margin of about 5 dB).

Besides these demonstrations and discussions in the fiber-optics laboratory, two additional CSELT-developed items in that emerging discipline were described: a new fiber-splicing device and a recently published textbook. The splicing unit, an inexpensive-looking simple flat spring-and-groove unit was developed there and then put into production by SIRTI, the STET company which has the responsibility for installation and maintenance of telecommunication systems. The textbook, *Optical Fibre Communications*, was recently completed by 19 CSELT researchers and has been published in Italy (in English); publication in the US awaits consummation of an agreement with a suitable publisher.

In the Systems Group, I met Dott. Ing. L. Chiariglione, who described a variety of projects related to videophone signal processing, still-picture transmission, character recognition and speech synthesis. An experimental system combining the last two techniques was demonstrated: a page with a set of short sentences typed upon it, one per line, was placed in a microprocessor-controlled carrier which moved the paper past the sensing scanner. At the end of each line/sentence, the detected "period" initiated a sequence of calculations for character recognition. The output of that step was printed out on a standard teletypewriter and was also fed into a syllable- and word-processing stage and then to a speech synthesizer subsystem. After a delay of about 10 seconds following the initial reading process, "spoken" words emerged from a loudspeaker. They sounded quite natural to my untrained (in Italian) ear. Chiariglione explained that the system depends for its realistic-sounding output on the fact that Italian has a relatively simple set of pronunciation rules; i.e., letters or letter-pairs have an essentially-one-to-one correspondence with the sounds they represent (as compared to English, e.g. *read*, in its present and past tenses, respectively). He indicated that, in addition, since Italian words are generally accented on their penultimate syllable, that simple rule had been incorporated into the speech synthesizer to add realism. What I had *not* detected in the demonstration was the fact that at least one word was included in the test material in which the correct accent was on a different syllable. He said that studies were now going on in Italy, although not at CSELT, to try to derive a second-order correction to the accenting algorithm. One other shortcoming of that simple system was noted; namely, the limited tolerance of the character-recognition system to rotation of the typed material. With a rotation of approximately 3-degrees of the page on its carrier, one particular type of incorrect interpretation occurred, namely o for u, but in this case the overall speech-synthesizer system was not badly affected. Twice that rotation, however, caused the first step in the process to break down and, without a recognizable set of characters to operate on, the syllable and word-forming steps could not proceed.

My exposure to the Technology Division's activities concentrated upon a discussion with Dott. Ing. Vittorio Ghergia, head of the Components and Materials Section. Within his group of about 35 people, 20 (about half of whom are professionals) are engaged in the evaluation of optoelectronic devices to support CSELT's overall fiber-optic systems efforts. Those in Ghergia's group are cataloging the characteristics of laser emitters and photodetectors for application in the 1.1-1.3 μm wavelength region, the so-called *second* window of low-loss fiber transmission. He commented that analogous activities in the *first* window, at 0.8-0.9 μm, were being carried on at the SGS-ATES laboratories and, as noted previously, in CSELT's Transmission Division. (CSELT is not active at all in the *third* window, 1.5-1.7 μm).

The others in his section are engaged in general materials analysis and device reliability studies (from a device-physics viewpoint rather than a statistical, parts-count viewpoint). A set of two scanning electron microscopes and an Auger spectroscopic analysis system (*ESN* 34-3:155) are available within his laboratories to support those activities.

The impression gained from my relatively short visit to the broadly based CSELT organization was that, considering its size, it deservedly occupies a significant position in the worldwide telecommunications-research community. From separate discussions with a number of Americans who ought to have known better, I judged that CSELT is relatively unknown. The fact that it is located well off the Milan-Rome-Florence-Venice tourist route in tourism-conscious Italy may account for some of this anonymity, but that is another story... (Philip Fire)

NEWS & NOTES

OPERATIONAL RESEARCH COMPUTERS

The above was the title of the Blackett Memorial Lecture, presented to some 150 people on 3 June by E.M.L. Beale. The venue was the Royal Society (*ESN* 34-3:143, [1980]). The lecture is an annual affair of the Operational Research Society (ORS); on this occasion the Silver Medal of the Society, its highest honor, which is awarded only once every year or two, was presented at the same time to Beale. This was a coincidence without precedent but, as the president of the society, George Mitchell, emphasized in his opening remarks, it was an event which did not set any precedent. Beale is a distinguished mathematician, recently made a member of the Royal Society, who has been a member of ORS for seventeen years. He is technical director of a computer services company, Scicon, and visiting professor of mathematics at Imperial College.

Beale is a bit of a pixie. He told me of his first job interview, with the Admiralty, 30 years ago. He was asked "what would you do to determine the effect on a battleship of a detonation of such-and-such an intensity at such-and-such a distance?" He started to respond "I'd take a random sample of battleships..." but was interrupted: "Don't you think you ought to do some calculation first?" "If I were a physicist," Beale replied, "I would do some calculations; but since I am a statistician..." Amazingly, he got the job!

Though he is a mathematician, Beale made clear in his speech that, like P.M.S. Blackett, a founder of OR for whom the lecture was named, he disliked excessive math in OR. But he felt strongly that optimization was useful—an opinion which is heard less often these days. He defined OR as a way to help organizations become clearer about their assumptions, and asserted that optimization models were especially useful because of their ability to help in this way. Among other advantages of optimization models, he pointed out that suppliers of data take their tasks more seriously when they know that the data will be used in such models. Furthermore, optimization studies make contributions long before the end of a project, helping to rephrase the problem from that originally posed. And he ridiculed the so-called "problem-oriented approach" to OR, asserting that "it leads to a whole lot of problems."

Beale said that the ability to handle real, large-scale optimization problems had improved in the past decade not only because of the improvements in computers but also because of the improvements in theory; for example, better knowledge of how to exploit sparseness in matrices. He spoke of improvements in problem-solving capability through integer programming and use of variables of other types; in addition to continuous and integer variables, he mentioned several others, such as "ordered sets of type 1" in which at most one of the variables is a nonzero. More expertise is required, and will continue to be required, in these types of mathematical programming than in linear programming. He mentioned also the recent improvements in nondifferentiable optimization, and in multi-criteria decision making.

Looking to the future, Beale predicted more simulation, more analytical work related to simulation (e.g., variance reduction using control variables, and optimization models derived from simulation models) and more optimization for routine decision making and control. He felt that the increases in dispersed computing power (through mini and microcomputers) would actually increase the loads on the service bureaus, through terminals and through batch work on mainframes, as well as their supply of software for local microcomputers. He summarized his remarks by saying that some OR scientists will branch out into new fields, but there will be no shortage of good problems in conventional fields. (Robert E. Machol)

ROYAL SOCIETY OF CHEMISTRY—A NEW FORMULA

In June, a new Royal Society, combining the roles of a professional organization and an academic body, began operating in the UK. The move followed the recent granting by the Privy Council of a charter to the Royal Institute of Chemistry and the Chemistry Society.

It had taken 15 years to complete arrangements for the unification of the two bodies under the chairmanship of Prof. Sir Ewart Jones, the Chemical Society president and the man chosen to be the first president of the new Royal Society.

Sir Ewart expects most of his first year to be spent dealing with detailed problems which arise in the society's organization but believes it will provide wonderful opportunities for chemists in Britain.

In particular, academics will be forced to look outside their own limited approach to chemistry. In the past, they have tended to concentrate on Chemical Society membership with its orientation towards publishing, arranging meetings, and other functions as compared to the Royal Institute of Chemistry which tended to have more people employed in industry and government laboratories and who were more concerned with institutional activites and professional qualifications.

Sir Ewart maintained that in recent years there had been too much emphasis on theoretical aspects of chemistry which, although interesting, tended to be too elitist. Work should be more practically oriented in future.

This would be far more likely to occur when university and polytechnic chemistry staff were operating in closer collaboration with professional and industrial chemists within the Royal Society of Chemistry.

A closer unity among chemists was particularly important as increasingly chemistry was impinging itself on everyday life, with more use of fertilizers, medicines, improved fuels and many other new products, according to Sir Ewart.

The new Royal Society could be expected to take a vital role in directing and informing the public on the effects of chemicals and chemistry on their lives.

The establishment of a body which will unite chemistry is the reversal of a trend that has seen the spread of many different specialized organizations. The first of these was the Chemical Society, set up in 1848, which was followed by the Royal Institute of Chemistry (RIC) in 1885.

Later, groups such as the Faraday Society, which represents the views of physical chemists, and the Society for Analytical Chemistry were also formed to ensure that their own specialized interests were protected.

It was not until the postwar years that serious moves were made among chemists to recombine these disparate elements. Finally, talks began in 1965 which resulted in a partial merger of the various groups in 1972. The Faraday Society and the Society for Analytical

Chemistry were incorporated as special divisions within the Chemical Society which was also given some of the responsibilities for RIC activities, although the institute nevertheless maintained control over professional and qualifying matters.

At the same time, a unification committee was established under the chairmanship of Sir Ewart, who is only the third man in the history of both the Institute and the Chemical Society to have been president of both bodies.

A key feature of the new body of 40,000 members will be the setting up of its six major divisions: analytical, inorganic, educational, industrial, physical, and organic, which will have their own memberships, presidents, and councils. In this way, the Royal Society of Chemistry hopes to ensure against future fragmentation of the organization.

Through this structure, the RSC hopes to achieve two major goals: greater external influence and greater internal efficiency. The latter aim will take up much of the new society's time at first. Only in later years will it take on the vital task of representing chemistry strongly throughout British society; for instance, through influencing health and safety and industrial bills as they go through Parliament, and protecting the professional interests of chemists.

ONRL STAFF CHANGES

In June we bade farewell to our Chief Scientist, Dr. Fred E. Saalfeld, who returned to his post as Superintendent of the Chemistry Division at the Naval Research Laboratory in Washington, DC. We also said farewell to Dr. Richard S. Hughes, who left for the Physics Department of Pacific Union College in Angwin, California, and to Commander Robert D. Matulka, who retired from the Navy and returned to the state of Washington to begin a new career in civilian life.

THE ROYAL SOCIETY

Prof. H.O.G. Alfvén, professor of plasma physics at the Royal Institute of Technology, Stockholm, and Prof. P.W. Anderson, consulting director of physical research at the Bell Laboratories, US, have been elected foreign members of the Royal Society.

INSTITUTE OF PHYSICS

The Institute of Physics has made the following awards for 1980:

Charles Vernon Boys Prize: Dr. A.E. Costley of the National Physical Laboratory, development of rapid-scan Fourier transform spectroscopy for characterization of electron cyclotron emission from pulsed plasmas; Duddell Medal and Prize: Prof. A.V. Crewe, Chicago University, development of the ultrahigh resolution scanning-transmission electron microscope; Max Born Medal and Prize: Prof. H. Faissner, Rheinisch-Westfalische Technische Hochschule, Aachen, experimental elemental particle physics, particularly in the field of "neutral" currents; Glazebrook Medal and Prize: Mr. M.C. Crowley-Milling, CERN, Geneva, development, design, and construction of the multi-computer control system of the 400 GeV proton syncroton at CERN; Guthrie Medal and Prize: Prof. M.E. Fisher, Cornell University, theory of phase transitions and critical phenomena; Maxwell Medal and Prize: Prof. B.J. Wallace, Edinburgh University, studies of critical phenomena in statistical physics using quantum field theory techniques; Rutherford Medal and Prize: Prof. P.G. Murphy, Manchester University and Dr. J.J. Thresher, Rutherford Laboratory, Didcot, for contribution to elementary particle physics through the measurement of elastic scattering and polarization differential cross sections for pion-proton scattering; 1979 Graduateship Examination: Mr. D.B. Mackay, Napier College of Commerce and Technology, Edinburgh; Honorary Fellowship: Prof. V.F. Weisskopf, MIT, US.

CHAIRS

Prof. E.A. Ash, professor of electrical engineering at University College, London, has been appointed to the Pender chair of electrical engineering at that college effective 1 October 1980.

Prof. M.H. William, currently professor of computer science at Rhodes University, Gramstown, South Africa, has been appointed to the chair of computer science at Heriot-Watt University, Edinburgh.

The title of professor of physics has been conferred upon Dr. T.H. Griffith in respect of his post at University College, London, effective 1 October 1980.

OBITUARIES

Dr. Emilie Boer, a pupil of Franz Boll and a member of the small band of international scholars who specialized in the study of ancient mathematics and astronomy, died at her home in Dresden, East Germany, on 5 April.

Prof. John Richard Daly, first occupant of the chair of chemical pathology at the University of Manchester and honorary consultant chemical pathologist at Hope Hospital, Salford, died on 7 April, after a short illness, at the age of 49. He had played a major part in the development of a highly sensitive method for assay of the pituitary hormone ACTH.

Prof. Robert A. Smith, who was principal and vice-chancellor of the Heriot-Watt University from 1968 to 1974 and president of the Royal Society of Edinburgh from 1976 to 1979, died in Edinburgh May 16. He was 71.

ERRATA

The 5 Portuguese naval officers mentioned in the article, "Marine Science is Looking Up in Portugal: Naval Programs," (*ESN* 34-3:137) who are undergoing training in Bay St. Louis, MS, are enrolled in a course at the Naval Oceanographic Office (NAVOCEANO) and not at the Naval Ocean Research and Development Activity (NORDA) as stated in the referenced article.

ONR COSPONSORED CONFERENCES

NATO Advanced Study Institute, "New Concepts in Multi-User Communications," University of East Anglia, Norwich, England, 4-16 August 1980.

Conference, "Physics of Transition Metals," The University of Leeds, England, 18-22 August 1980.

International Conference on "Physics in One Dimension," Fribourg, Switzerland, 25-29 August 1980.

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 Structures, Leicester, England 8-12 September 1980.

International Symposium on Gallium Arsenide 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.

European Visitors to the US, Supported by ONR London

Name of Visitor	Affiliation	Navy Lab./Org. to be Visited
	AUGUST	
Prof. D. Clark	Dept. of Chemistry, Univ. of Durham, UK	NRL, NSWC
Dr. S. Cornbleet	Dept. of Physics, Univ. of Surrey, Guildford, UK	NOSC, NPG School
Dr. J. Cortadas	Dept. de Quimfca Macromolecular, Escuela Técnica Superior de Ingenieros Industriales, Barcelona, Spain	NMRI, ONR, NORDA
Prof. M.G.D. El-Sherbiny	Dept. of Mechanical Design & Production Engineering, Cairo University, Egypt	NRL, ONR, DTNSRDC NSWC
Dr. M.J. Folkes	Dept. of Non-Metallic Materials, Brunel University, Uxbridge, UK	NRL, NSWC
Prof. P. Meares	Dept. of Chemistry, University of Aberdeen, UK	NRL
Dr. R.G. Van Welzenis	Dept. of Physics, Eindhoven University of Technology, The Netherlands	NRL, NOSC, NPG School
	SEPTEMBER	
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 Science, Shrivenham, UK	NRL, DTNSRDC, NSWC
Dr. D. Price	Dept. of Chemistry & Applied Chemistry, University of Salford, UK	NRL, DTNSRDC
	OCTOBER	
Dr. K. Allen	Adhesion Science Group, City University, London, UK	NRL, NSWC
	DECEMBER	
Dr. F. Durst	Sonderforschungsbereich 80 an der University Karlsruhe, West Germany	NRL, ONR, NOSC

ONRL REPORTS

C-1-80

3rd Europhysical Conference on Lattice Defects in Ionic Crystals by Lawrence Slifkin

The 3rd Europhysical Conference on Lattice Defects in Ionic Crystals took place at Canterbury, England, September 17-21, 1979. The topics covered included ion transport, defect configurations and reactions, dislocations and their interactions with point defects, and color centers. This report summarizes the results and discussions pertinent to all of these papers, except those dealing with color centers.

C-6-79

Fifth International Conference on Erosion by Liquid and Solid Impact, Cambridge by Arthur M. Diness

The Fifth International Conference on Erosion by Liquid and Solid Impact was held at Cambridge University, 3-6 September 1979. The general chairman was the renowned Prof. David Tabor. The major topics treated during the meeting were (1) particle-caused erosion of brittle solids, (2) particle-caused erosion of ductile solids and (3) cavitation erosion of materials. The meeting provided a useful forum for new ideas on all aspects of erosion, as well as opportunities to couple parallel work underway across the world.

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.