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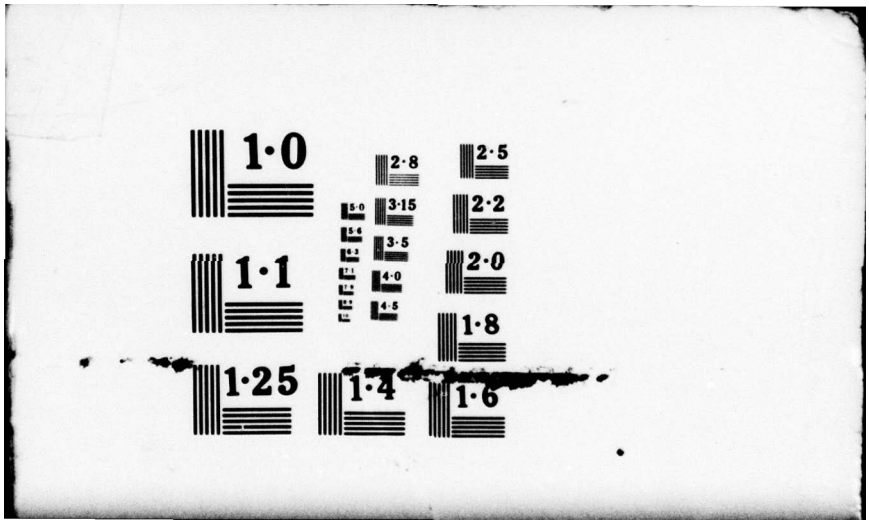
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This is a monthly publication presenting brief articles concerning recent developments in European Scientific Research. It is hoped that these articles (which do not constitute part of the scientific literature) may prove of value to American scientists by disclosing interesting information well in advance of the usual scientific publications.

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

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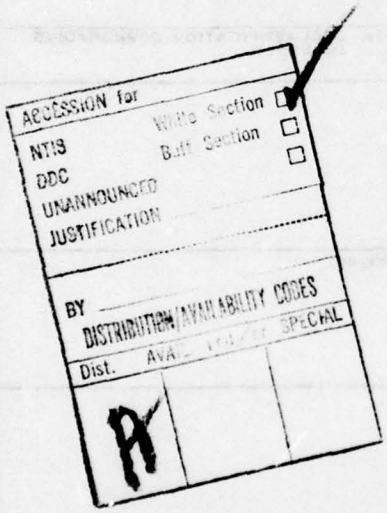

EUROPEAN SCIENTIFIC NOTES
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Aubrey W. Pryce and Victoria S. Hewitson

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HERBERT SOLOMON
Chief Scientist

P.F. GIBBER
Captain, USN
Commanding Officer

BIOLOGICAL SCIENCES

URSI PURSUED: MILLIMETER WAVE BIOPHYSICS

In a preceding article (*ESN* 32-11: 363), I proposed to view the recent Open Symposium on the Biological Effects of Electromagnetic Waves in terms of two types of research target: first, the effects of weak non-ionizing fields on intact animals; second, the search for simpler systems which display in unequivocal ways the effects of such fields and which serve efficiently as objects for the elucidation of chemical-biophysical mechanisms. The first area was considered in that article. The second is the subject of this one.

Hitherto, experimental work on cells, organelles, and non-living preparations has been almost entirely empirical or, at best, suggested by conjectures about the cause of symptoms reported in man and experimental animals. It is now possible, I believe, to look at the results of current studies, and to plan new ones, in the light of some simple propositions derived from physical theory. For this we have to thank H. Fröhlich whose arguments place the whole subject within a framework open to experimental validation (cf. *ESN* 31-11:433, 435). I am not able to judge whether the mathematical theory is right or wrong. One part of it was in fact criticized in the Russian literature by M.A. Lifshits and then defended with much conviction by T.M. Wu and S. Austin of the State University of New York. But a debatable theory with broad implications is surely better than none at all. Without trying to summarize Fröhlich's ideas here, my purpose will be served by simply stating the propositions that I find useful in thinking about the papers given at Helsinki, at risk of going beyond what he intends.

Here they are: (1) Supramolecular sensitive domains in biological systems can be raised by metabolic energy to a single coherent metastable vibrational state which constitutes an intermediate in the mechanism of a biologically specific reaction. (2) The resonance frequency of such a domain is likely to be in the range 100-1000 GHz though not necessarily confined to it. (3) Supply of microwave energy at the resonance frequency above a critical rate also generates the coherent state within the sensitive domain and thus modifies the behavior of the system. (4) The microwave action spectrum will be highly frequency-specific, having the character of one or more resonance curves, possibly damped by mode-softening occasioned by long range dipole-dipole interactions. (5) The "dose-response" relationship will tend toward a step function at a critical level of absorbed energy. In practice the curve may be sigmoid or may even show an optimum response. The latter type of behavior, although almost universal in biological systems and known for a century or more, is now called a "power window" in microwave jargon. (6) Ability to respond to microwave stimulation is likely to be such a highly specific property that the search for sensitive systems will require extremely delicate and perhaps novel fractionation techniques. Systems with a single highly specific metabolically coupled biological activity would be natural and fruitful objects of study while little would be expected, say, from relatively degenerate systems such as the erythrocyte membrane or synthetic lipid or lipoprotein bilayers. By the same token, mass production processes like hematopoiesis or spermatogenesis would probably be swamped by myriads of simultaneous reactions and compensatory shielding of any small scale local effects. (7) Long range coherent interactions involving more than one enzyme system may give rise to slow chemical and electric oscillations of which those occurring in the brain may be an important instance. These can presumably be modified by low-frequency external fields (ELF) and perhaps also by microwaves pulsed at the appropriate low frequency.

One hoped that the opportunity would be taken at Helsinki to organize an authoritative discussion of these speculative ideas and the current status of corresponding experimental approaches. But Fröhlich himself was not there, and the few other theoreticians managed to arouse little comment. A very good paper was given by F. Kaiser (Univ. of Stuttgart) who enlarged upon the Fröhlich brain wave model and discussed the solution by various methods of the nonlinear differential equations. These predict the existence of nonlinear self-sustained

oscillations without external drive and the creation of propagating pulses by extremely weak ELF stimulation at the correct frequency. Quantum models of the supramolecular biological solid state were presented in a poster by J. Achimowiecz (Military Inst. of Aviation Med., Warsaw, Poland) who drew an analogy between the mechanism of onset of bulk superconductivity by cooling an A,B alloy and the initiation of local superconductivity in an enzyme-substrate complex by conformational transformation and low-frequency vibration. A quantum cooperative process between neighboring superconducting regions, Achimowiecz said, may account for the efficiency of enzyme action. The complexes, being extremely sensitive to "system-generated electromagnetic fields" are also sensitive, I presume, to applied fields, although it was not clear whether the resonance frequencies would be in the same range as those predicated by Fröhlich. It is too bad that there was so little discussion of these important questions and no attempt to find by calculation whether experimentally effective specific absorption rates (SAR) needed to produce biological responses are compatible with the actual rates of quantum absorption in the postulated sensitive regions of the target organism.

Now, having laid a foundation, we can talk about the Symposium in more concrete terms. First I shall mention some papers on purely physical measurement; shall touch upon one or two unpromising biological targets; and shall hope then to enter the territory of positive results and bright ideas.

Although much is known about the dielectric and microwave spectroscopic properties of cell constituents—proteins particularly—much more is needed, especially at the higher levels of organization where changes associated with cell function are to be expected. Only three Helsinki papers offered new information. K.R. Foster, R.D. Stoy and H.P. Schwan (Univ. of Pennsylvania, Philadelphia) presented an abstract but were not present to discuss their poster. They have microwave dispersion data on dog brain tissue over the range 0.01-7.0 GHz and have analyzed the results in terms of free and bound water in a suspension of nonconducting spheres. An extremely sensitive new method for microwave spectroscopy of transparent materials was presented by C.C. Davis (Univ. of Maryland, College Park) with M.L. Swicord (Food and Drug Administration, Rockville, MD) in which a split laser beam is used to detect the change in refractive index produced by microwave absorption. The sensitivity is said to be 10^{-12} to 10^{-13} in refractive index. Data for water and dihydroxyethane between 8 and 12 GHz were given. Preliminary data were shown for DNA solutions, but the goal of detecting microwave resonances in biological systems seems far off. Many data obtained by scanning and computer processing were shown by O.P. Gandhi *et al.* (Univ. of Utah, Salt Lake City). They were obtained from various dense aqueous solutions and suspensions of biological materials at 0.05-GHz intervals over the range 26.5-90.0 GHz. Since the medium (water) absorbs intensely over this range the resolution of any contribution from solute or suspensoid must be very difficult and the calculation of optical constants impossible without making debatable assumptions. It seems that technological cleverness has swamped common sense. In any event, as A.J. Berteaud (Centre National de la Recherche Scientifique, Thiais, France) remarked, spectroscopic data unaccompanied by action spectra are of doubtful value in the present context.

Now we come to what I had the temerity to call "unpromising" investigations. A miscellany. Two teams are looking at red cell membranes. J.W. Allis and C.M. Weil (EPA, Res. Triangle Park, NC), absent apparently, described in an abstract their plans for making spectrofluorimetric measurements on biochemical samples during microwave irradiation. D.J. Peterson *et al.* (Univ. of Utah, Salt Lake City) irradiated rabbit red blood cells at unspecified power densities over the range 12.5-18.0 GHz and could find no change of potassium or hemoglobin leakage other than that attributable to temperature change. The relative roles of lysis and membrane permeability change were not made clear.

Equally unpromising is the work on lipid bilayers presented by S.I. Alekseev and V.V. Tyazhelov (Acad. Sciences USSR, Moscow) who found at 900 MHz that irradiation increased the frequency of opening and closing of channels without changing their relative value. The work is redeemed by the report of O.V. Kolomitkin *et al.*, from the same laboratory, that the bilayer properties are modified when rat brain synaptosomes containing

glutamate receptors are added to the medium. The fragments cause a stepwise increase of bilayer conductivity, and this is increased by irradiation at 820 MHz, possibly by selective heating of membrane channels.

The frog sciatic nerve provided D.I. McRee (Nat. Inst. of Env. Health Sciences, Res. Triangle Park, NC) and H. Wachtel (Duke Univ., Durham, NC) with a membrane supposedly sensitive to small changes which might later be reflected in changes of performance. It was indeed found that the time required for the action potential to decrease to one half of its maximum value during rapid repetitive nerve stimulation was reduced considerably under irradiation at 2.45 GHz; also, an initial increase of refractory period was noted. These interesting results require confirmation, for it was admitted that despite precautions with circulating cooling water there may have been appreciable temperature changes at the points of entry into the waveguide.

If the brain is sensitive to nonionizing fields and if most effects on living animals originate there, one would expect to find many attempts to detect some of the components of cerebral function in preparations from the isolated brain and to use these in studies of microwave and ELF effects. One such has already been mentioned: the modification of lipid bilayer properties by synaptosomes. There were only two others. In one, preparations of synaptosomes and receptors have been used by J. Lords *et al.* (Univ. of Utah, Salt Lake City) to find whether microwaves alter the release of transmitters (atropine, gamma-aminobutyric acid, acetylcholine) and/or the formation of transmitter-receptor complexes. Initial fractionation procedures and electron microscope techniques have been worked out. Tentatively, it seems that irradiation at 2.5 mW/cm^2 may have some effect. The difficulty, of course, is in finding a property that manifests some characteristic of brain function with which to correlate such effects. The brain is not simply an assemblage of excitable elements, analogous for instance to peripheral nerve, but rather an integrated structure in which long-range cooperative interactions make it the seat of global electrochemical oscillations which may be disrupted by fragmentation. One may well ask whether these properties can be preserved in the test tube.

The approach used by W.R. Adey and S.M. Bawin (Veteran's Administration Hospital, Loma Linda, CA) is to study the putatively relevant ionic interactions in forebrains cut out from the newborn chick. The experiments then done are based on the hypothesis, if I understand it, that cerebral functioning, and in particular the generation of the electrochemical oscillations detected in electroencephalography, is closely correlated with highly labile exchanges between monovalent and divalent cations (especially H^+ and Ca^{++}) bound to the polyanionic surfaces of the dendrites; further, that long range cooperative or amplifying processes involving interaction with the extracellular electric field result in slow wave propagation of these ion exchange processes across dendrodendritic contacts. Since the fields are weak, externally applied fields would be expected to influence these processes. The test procedure adopted is superficially simple in concept if not in execution: the excised forebrain is tagged, by incubation for 30 minutes, with radioactive calcium, $^{45}Ca^{++}$, and then the efflux of the tagged calcium measured during exposure to various chemical and electromagnetic environments. Aside from the testing of the hypothesis by varying external concentration of hydrogen ion, calcium, and sometimes lanthanum, concentrations, the important result is that the Ca^{++} efflux is influenced by fields of quite modest intensity; for example, increased by 15% when exposed to 450 MHz amplitude-modulated at 16 Hz, power density 0.75 mW/cm^2, measured internal voltage gradient about 50 mV/cm; decreased by about the same amount in sharply defined ELF fields within the range 6 to 20 Hz at 10 to 100 V/m and measured internal gradient about 10^{-4} mV/cm. For both pulsed microwave and low-frequency fields these effects occurred only within narrow "windows" of frequency and amplitude, in striking accord with the Fröhlich predictions. Interesting as these results are, the absence of any convincing proof that they correspond to significant changes in brain function is a drawback that it will be difficult to remedy. I do not know whether EEG activity persists in the preparations used by Adey and Bawin nor whether it could readily be recorded even if present. The observations of V.V. Tyazhelov *et al.* (Acad. Sciences USSR, Moscow Region) may be relevant: according to these au-

thors, bioelectric activity can be induced in the rat brain for as long as 3 hours after death by microwave irradiation at power densities less than 50 mW/cm^2 and a temperature rise less than 0.5°C. The activity seen is different in different parts of the brain. It persists for about 10 s after turning off the field.

Other isolated cells from vertebrates, both normal and neoplastic, have been exposed to weak fields. The work of Chiabrera *et al.* (Univ. of Genoa, Italy), in connection with the promotion of oriented osteoblastic activity in the healing of bone fractures, is interesting. Of exceptional interest, however, are the experiments of V. Riley *et al.* (Pacific NW Res. Foundation, Seattle, and Univ. of Washington, Seattle) in which ascites tumor cells have been injected subcutaneously into mice after exposure for 20 minutes *in vitro* at controlled temperature to a 30-MHz field at 0, 5, or 10 V/cm. Striking effects were seen: decreased percentage of samples developing into tumors, increased latent period, progressive fall in rate of volume increase, and eventual regression. These phenomena are clearly distinguished from the effects of heating. A rise of temperature from 42 to 43°C, for instance, causes a decrease of latent period, as measured in the Warburg manometer, rather than an increase. The changes are evidently produced at the cellular level by low intensity irradiation, and the mouse assay provides an excellent method of biological amplification. More information is needed in order to establish a dose-response relationship. This should be done by varying the duration of exposure, rather than by changing the field strength as, it seems, has been done hitherto. Because of the choice of such a relatively low frequency in this work, its relevance to the Fröhlich hypothesis is uncertain.

Let us pass from vertebrate cells to colony-forming yeasts and bacteria, the types of organism which provided much of the original impetus for laboratory study of the effects of weak nonionizing fields. It is now almost six years since several short papers on the subject, given at a scientific session of the USSR Academy of Sciences, 17-18 January 1973, were published in English. The results offered were welcomed by Fröhlich as conforming to several of his predictions, but the absence of much important detail made critical evaluation almost impossible. Acceptance became contingent upon independent confirmation. Successes and failures have been reported concerning several of the Russian claims, though too often with related rather than identical cell types, and the time is surely ripe for thorough discussion at an international meeting such as that at Helsinki. Unfortunately, reprehensibly in my view, the subject was treated with the utmost casualness, relegated to an evening session and dubbed a "workshop," which it was not by any stretch of the imagination. Few of the key personages were present. N.D. Devyatkov, apparently the leader of the Russians working in this field, was not there, nor were any of the 26 or so authors who presented their work at the P.N. Lebedev Physics Institute in 1973. The sole representative of current European experimental work was Berteaud who has for some years collaborated with D. Averbeck and associates at the Fondation Curie in Paris. The most meticulously documented work on the growth of yeast in millimeter wave fields has come from the Gesellschaft für Strahlen und Umweltforschung at Neuherberg near Munich and the Max-Planck-Institut für Festkörperforschung near Stuttgart. Yet neither of the authors, W. Grundler and F. Keilmann, was present. Indeed, it was asserted by the theorist Kaiser that their paper had been rejected. So it was hardly surprising that the discussion was fragmented, sometimes ill informed, and occasionally conducted at cross-purposes.

The reports given were about equally divided between positive and negative assertions as to the biological action of microwaves. D.W. Hill *et al.* (Univ. of Utah, Salt Lake City) failed to establish any effect of 65-75-GHz irradiation at 10-70 mW/cm^2 upon suspensions of *Escherichia coli* and LaCrosse virus (Bungamwera group). As Berteaud suggested, the radiation was probably effectively shielded by the aqueous medium in spite of the otherwise undesirably high incident power density. Also negative were the results obtained by S. Baranski *et al.* (Military Inst. of Aviation Med., Warsaw, Poland, read by Achimowiecz in absence of the authors) who looked for possible alterations in the genetic functions of fungi. They used the ascomycete *Aspergillus nidulans* and the myxomycete *Physarum polycephalum*. The incident radiation frequency was

2.45 GHz, continuous or pulsed at 1 μs and 600 Hz, with exposure at 10 mW/cm² for an hour. In the former case the morphological mutation rate did not differ from the spontaneous rate even in presence of caffeine. In the case of *Physarum* there was a large acceleration of DNA synthesis which may have been thermal in origin.

The most interesting report of a negative result was that given by Berteaud on behalf of himself and colleagues because of its bearing on their previous work on the growth of bacteria after irradiation. Using a strain of yeast well characterized in regard to its response to ionizing radiation, they were unable to find any effect of microwaves (70-75 GHz) on nuclear or mitochondrial mutation or on the production of cytoplasmic "petite" colonies. On the other hand they found, using two diploid strains, that the formation rate of zygotes was highly dependent upon temperature and upon the incident power density between 6 and 60 mW/cm². Use of these organisms in irradiation experiments on other test objects can thus serve as a measure of any temperature increase occurring under the conditions of exposure. These experiments were apparently done in the same way as those on *E. coli* described in their earlier published work. They serve to show that temperature change could not account for the results then obtained. These, it will be recalled, appeared to confirm the Russian claim that weak microwave fields between 70 and 75 GHz cause highly frequency-dependent changes of cell multiplication rate, with regions of inhibition separated by regions of slight stimulation. Berteaud was asked whether there are plans to repeat the earlier experiments in the light of the new results. His confidence in those experiments is evidently great enough for him to consider repetition unnecessary. In any event his colleague, Averbeck, is now occupied with more readily reproducible phenomena attending the simultaneous or sequential irradiation of microorganisms with x-rays and microwaves. The strictly exponential x-ray dose-survival curves are distorted in microwave fields. A progress report on these studies would have been most welcome.

Other positive results of a tantalizing nature were shown by M.L. Swicord *et al.* (Bur. Radiol. Health, Rockville, MD) who at first found that induction of colicin in *E. coli* could be produced by irradiation at certain frequencies between 33 and 50 GHz. The very sharp frequency dependence of the induction ratio is illustrated by the following numbers: ratio 1 at 45.75 and 46.10 GHz, ratio 8 at 45.9 GHz. The ratios were also positively dependent upon power density: e.g., 1 at 1 μW/cm² and 8 at 1000 μW/cm². From the graph shown it seemed that the power dependence was not of the type anticipated by Fröhlich, with a pronounced threshold value. Unfortunately the culture suddenly became noninducible even by ultraviolet radiation. It was agreed that the system is erratic.. However, the earlier results of A.Z. Smolyanskaya and R.L. Vilenskaya were in some particulars substantiated, although those authors did find a definite threshold between 1 and 10 μW/cm² succeeded by a flat response from 10 to 1000 μW/cm². It was suggested in discussion that despite this measure of agreement further work with such an undependable process would be ill-advised and a lysogenous system such as that of lambda phage would be more rewarding.

Our pursuit of URSI, then, has not taken us very far, although it had its good moments. There were some good experimental papers and a few good ideas. There was a little bit of theory, but little attempt to join theory with practice or to thrash out ways in which this may best be done. There must surely be an intensification of effort to detect the microwave resonances and long-range interactions underlying some of the alleged biological phenomena for which fairly good evidence now exists. On the physical side, sketchy evidence from laser Raman spectroscopy of bacteria has been published and should have been discussed, but criticisms—justified to my mind—were muted in the absence of the authors. It would have been useful to hear these judgements ventilated in the light of current attempts to repeat the observations independently in more acceptable form and to extend them to the anti-Stokes side of the incident wave. Brillouin scattering and other solid state techniques will have to be explored in greater depth, but always with proper biological monitoring from the point of view of normal functioning.

As for the good experimental ideas that emerged, those that appealed to me were: the use of lysogeny as a state possibly inducible by microwaves; the use of ascites tumor cells as targets, and

their hosts as biological amplifiers; the incorporation of a biological temperature probe during irradiation of cells; and the simultaneous physicochemical and electrophysiological study of the smallest available functioning domains of small or embryonic brains.

One hopes that some of these matters will be more fully and coherently represented at the next meeting. (J.B. Bateman)

THE HOSPICE CONCEPT: ST. CHRISTOPHER'S

In recent years, the medical and allied professions have paid much lip-service to "quality of life." Specifically, there have been attempts to furnish patients with incurable diseases the means to "die with dignity." For example, legislation in several states of the US now permits such patients to refuse, in advance, heroic medical efforts to prolong their lives. Similarly, more attention is being paid to WHERE death occurs, since the traditional place—an acute care hospital best equipped to handle patients expected to get well—is increasingly recognized as unsatisfactory both for the patient and for the medical staff.

A solution currently in vogue is that of "hospices," which are patient care facilities specifically staffed to care for the terminally ill. The concept is hardly new, but has received considerable impetus from Great Britain, and from St. Christopher's Hospice in Sydenham near Central London in particular. I journeyed to St. Christopher's during October 1978 to learn more about this now-famous institution.

I was not alone. Several busloads of student nurses from Sweden, a group of London hospital nurses, and a sprinkling of chaplains, sociologists, and nurses from as far afield as the United States filled a small lecture hall to view a professional-quality film about the Hospice and to participate in a question-answer session. We were told that more than 4000 visitors sat through such sessions last year.

The dynamic Director of St. Christopher's, Dr. Cicely Saunders, was not present as she apparently now spends a good deal of time on the lecture circuit abroad. Nevertheless, it was obvious that the resident staff are both well equipped and very enthusiastic about their ability to provide solace for both the dying and for their families.

The Hospice, opened in 1967, now admits about 600 patients yearly. Although all die within a relatively short period, some 12% are allowed to return home for varying periods. In this way, and by encouraging families (including young children) of staff and patients to wander about, the Hospice avoids the stigma of being labelled a "death house." More than 150 unpaid volunteers participate in patient care activities of one kind or another.

A very high nurse-to-patient ratio, extensive use of the team (doctors, nurses, social workers, chaplains) approach, and religious (Protestant) overtones contribute to a very personal touch for patients. Importantly, they can always find someone to talk to—unlike the situation in many acute care hospitals where staff members are discouraged from becoming personally involved with patients, particularly the dying. Generous use of analgesics, including opiates, is encouraged so that patients, instead of being treated for pain, are medicated in advance to avoid discomfort.

One cannot but be impressed by the almost evangelical atmosphere at St. Christopher's. Certainly, there are hypothetical weaknesses: the approach can hardly be cost-effective, and by limiting admission to those in the terminal stages of cancer, St. Christopher's has stacked the cards in its favor: such patients do not linger for long. Nevertheless, the Hospice fulfills a very real need, and the concept is enjoying tremendous popularity, particularly in the US where it has received enthusiastic (and financial) backing from the Department of Health, Education and Welfare. (CAPT P.F.D. Van Peenen, Liaison Technologist from the Uniformed Services Univ. of the Health Sciences, Bethesda, MD)

ONRL REPORTS

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RIFT VALLEY FEVER IN EGYPT

In August of 1977, an epidemic of an apparently new human disease appeared in the Nile Delta region of Lower Egypt. It waned by the end of the year, but, according to official estimates, only after affecting 20,000 persons and causing 580 deaths. Immediate worldwide interest was aroused, at least in part because the disease superficially resembled the highly virulent hemorrhagic fevers (Ebola, Marburg, Lassa) which have suddenly appeared in Equatorial Africa in recent years. The latter had been intensively studied epidemiologically by internationally-constituted teams working in crisis-like atmospheres. By contrast, in the case of this newest outbreak, the Egyptian government chose to handle on site investigations itself.

Fortunately, the Cairo-based US Naval Medical Research Unit No. 3 (NAMRU-3), which has enjoyed a virtually uninterrupted 32-year history of collaborative medical research with Egyptian colleagues was in a position to lend assistance.

NAMRU-3 had a staff of experienced researchers headed by Commanding Officer Capt. R.H. Watten, MC, USN and including such well-known names as Zoheir Farid, MD, tropical medicine specialist, and Harry Hoogstraal, PhD, zoologist, in addition to newcomer Lt. Jim Meegan, MSC, USN, virologist. In short order, Meegan isolated a virus from clinical specimens. But, using a wide range of diagnostic antisera available for pathogens known to occur in the area, he was unable to identify it. The isolate was taken to the Yale Arbovirus Research Unit where, to everyone's surprise, it was definitively identified as the agent of Rift Valley Fever, a disease previously known only from the Sub-Sahara.

This year, the NAMRU-3 personnel mentioned above, working with experienced Egyptian technicians and colleagues from the Egyptian Ministry of Agriculture have been energetically tackling the important question of how the disease got to Egypt, and which vectors are now transmitting it. The question is of great practical importance because the disease seems to be spreading and, being a zoonosis, is causing impressive loss of livestock in a country which badly needs every ounce of protein it can produce. The possibility that Rift Valley Fever may jump the border is a very real danger to neighboring countries and even to the US which has always had stringent regulations to prevent its entry. (CAPT P.F.D. Van Peenen, Liaison Technologist from the Uniformed Services Univ. of the Health Sciences, Bethesda, MD)

EARTH SCIENCES

GEOPHYSICAL FLUID DYNAMICS IS ALIVE AND WELL IN EUROPE

At the end of August, the Fifth European Geophysical Society (EGS) and the Sixteenth European Seismological Commission General Assembly met on the Campus of the Université Louis Pasteur in Strasbourg, France. This location was chosen for Strasbourg is a crossroad city that spans both French and German traditions and cultures and because the Louis Pasteur University has had a long history of scientific interest and expertise in seismology and geophysics.

As this was a large EGS meeting, I will limit myself to reporting on only one of the symposia, but before doing so let me say a few words about this recently formed Society. Through its annual meetings it seeks to provide an opportunity for scientists working in the geophysical sciences to meet and exchange ideas. Although the Society is European, its meetings are attended by scientists from other Continents. Younger scientists and research students are encouraged to participate, and the Society has a Young Scientist's Travel Award Scheme (limited to candidates not older than 27 years of age) that aids them in attending. This year, a maximum award of about $160 was given for this purpose. At present such an award is also open to US candidates. The next EGS meetings will be held in Vienna (mid-September 1979) and in Budapest (late summer 1980). Both will contain symposia devoted to geophysical fluid dynamics (GFD). The convener for the Vienna GFD symposium will be Dr. S. Tibaldi (European Centre for Medium Range Weather Forecasting, Bracknell, UK). US scientists interested in participating at these future EGS meetings should contact either Tibaldi or Dr. P. Davies (Univ. of Newcastle upon Tyne, UK).

The GFD Symposium was one of the largest at this combined conference, with more than 50 papers and some 60 participants. Its success attests to the well-being of GFD in Europe: Such countries as Ireland and Spain were represented in the symposium for the first time. The EGS program committee coordinator was Dr. S.A. Thorpe (Institute of Ocean Science, Wormley, UK); Prof. B. Gjevik (Univ. of Oslo, Norway) and Dr. P. Davies were the conveners; and because of their efforts this symposium was a success. There were four invited papers of 30 minutes each, while the contributed ones were 20 minutes long with five minutes set aside for discussion. The above format worked well, although longer coffee breaks might have stimulated additional discussions. The papers presented could be roughly divided into six topics: Thermal convection, topographic effects, shelf oceanography, turbulent mixing, internal gravity waves, and dynamics of large scale atmospheric flows. Rather than discuss each presentation, I will describe the highlights and refer the interested reader to the EGS compilation of abstracts of the various talks which may be obtained by writing to one of the conveners or by consulting a forthcoming issue of *EGS* in which they will be published.

Thermal convection is a central problem in fluid dynamics and more particularly in GFD for two reasons: We are surrounded by a fluid environment (oceans, atmosphere, Earth interior, etc...) in which destabilizing temperature gradients are present; the problem of thermal convection has been and still is a testing ground for new experimental and theoretical work which strive to understand the complex flow regimes that develop as the flow becomes turbulent. Since Lord Rayleigh was one of the first to consider this problem, a nondimensional number that bears his name enters these studies. It measures the relative importance of the destabilizing effects due to buoyancy versus the stabilizing tendencies due to the viscous dissipation of motion and diffusion of heat. Prof. E. Palm (Univ. of Oslo, Norway) presented the review paper on this subject and began by discussing theoretical and experimental results pertaining to unstable flows i.e., flows in which convection has begun. These exhibit a rich panoply of shapes and planforms that develop as a result of convection. The often publicized regular hexagonal cells first obtained by Bénard (for the wrong reasons) are examples of such planforms. Hexagons, rolls, cross rolls and zigzags are but a few of the name of shapes associated with the resulting flow patterns. As possible geophysical applications, Palm showed Tiros V cloud pictures that exhibited "spoke" patterns reminiscent of those seen in the experiments of Clever and Busse [*J. Fluid Mech.* 65 (4), 625 (1974)]. Palm discussed the difficulty of interpreting cloud pictures as convection patterns. Convection in the Earth core and mantle is another important geophysical application that deals with the study of the dynamo problem (origin of the Earth's magnetic field) and with continental drifts. Palm concluded his presentation by showing slides of fissure and stone polygons found in Spitzbergen, Norway, where large stones become sorted by a convection-like mechanism and form regular polygonal patterns on the flat ground; these shapes deform to parallel, uniformly spaced rows if the terrain exhibits a slope (see also *ESN* 30-7:301).

P.L. Garcia Ybarra and M.G. Velarde (Univ. Autonoma de Madrid, Spain) investigated convection in a binary gas mixture; instability can now set in for conditions under which a single gas would be stable. R.C.J. Sommerville (National Center for Atmospheric Research, Boulder, CO) and T. Gal-Chen (Univ. of Toronto, Canada) tested the accuracy of a numerical scheme on a convection problem previously solved analytically and experimentally by R. Krishnamurti (Florida State Univ., Tallahassee) who considered the effect of slow, uniform vertical motion on convection. Such vertical motion is a crude representation of vertical velocities induced by large-scale atmospheric flows. Except for some fine points, the numerical experiments are in agreement with observational and theoretical findings of Krishnamurti. R.M. Clever presented work done with F.H. Busse (UCLA, Los Angeles) and led us through the maze of various possible transitions and types of instabilities, and their corresponding planforms and shapes (some of which bear the descriptive names of zig-zag and skewed varicose).

Mountains are believed to play a fundamental role in large-scale atmospheric flow dynamics for at least two reasons: They are responsible for what

is called lee-cyclogenesis, i.e., the formation of low-pressure disturbances in the lee of the mountain range, and they interact with zonal flows and can extract energy from such flow. Let me first discuss the invited paper of S. Tibaldi on lee-cyclogenesis; he reviewed present knowledge and lack thereof in this field. His lecture dealt with a synoptic case study of flow over the Alps. He compared results of that study with those obtained from numerical models. Two mechanisms appear to be at work: The mountain range (*ESN* 31-6:239), acting as a barrier, deforms the low level thermal field which tends to be advected around the mountain while, at the upper levels, the flow proceeds unimpeded. Cyclogenesis in the lee of the mountain results from an interaction between these two mechanisms (for more details the interested reader is referred to A. Buzzi and S. Tibaldi, *Quart J. Roy. Meteor. Soc.* 104, 271). Numerical models appear to reproduce well the low level dynamics but fail to represent the mid-tropospheric conditions adequately.

The other important role played by the mountains was clearly presented by Prof. J.G. Charney (MIT, Boston) who described some far-reaching ideas pertaining to the interaction between large-scale atmospheric flows and topography. Very long waves that girth the globe with a few wavelengths tend to propagate westward with periods of 5 or 15 days. The 5-day period waves were followed 18 times around the globe. Their persistence, during some 90 days, excludes the possibility that they are free waves for viscous damping would erase such disturbances on time scales much shorter than this. Charney, J.G. Devore (UCLA), J. Peagle (Univ. of Utah, Salt Lake City), D. Strauss (MIT), and M.J. Suarez (UCLA) postulated that these disturbances could be forced by the fluctuations experienced by the zonal flow when topography is present. In the Northern Hemisphere, the large-scale topography exhibits a strong wavenumber two component owing to the presence of the Rockies and the Himalayas. Charney's far reaching conclusion asserts that the atmosphere possesses a quantized class of multiple equilibrium states which can themselves become unstable. The climate problem must now be viewed differently: the transition probabilities that the atmosphere lies in a given state must be taken into account before one can consider climate dynamics.

On smaller scales, when the Earth rotation can be neglected, flows over mountains produce peculiar types of internal gravity waves called lee-waves. Flows of this type containing moisture were considered by A. Barcilon and J.C. Jusem (Florida State Univ., Tallahassee) and P.G. Drazin (Univ. of Bristol, UK). They found that under stable conditions the presence of moisture can substantially decrease the drag exerted by the mountain on the air stream. N.T. Stevenson (Univ. of Manchester, UK) considered analytical solutions for lee-waves in the presence of dissipation. These theoretical findings were complemented by experimental observations using schleiren techniques. Still on small scales, K.J. Richards (Cambridge Univ., UK) discussed a numerical model capable of predicting waveforms generated in an open, turbulent channel flow over a sand bed. His results appear to agree well with observations.

Most of the papers in oceanography dealt with shelf related dynamics. L.P. Røed (Univ. of Bergen, Norway) presented work done in collaboration with J.R. Buckley (Seakam Oceanography Ltd., Sidney, B.C., Canada), and T. Gammelsrød, J.A. Johannessen, and O.M. Johannessen (Univ. of Bergen, Norway) on winter observations of upwelling at the edge of the Arctic ice pack. Most of these observations can be explained by theoretical predictions that recently appeared in the scientific literature [T. Gammelsrød, M. Mork, L.P. Røed, *Marine Sci. Comm.* 1 (2), 115]. The dynamics of river plumes and fronts associated with bodies of fresh water when they enter more brackish waters are of special interest, for the mixing that takes place in the frontal region, if artificially enhanced, could decrease the formation of ice that occurs at the river's surface. T.A. McClimans and S. Saigrov (River and Harbor Lab., Trondheim, Norway) considered hydraulic models to study these flows. They found that river plume mixing can be simulated in the laboratory with some success for rivers whose widths are much larger than their depths. L.P. Røed presented interesting results pertaining to a rather simplified model of inertial (i.e., nonlinear) coastal currents when the effect of the Earth's rotation is taken into account. These currents are assumed adjacent to a vertical wall which possesses curvature, and they can be controlled (in a hydraulic sense) by the curvature of that wall which can "block" a portion of the flow field ad-

jacent to it. Some of this methodology might be used to describe some of the Gulf Stream dynamics. Of significance, H.J. Kümpel and J. Zschau (Univ. of Kiel, FRG) discussed observations of extremely sensitive pendulums. Strong surges in the North Sea could cause a vertical pendulum, located some 70 km from the coast, to tilt by some tens of milliseconds of arc, an amount several hundred times larger than the accuracy of the instrument. The measured tilt precedes the surge in the German Bay area by some 12 hours. Data gathered over the last few years were used to simulate forecasts (hindcasts would be a better term) of very severe storm surges which hit the North European coasts during November and December 1975. All of the storm surges could have been predicted with remarkable accuracy. Embarrassingly, some of these predictions seemed to be superior to those obtained by numerical models of storm surges.

Understanding of the way in which turbulent transports of momentum and scalars such as heat, salt, or water vapor are accomplished in the atmosphere and the oceans is a difficult and fundamental problem. P.F. Linden (Univ. of Cambridge, UK) presented an interesting review paper on this subject. In these processes the nondimensional number of fundamental importance, called the Richardson number, measures the ratio of the potential to kinetic energy stored in a parcel of fluid. Linden showed that the assumption of uniform gradients in velocity and density must be relaxed if mixing is to take place. For nonuniform gradients in density and velocity the local Richardson number can be made as small as necessary for turbulence to form and mixing to take place. One of the central themes of this review paper dealt with the dynamics of interfaces. How do they form? Where does the energy for their formation come from? Why do interfaces remain sharp? etc. Linden discussed results of an experiment in which the energy source (mechanical stirrer) was located far from the interface. He found that the interface remains sharp if the initial Richardson number is large ($\sim$9). When that number reaches half this value, the interface is lost. He also discussed results of another of his experiments [*J. of Fluid Mech.* 87,(3), 417 (1978)] which describes how an interface sharpens or becomes erased.

S.C. Dickinson presented work done with Prof. R.R. Long (Johns Hopkins Univ., Baltimore, MD) that dealt with an experiment designed to test a theory that predicts the position of a turbulent front and its evolution in time. They found that the experimental results are in agreement with the theory which predicts a behavior like $t^{\frac{1}{2}}$ where t denotes time measured from the start of a mechanical stirrer. Some experimental results pertaining to the movement of a coaxial cylindrical turbulent front in a homogeneous rotating fluid were also discussed.

The review paper on internal gravity waves was given by Thorpe. He pointed out that waves, which are generated when a stable density stratification is disturbed, were, in the past, considered a nuisance by oceanographers. His presentation was enlivened by some very interesting movie sequences showing formation and evolution of such waves in a long tank. The tank was filled with a stratified brine solution and tilted impulsively so as to produce a density stratified flow in which velocity varied with depth. Using such visual observations, he discussed the formation of lee-waves and the role played by the layer at which the wave-velocity equals the velocity of the stream (critical layer). No disturbance was seen to propagate upwards from such a layer. Also, various stages leading to the breaking of the internal waves were seen. Thorpe pointed out that the atmosphere and oceans exhibit a very different internal gravity-wave spectrum, for in the ocean the spectrum exhibits a distinct separation of scales between the internal gravity waves and other types of motions while the atmospheric spectrum shows no such scale separation. S.A. Maslowe (Imperial College of Science and Technology, Univ. of London, UK) discussed the propagation of solitary internal waves when their wavelength is long compared to the depth of the region on which they propagate. Using a layered model, he proceeded to find exact solutions for that model and discussed some of the implications of these solutions which have not yet been observed in nature.

In conclusion, the intellectual stimulation found in the topics presented at the Symposium on Geophysical Fluid Dynamics, coupled with the charm of Strasbourg made it a very worthwhile meeting. (Albert Barcilon, Geophysical Fluid Dynamics Institute, Florida State Univ., Tallahassee, FL)

WEATHER AND SEA PREDICTION

The Tenth International Liège Colloquium on Ocean Hydrodynamics was held on the Sart Tilman campus of the Université de Liège, Belgium from 8 to 12 May 1978. There were 32 lectures of which several were invited scholarly reviews. Four of the invited lecturers (Prof. Dr. S.A. Kitaygorodskiy, USSR Academy of Sciences, Moscow; Prof. Roberto Frassetto, Laboratorio per la Studio della Dinamica delle Grandi Masse, Venezia, Italy; Prof. Robert O. Reid, Texas A&M University, College Station; and Prof. James J. O'Brien, Florida State University, Tallahassee) were awarded the Medal of Honour of the Université of Liège. The 75 participants from 14 countries were a mixture of engineers, modelers, meteorologists, and oceanographers, all of whom appeared from the discussions to be learning from each other. For the purpose of this article the papers will be discussed in three major categories: (a) storm surges, (b) wind induced coastal currents, and (c) wind generated waves and atmospheric effect on mixed layers of the ocean.

Storm Surges. The largest number of papers (about one third) dealt in some manner with the problem of storm surges. Reid opened the meeting with an excellent review of the storm surge modeling literature. He noted that before 1950 the modeling of storm surges was one dimensional, that in the 1960s numerical models were increasing, and that by the 1970s sophisticated multidimensional models had been introduced. Reid devoted most of his lecture to the following aspects of contemporary storm surge modeling: (a) bottom friction, (b) stratification effects, and (c) effect of waves. He went into considerable detail on recent work, considering transient bottom boundary layer conditions and the apparent failure of traditional coefficients especially in the case of a nonsmooth bottom. His presentation suggested that the problem may be overcome by the use of closure schemes, involving formulation to simulate the varying vertical exchange coefficients. Reid continued on the sub-topic of stratification effects, with specific reference to the production of baroclinic currents in shallow water estuaries. The effect of surface waves or storm surges raised questions regarding the drag coefficient and wave set-up, wave induced drift (geostrophic tilt), waves feeling the bottom (bottom stress), and on a larger scale the effect of waves eroding barrier islands. Finally, the advantages and disadvantages of the techniques used by modelers, such as, finite differences and finite elements, were briefly discussed.

The latter topic stimulated much discussion during the week, and was taken up in the second paper of the Colloquium presented by Dr. W.C. Thacker (National Oceanic and Atmospheric Administration, Sea-Air Laboratory, Miami, FL). Thacker suggested that irregular shore line features can be incorporated into storm surge calculations by applying an irregular grid finite-difference technique which appears to be similar to finite-element techniques and which is less expensive to run on the computer. However, as was brought out in the discussion, the model must be thoroughly tested with comparisons to real wind and real surge situations.

Dr. Norman S. Heaps [Institute of Oceanography (IOS), Bidston Observatory, UK] presented work dating back more than 25 years. From early one-dimensional plate models of the Irish Sea, Heaps was able to deduce some of the mechanisms such as the resonance of the Irish Sea and the wind set-up time (5-6 hours) related to storms moving across the Irish Sea at 20 m/sec. These storms are secondary lows that are no older than 18 hours when they produce the surges. A 14-ft surge at Avonmouth in January 1976 and a 6-ft one at Liverpool in November 1977 were cited as triggers for the accelerated effort to improve the public forecasts. Fortunately, for more than 20 years, basic research scientists had been developing theoretical techniques, and during the last 4 considerable progress has been made. The schemes developed require input from the dynamic finite-difference 10-level fine-mesh atmospheric model now in use by the British Meteorological Office for operational weather prediction. Some preliminary results at North Sea ports using the basic scheme for a coarse grid covering the entire Northwest European continental shelf were reported by Dr. R.A. Flather (IOS, Bidston). The results were good, and an operational test is scheduled for the winter of 1978-1979.

Other papers offering prediction schemes for storm surges included a report by Prof. Dr. Günther Fischer (Me-

teorologisches Institut der Universität, Hamburg, FRG) on a test of hindcasting the 3 January 1976 surge at North Sea ports. As in the British scheme input from a German Weather Service operational eight-level atmospheric model was used. The University of Hamburg used a higher drag coefficient, and the surface geostrophic wind was computed from the atmospheric prediction model. Even with some post manipulation, the Hamburg model appeared to have some trouble on the continental coast of the North Sea. Dr. J.O. Backhaus (Deutsches Hydrographisches Institut, Hamburg, FRG) reported on results with a three-dimensional fine-mesh North Sea model using the 3 January 1976 data. As in the case of the British, this applied model was based on an earlier one developed at the Institut für Meereskunde, Universität Kiel. This multilayer barotropic model uses constant wind stress, but a nonlinear bottom friction term. Backhaus reported that for the case studied, the tidal surges and circulation patterns for the German Bight were reproduced. Dr. Francois C. Ronday (Université de Liège, Belgium) described a numerical technique to forecast tides, storm surges, and circulation in the English Channel and its vicinity. Interestingly, the eddies, one cyclonic and the other anti-cyclonic, were indicated by the computation. Dr. Y. Adam (Ministére de la Santé Publique et de l'Environnement Bruxelles, Belgium) presented the Belgian applied scheme for forecasting storm surges, which like the British one, is scheduled for operational tests next winter. The Belgian scheme has a coarse grid and uses coarse-grid data input from the British atmospheric prediction model. Not surprisingly, their results are not as finely tuned as the British. All of the efforts to improve storm surge forecasting have used older basic work on the problem, accomplished when the frequency and height of storm surges were of purely academic curiosity, and not as now of serious economic concern.

Economic and social pressures in the UK and on the Continent have accelerated the development and implementation of new techniques for forecasting storm surges. In Venice Frassetto is leading a scientific effort to improve the forecasting of flooding (storm surges) of the city, the frequency of which is increasing. Reportedly last year museums, merchants, and residents were warned to move their valuables to higher positions no less than 30 times. Fortunately many of these evacuations proved unnecessary, as the water did not rise to damaging levels, however, as the city sinks (20 cm per century) and the climatic changes result in more storms passing over Venice, the prediction problem must be solved. Frassetto's group has studied tides, seiches, and other periodic oscillations of water level in the Gulf of Venice. They know there is a period of 12 to 15 days for maximum sea level occurrence, that a storm pulse will cause a 22-hour period in water height, and that 25 m/sec wind set-up will push up to 2 to 3 m of water (as in April 1966 when Venice was flooded). They now know that the Adriatic response time to the wind is 6 hours (about the same as for the Irish Sea), and that 35% of the flood cases are from rapid local cyclogenesis (secondary lows) as in the Irish Sea. Currently Venice can and does have a good 6-hour flood forecasting procedure, but economic factors demand a 24-hour forecast capability in order to close the port floodgates and properly divert and reschedule the commercial shipping traffic. These conditions have forced Frassetto's group into meteorology as to forecast Venice's flooding more than 6 hours in advance requires forecasting new secondary low developments at least 24 hours in advance. Unfortunately this remains a major problem in meteorology, but as Frassetto stated, the Ligurian Sea with the nearby Alps and network of observing stations may provide a natural laboratory for study of this type of cyclogenesis.

Wind Induced Currents. For the purpose of this report, storm surge papers have been arbitrarily separated from presentations that emphasized wind-induced coastal currents. The most eloquent paper on this subject was by Prof. Dr. J.C.J. Nihoul (Université de Liège, Belgium) who has carefully developed a North Sea model that incorporates variations of the eddy viscosity with depth. The model is somewhat like N. Heaps' model for the Irish Sea. In Nihoul's model, an analytical solution of the Ekman equations, with variable eddy viscosity, is formulated in terms of wind stress, the vertical mean current, and associated height of the sea. The solution is accomplished layer by layer. The model is three-dimensional with the capability to predict at each grid point the elevation of the sea, vertical mean current,

and a vertical profile of velocity. My interpretation is that Nihoul used a logarithmic function to represent the eddy viscosity near the bottom, then a parabolic function for intermediate depths, and a linear function near the surface. Tests of the model revealed that in the North Sea winds exceeding 10 m/sec can generate currents of up to or greater than 1 m/sec.

Other coastal current papers included one on a numerical modeling technique to simulate water circulation in Lake Geneva, and a report on the experimental application of a Belgian model to forecasting coastal currents already discussed in regard to storm surge forecasting. Topics in this area ranged from surf zone to "blue water" ocean currents. Mr. A. Hauguel (Laboratoire National d'Hydraulique, Chatou, France) discussed a model for longshore currents in the surf zone. As Hauguel pointed out, these currents are important for scouring around shore installations, as their maximum velocity is as great or greater than tidal ones. From the numerical model for longshore currents, the height and direction of waves are calculated by using a ray refraction technique, then the currents (assumed to be steady in time) are taken into account to compute the wave propagation. From the surf zone it is natural to progress to coastal current papers. One was presented by Dr. Alan J. Elliott (NATO's SACLANT Anti-Submarine Warfare Research Centre, La Spezia, Italy) who reported results from a study of low-frequency near-bottom currents at a depth of 80 m at two locations about 100 km apart off the west coast of Italy. There appeared to be no significant coherence between any of the wind and current records; however, sea level did show coherency to synoptic-scale wind field, but not to local winds. The current mooring data indicated that currents north of the Elba River flowed parallel to the local coastline, with characteristic periods of 10-20 days.

Dr. Seto Sethuraman (Brookhaven Naticnal Laboratory, NY) discussed a study on the mechanisms of near surface wind-generated currents in the Atlantic Ocean about 10 km off Long Island. The statistical studies reported by Sethuraman indicate that wind-generated ocean currents are related to the steepness of the surface waves accompanying changes in the wind direction, as for example, with the passage of a synoptic scale atmospheric front. He reported that the surface shear stress increased by 4% following a frontal passage, and that wind-generated currents increased after frontal passage to about 8% of the wind speed. The Brookhaven work appears to be a very good observational program, obtaining much needed real world data.

Limitations in predicting oceanic baroclinic coastal circulations were discussed in detail by O'Brien. He addressed four: (1) physical approximations in deriving the fundamental equations; (2) standard implications to the basic equations; (3) errors due to numerical approximation; and (4) boundary conditions, initialization, and data input. Reid continued the last theme with an eloquent discussion of open boundary conditions.

Wind Waves and Mixed Layer. The remainder of the papers at the Colloquium dealt with atmospheric effects of the ocean's mixed layer and wind-generated waves. The keynote paper for each of these topics was presented by Kitaygorodskiy. In his first he described, in a tutorial way, a box model which considers the entrainment of heat flux in the shear zone. He discussed the three fundamental equations used, namely, turbulence, heat, and momentum conservation (the turbulent energy equation and potential energy change being due to entrainment), and presented three ways of closing the problem, all of which require computing small differences between large terms. To obtain realistic values of the Richardson number, he enlisted help from laboratory experiments of S. Turner (Cambridge University, UK) and O. Phillips (Johns Hopkins Univ., MD). In his model, the initial stratification demands precise bathythermograms and routine meteorological data. Interestingly, he reports heat flux is not related to mixed layer depth, but stressed that entrainment is most important.

Later Kitaygorodskiy presented another excellent lecture on the wind wave forecasting problem wherein he reviewed the literature, particularly O. Phillips' hypothesis and his own work. He noted that according to theory (*i.e.*, Phillips), waves grow too slowly. He approached the wave generation problem from a turbulence viewpoint, and concluded that this approach to wave generation is better than the earlier theories for shallow water. Wave papers included both those with observational data and numerical models. An example

of the observational papers was that by Dr. Mark Donelan (Centre for Inland Waters, Canada) who presented laboratory and field measurements of the air-water momentum transfer as related to wave spectra measured at various fetches, reporting that the fraction of momentum remaining in the wave field is up to 20% of the total transferred across the air water interface. Dr. W. Rosenthal (Max-Planck-Inst. für Meteorologie, Hamburg, FRG) discussed a numerical wave prediction model based upon a hybrid approach using wind sea state (a classical source function), and provision for swell. The model appeared to work well using an actual wave data set.

The Tenth International Liège Colloquium on Ocean Hydrodynamics was an outstanding success. For further details see the proceedings which will appear in the Elsevier Oceanography Series. (Paul F. Twitchell, ONR, Boston, MA 02210)

ENGINEERING

ULYANOV (LENIN) ELECTROTECHNICAL INSTITUTE

The Ulyanov (Lenin) Electrotechnical Institute in Leningrad, founded in 1886, is said to be the oldest Institute in Europe on electrotechnology. Originally the telegraph was the primary interest. Prior to the revolution work began on electric power systems, and after the revolution significant contributions were made to the development of the plan for the electrification of the USSR. Later in the 30s and 40s, efforts in electric devices and electronics were undertaken.

The first rector of the Institute was Alexander Stepanov Popov after whom the Popov Society is named. This Society was the host to IEEE exchange group of which I was a member on my visit to the USSR (see the proceeding issue *ESN* 32-11:368). Some 12,000 students now attend the Institute, of whom 35 to 40% are female. There are more than 1000 faculty members, 120 of whom are professors and doctors of science, and three of whom are corresponding members of the Academy of Sciences. The undergraduate degree requires 5½ years to complete, and is said to be equivalent to a US Masters degree. A year before graduation, students are assigned to other organizations where diploma work is completed. About 85% of the graduates go to industry, the remainder to research institutes. The better students are said to receive offers of 4 to 6 positions. Although a committee ultimately makes the assignments, the wishes of the students weigh heavily in the decisions. The graduate must remain for 3 years in his first assignment, after which he is free to seek another. Beginning pay is 120 to 140 rubles per month ($170 to $200 per month). After 5 years of work every engineer must undertake additional education. Typically this consists of alternating 3 days of work and 3 days of schooling for a period of 6 months. He must also complete a research project.

At present there are about 500 foreign students at the Institute. Foreign graduates, numbering about 1500, have come from countries and areas such as Poland, Czechoslovakia, Bulgaria, Hungary, Africa, Asia, Cuba, and South America.

Three fields of general concern to the Institute are (a) physics of solids and microelectronics, (b) radio technology (including communications, broadcasting, and television), and (c) the theory of control and calculation technology. We were given brief tours of and discussions on microelectronics, the computer center, medical electronics, and the Popov Museum.

Microelectronics. In the microelectronics area interests include production technology, functional electronics, optical electronics, acoustic electronics, computer-aided design (CAD), metal-oxide semiconductors (MOS) and bipolar technologies, testing (built-in testing), and microprocessors. Emphasis is on instruction, research, simple demonstrations, and design. Fabrication is accomplished mainly in collaboration with industries such as Svetlana, Positron, and others. Although ion implantation techniques are taught at the Institute, there are no in-house implantation facilities. However, a very ambitious building program is underway at the Institute (attesting to the serious intent of the Soviets in this area), and microelectronics processing laboratories are included in this program. Interestingly, the new buildings have much greater aesthetic appeal than is the norm for Soviet architecture.

Questions regarding current industrial technologies yielded little in the

way of information. For example, we were unable to learn what kinds of logic (TTL, ECL, I^2L, etc.) are utilized. We were told, however, that emphasis is on 8- and 16-bit devices for automatic production control, that yields are of the order of a few percent for chips 2 to 6 mm on a side with 5,000 to 12,000 gates, and that 32- and 64-pin packages are used.

Computer Center. A tour of the Institute's computer center revealed an array of computer equipment with ES (EC in Russian) designations of 6012, 6022, and 7022, and Minsk 32. Carl Zeiss (Jena, GDR) magnetic tape units were in evidence. The center is getting a new several-megabyte ES-1065 system, which will accommodate 100 to 200 terminals. Present capability includes 512-K core memory, 600-nsec access time, 1.2-μsec cycle time, 200-nsec clock time, and 7 megabytes of disc memory. FORTRAN and other US computer languages (in English) are used, and we were told there is no interest in converting to the Cyrillic alphabet.

Department of Biomedicine and Protection of Environment. Although this title implies a broader mission, this Department was said by our host, Lenin Prize winner Dr. V.M. Akhutin, to be the first department of medical electronics in the Soviet Union. Akhutin's primary interest is the application of electronics to health care delivery for remote regions of the USSR. To illustrate the nature of his work he showed us photos of aspects of the system in operation in the Azerbijian Republic, which is populated by two million people served by one hundred physicians. It is not practical to place a clinic in every village, and so a large center was established in Baku, a large city. In addition to medical facilities the center has at its disposal communications facilities, a computer, ambulances, helicopters, and fixed wing aircraft. The computer is the "brain" of the center, storing medical information, providing consultation information to physicians in remote locations, regulating dispatch of assets, decyphering EKGs, etc. Physicians carry special devices that allow them to digitize medical data near the patient and to transmit the data via telephone or radio. The distortion vulnerability of analog data transmission is thereby avoided. Distance from the most remote village to the center in Baku is approximately 300 km. Pictures of the operating room in Baku revealed a large digital display with digits 4.5 cm high presenting data on temperature, heart rate, respiration rate, etc. The intensive care room features special displays for each bed.

Akhutin noted three areas in which improvements are being sought, viz., (a) communications within the hospital, (b) communications between patient and computer, and (c) galvanic-contact-free sensors for monitoring patients.

Preventive medicine is endorsed and encouraged in the new Soviet constitution. We were shown a photo of an instrument that will be utilized in a preventive medicine program. It answers and records sixteen biological parameters in four minutes and does not require that the patient undress. In the proposed scheme each patient will have a card which stores his medical data. This is inserted into the instrument while his medical parameters are being determined, and any deviations from tolerance are signaled.

In a tour of his laboratories, Akhutin mentioned instruments to be used in training swimmers and in monitoring their performance so as to attempt to predict the probability for their success in the Olympics. He voiced words to the effect that this would bring victory to the Soviet swimmers—but appeared in fact to be joking about the difficulty of competing with the East Germans, who so dominated swimming in the last Olympics.

The Alexander Stepanov Popov Museum. Soviets refer to Popov as the father of radio, and this museum contains an interesting collection of his transmitters, receivers, and related memorabilia. In 1895 he achieved communication over a distance of 80 m, extending this in 1899 to 25 miles. On exhibit at the museum is a North American Philadelphia newspaper dated September 11, 1901, that reports Popov's 260-mile wireless link between North America and a ship in the Atlantic. Although Marconi is generally accorded significantly more credit internationally for the overall development of wireless communication, there can be little question that Popov was a very significant contributor. (Ted G. Berlincourt, Office of Naval Research, Arlington, VA)

MECHANICAL ENGINEERING AT THE UNIVERSITY COLLEGE OF SWANSEA

The University College of Swansea has a well-developed program in the Department of Mechanical Engineering from the undergraduate level through doctoral studies. The Department's research program in the field of lubrication is a particularly distinguished one, and hence most of this report will deal with this and with the program in human reaction to vibration. During my visit, I was conducted around the Department and shown the various facilities by Prof. F.T. Barwell, Head of the Department, who is retiring soon.

Research in lubrication takes place at the Swansea Tribology Centre, which is a contract research organization carrying out applied research, development, and design work for industry. Examples of activities at the Centre are: The design and kinematic behavior of rolling contact bearings including measuring the stresses that develop in rolling contact and the performance of complete bearings; the evaluation of fluid and solid lubricants and dry bearing materials; the analysis of failures in industrial plants; the redesign of installations to avoid recurrence of failure; the design assessment and actual design for new plant installations; and the training of engineers in tribological subjects.

The wear of surfaces and the effect of additives for lubricants in diesel engines are being studied by Mr. Mervyn H. Jones. An important instrument in these studies is the ferrograph, which is a magnetic chip detector. In the ferrograph, oil containing chips is run down a thin glass slide placed against a powerful magnet. The magnet attracts magnetic particles from the oil and precipitates them against the slide. Since the larger particles are precipitated earlier than the smaller ones, there is a gradation in particle size that can be observed on the slide in the direction of flow. The particles are then counted, using optical techniques, and their characteristics are noted. For instance, particles caused by the sliding contact between surfaces as in equipment being run-in have the same characteristics as those that occur in machining. Slip failures are involved here. In the case of rolling contact between surfaces, failures of the surfaces are caused by fatigue, and hence the surfaces spall and the particles observed have sharp, jagged edges. Failures caused by combined sliding and rolling result in large bits being broken out of the surface. In the case of nonmagnetic particles, the lubricant is doped with an additive that adheres to the particles and makes them magnetic. The process of analysis then is the same as for magnetic particles. Barwell, being interested in the arthritic degeneration of joints in vertebrates has also studied the suspension of particles in the synovial fluid that lubricates such joints.

The question of a proper strategy for the lubrication of engines was then discussed. Is it proper to change the filter of an engine but to keep the old lubricating oil, or to change the oil and keep the old filter? At Swansea they have noted that the old filter is partially clogged with particles from the mating bearing surfaces and therefore seems to do a better job of filtering the lubricant. However, the danger that the filter may become so loaded with particles as to cause too great a pressure drop in passaging oil through the filter is a consideration that mitigates keeping the old filter indefinitely. It was also noted that if the oil is used for too long a period, the long-chain additive molecules are broken and the lubricating properties of the oil degenerate.

An on-going study of the traction behavior of elastohydrodynamic lubricants that behave like elastic solids under extremely high pressure is under the direction of Dr. Brian J. Roylance. Such lubricants are useful in traction drives when at the point of contact, the pressure renders the lubricants solid and the traction afforded can become high. These lubricants have been studied for rolling contact applications in continuously variable speed transmissions. The application of such lubricants has also been studied for gears, however, the difficulty here is that the point of contact between the mating gear teeth experiences sliding as well as rolling at all points along the line of action except the point on the common axis between the two gears. Another generalized effect of lubricants as applied to gears is on inter-grain stresses in the materials of the gears or other mating surfaces. Where a material is made up of many crystal grains whose properties are not the same in all directions the random

orientation of the grains causes high stresses between the grains when an overall stress is applied to the polycrystalline material. In the case of contact stresses during rolling, the point of contact represents a small area and the force transferred through it is great; the overall stress applied to the material then causes extremely large stresses to exist between separate crystal grains. If a lubricant is used that can separate the mating surfaces appreciably and thus spread the load over a larger contact area, the intergrain stresses will be reduced and rolling fatigue failures will be decreased. Such effects are also being studied by Roylance.

The problem of turbulent flow journal bearings is under investigation by Dr. John O. Medwell. In this study an apparatus containing a 2½-in.-diam. shaft can be run to speeds of 60,000 rpm's per minute with bearing clearances varying between two and five thousandths of an inch and eccentricity ratios of 0.7. The eccentricity ratio is the distance between the centers of the journal and the bearing divided by the average radial clearance. In the apparatus, Reynolds numbers up to 10,000 are achieved, based on a scale length of the clearance and a velocity scale of the relative velocity between the two surfaces. The main thrust of these studies is to arrive at an optimum design of lubricant inlet for the best heat transport from the bearing. The apparatus contains temperature probes, and thus far there has been no difficulty in convecting away the heat dissipated in the lubricant.

The program on human reaction to vibration is under the direction of Mr. M.J. Clark. Apparatus that simulates the vibratory conditions in railroads, helicopters, hovercraft, and the like, is used to subject an individual in a seated or standing position to either a sinusoidal or a complete spectrum of excitation. The studies here, carried out in conjunction with the Department of Psychology, seek to establish quantitative criteria regarding comfort in the use of hand tools such as pneumatic drills and chain saws, and the degeneration of human tissue including loss of circulation and sensitivity in the hands.

Various studies in two-phase flow, aerodynamics of high-speed vehicles, unsteady flow through turbines, compressors, and pumps; surging of flow through fans and associated flow systems; the excitation of acoustic and mechanical oscillations due to vortex shedding; and flow-induced vibrations involving nonlinear stiffness complete the picture of the Department's research program. (Martin Lessen)

MATERIAL SCIENCES

INTERNATIONAL CONFERENCE ON DEFECTS AND RADIATION EFFECTS IN SEMICONDUCTORS

The International Conference on Defects and Radiation Effects in Semiconductors, held in Nice, France, in September 1978, was one of a group of three small specialty semiconductor conferences timed to bracket a very large one in Edinburgh. The Conference forms part of a series that has had a substantial history as it was the tenth meeting, and therefore in view of the roundness of that number, it may be especially valuable to attempt to assess where the field stands. To state a conclusion briefly at the beginning, it seems to us that the field is promising and that we are probably in the early part of the S learning curve with prospects of rapid growth in the next few years. It has been a long time coming. (By contrast, the color centers in alkali halides that are also formed by radiation are very well understood, and this area seems to be nearing maturity.) Considering the apparent difficulty of the study of defects and radiation effects in semiconductors, what is it that continues to push the investigators? From a practical point of view there are two sets of problems to be solved. One arises from the discovery that ion implantation is sometimes a very useful way to dope semiconductors. However, the process inevitably also creates radiation damage that normally has a deleterious effect. Knowing what this damage is and how its optical, thermal, and electrical properties may be controlled is obviously very pertinent. The other point is that impurities and defects in semiconductors are the basic building tools for devices. Their origin, diffusion, and annealing are all part of the great explosion in semiconductor technology. Here we are at the heart of the business.

The opening sessions of the Conference were devoted to theory. It is here that there seems to be the greatest opportunity for progress. Within the last year a large number of theorists have begun to tackle the problem in new ways. To be of maximum usefulness in identifying the nature of defects, a theoretical calculation of trap levels accurate to 0.1 eV would be needed. Consider for a moment a simple defect in silicon formed by removing a silicon atom from its normal position. The atom is bonded to its four nearest neighbors in a tetrahedral array. Therefore the vacancy is surrounded by four dangling bonds. These lead to multiple energy levels as electrons are added to the vacancy, and one wants to calculate them. In such a calculation there may be more than one electron in the center, thus the electron-electron interaction should be included in some way, and various ways of doing this are all approximate. If a number of electrons are involved, the degeneracy of some of the levels may be lifted by Jahn-Teller splitting. Experiments that use pressure to align random Jahn-Teller splittings show that the splitting energy may be of the order of a half to several eV. If a vacancy is formed, the nearest neighbors will relax to new equilibrium positions. In one case calculated by M. Jaros (The University, Newcastle upon Tyne, UK) distortions of 0.1 to 0.2 A were involved, and the energy change resulting from the distortion was 1 eV.

There have been numerous calculations to attempt to solve the problem or parts of the problem of calculating energy levels in semiconductors. It is probably fair to say that the approximations involved make the absolute values of the energy levels unreliable, but differences between two calculations using the same approximations are often quite useful in a qualitative way.

Within the last year, groups at Bell Laboratories and IBM, as well as Jaros and his collaborators, have been exploring a new approach. G.A. Baraff and M. Schlüter (Bell Laboratories, Murray Hill, NJ) discussed their work in this regard. Their calculations are based on a scattering type Green's function that is evaluated using the unperturbed eigenstates and energies of a self-consistent pseudopotential bulk crystal calculation. The perturbed crystal wave functions are expressed as a linear combination of atomic orbitals (LCAO) expansion using orbitals centered on atomic positions lying within the range of the impurity potential. The Green's function equation is subsequently iterated to produce a density matrix which is then used to construct a new impurity potential within the local density formulation. The whole process is repeated until self-consistency is achieved. Unfortunately, numerical results for a relaxed vacancy in silicon had not yet been obtained at the time of the meeting, and it is left to the future to learn how useful this new approach will be for calculating energy levels, wave functions, relaxations, and charge densities for defects in semiconductors. However, charge density distributions have been developed for pure crystalline Si and for the case in which a single Si atom has been removed. These plots give a much more detailed description of what a "bond" is between Si atoms and what a "dangling bond" looks like when one atom is removed.

Among semiconductor materials, silicon is both most widely used and best understood. G.D. Watkins (Lehigh University, Bethlehem, PA) reviewed the knowledge available on vacancies and interstitials in Si. From theoretical calculations it is expected that a vacancy can introduce as many as four energy levels into the forbidden band gap of Si depending on the number of electrons or holes trapped at the vacancy. While a number of energy levels have been found in silicon using older techniques such as electron paramagnetic resonance (EPR) and newer ones such as deep level transient spectroscopy (DLTS), Watkins felt that only one electrical level—a hole trap about 0.11 eV above the valence band—could definitely be assigned to the silicon vacancy. The evidence here rested on similar annealing behavior of the EPR, which identifies the center, and the DLTS, which gives its energy level. Further studies have given the energy of migration of the vacancy and followed it as it becomes associated with impurities such as Ge, B, and O.

When vacancies are created by irradiation in p-type silicon, the ejected atom becomes an interstitial that is mobile even at liquid helium temperature. It may diffuse to a substitutional impurity, be trapped there, and exchange places with the impurity atom so that the impurity is now in an interstitial

position. In n-type silicon, irradiation produces pairs of vacancies rather than isolated vacancies. R.H. van der Linde and C.A.J. Amerlaan (Univ. of Amsterdam, the Netherlands) showed that these divacancies could be aligned by stress or by illumination in their absorption band with linearly polarized light. Even at temperatures as low as 15 K, however, this alignment disappears in a few minutes.

There is a great deal of interest and activity in the use of the III-V compounds, such as GaAs and GaAlAs, in devices. The understanding of the nature of defects and irradiation effects in these materials is considerably behind silicon. However, a major advance was reported by T.A. Kennedy and N.D. Wilsey (Naval Research Laboratory, Washington, DC) who found an EPR spectrum for the gallium vacancy in heavily zinc doped GaP after electron irradiation. This appears to be the first clear EPR spectrum in a class of materials for which it was predicted, even at this Conference, that none would be found.

The II-VI compounds were reviewed by Paul Dean (Royal Signals and Radar Est., Malvern, UK). His main conclusion from very elaborate analysis of low temperature luminescence and excitation spectra is that the edge emission of ZnSe and ZnTe shows no evidence of involvement with vacancies or other intrinsic defects. His work has been reviewed more completely in a recent article in *ESN* (32-11:391). Other studies reported at the Conference were involved with Ge, diamond, hydrogen in Si and Ge, and the effects of dislocations.

Two presentations dealt with Mössbauer spectroscopy of Co in Si and of Sn in GaAs. This method combines some of the virtues of a trace method with a defect specific method like EPR, allowing one to distinguish different sites in the crystal.

Because of their practical importance, a great deal of attention has been given recently to diffusion of defects and impurities in semiconductors and to the use of ion implantation followed by laser annealing as a way of doping semiconductors.

The diffusion results seem to be far from clear. It is difficult to decide what are the basic processes in Si and Ge. The additional complications introduced by radiation enhanced diffusion and the interaction of impurities when several are present makes this a technically important area that is now imperfectly understood at a basic level. One positive result is that diffusion of self-interstitials in Si is now considered dominant over vacancy mechanisms.

Ion implantation has been going on for some time; during the last year or two in the West there has been a great interest in the use of laser annealing which was first studied in the USSR. The process that is widely used is as follows: Under ion bombardment a thin layer of the semiconductor is made amorphous, and this layer traps a high concentration of the bombarding ions. A short laser pulse of a few joules/cm^2 melts the amorphous layer and perhaps a small amount of the crystal substrate. After the laser pulse ends, the liquid solidifies by growing as a single crystal from the substrate. This makes it possible to achieve a higher concentration of impurities in the semiconductor surface layer than can be achieved by ordinary diffusion. At the same time, the laser annealing succeeds in removing the radiation damage resulting from the ion implantation. Care must be taken to put in enough laser energy to melt all of the amorphous layer while not using so much that the final surface becomes pitted or unregular. All in all the use of laser annealing seems to be a useful tool to add to the armory of techniques available to the semiconductor device developers.

In giving a closing review at the Conference, J.W. Corbett (New York State Univ. at Albany, NY) said that the field is past the slow initial growth and is poised for a rapid advance. He suggested that theory may be becoming sufficiently precise to allow identification of centers from predicted energies. A wide variety of sophisticated measurement tools is now available. Corbett indicated that these are most effectively used when several are brought to bear cooperatively on the same problem.

The Conference, though small, was an extremely active and lively one spreading in many directions with great energy. The proceedings will be published by the British Institute of Physics next year. Surprisingly, the attendance at the Conference held up well even though the weather was at its end-of-the-summer best and the beach at Nice was just across the street luring delegates with its

macroscopic and microscopic charms. With the Conference running from 0900 to 1800 hours, the only way to leave with a Mediterranean glow was to eliminate lunch in favor of sun. For many that sacrifice was painful but still well worthwhile. [(Clifford C. Klick and A.K. Nedoluha, US Army Research and Standardization Group (Europe)]

STRESS CORROSION TEST METHODS

In stress corrosion testing, as in "punk" fashions, there is apparently nothing new under the sun. Imagination and variety abound, as I observed at the annual meeting of the European Federation of Corrosion's Working Party on Stress Corrosion Test Methods held 19-20 September 1978 in Firminy (Loire), France. Unlike many other meetings on stress corrosion cracking (SCC), this one was not concerned with mechanisms of the failure process, but with the rather specialized aspect of electrochemical methods of testing and predicting SCC behavior. Prediction of the potency of the environment in promoting SCC in alloys constitutes one of the major problems in avoiding service failures, and the meeting was entirely concerned with this aspect. This is not to say that the topic of SCC testing has nothing to contribute to the understanding of cracking mechanisms. Clearly, the study of mechanisms and the prediction of service behavior are areas that cannot be separated, and each makes valuable contributions to the other. A total of 30 papers were included in the program, including two invited reviews, given by Prof. R.N. Parkins (Univ. of Newcastle upon Tyne, UK) and Dr. M. Keddam (Univ. of Paris, France); the rest were shorter papers with very generous discussion periods. The meeting attracted about 90 attendees to the pleasant locale in the hills of southern France. Although 8 countries contributed to the program, the meeting was mainly Franco-British, with two-thirds of the papers from these two countries. About half the attendees were from France.

There are numerous tests for SCC, which can be grouped into two categories: 1) those that discriminate between susceptibility to SCC for various members of a family of alloys in a given environment, and 2) those that provide information about the environmental conditions which lead to SCC. Both types of test have their uses, but it is the latter type that provides the designer with more significant information, because he wants to keep well away from SCC in general and doesn't particularly care whether one alloy is only slightly better than another in this regard. In the introductory lecture, Parkins noted that the physical metallurgy and fracture mechanics of SCC have been extensively studied, and there is now fairly good working knowledge of both aspects. In other words, we know quite accurately how to determine K_{ISCC}, and we can conduct alloy screening tests, but we cannot always accurately answer the question: "Will alloy A stress corrode in environment B?" Usually unless there is prior service experience, we cannot definitely predict the behavior. We know, of course, that conditions for SCC are highly specific, that there are certain environments that can lead to SCC in certain alloys, that there are specific ranges of potential and pH that favor SCC, etc. However, the designer needs specific information about the kind of environmental conditions to avoid in a given case (chemical concentrations, temperature ranges, potential ranges). With this information, it is possible to design out SCC problems in most cases. As pointed out later in the program by C. Edeleanu (Cambridge Univ., UK), this basic information may be usefully or necessarily augmented by on-line environmental checks and *in-situ* tests. Ultimately, we would like to be able to predict SCC behavior for any given alloy/environment combination without any experiments at all, but this is a long way off.

Parkins presented a useful conceptual framework in which to view the general SCC environmental problem, noting that SCC requires a sort of critical balance between activity and passivity. Under conditions of complete activity, the alloy experiences general corrosion, while if completely passive, the base metal is protected. Only at some intermediate condition does SCC occur. This idea has not only mechanistic implications relative to film breakdown and repair but also implications with respect to testing to predict susceptibility to SCC. Therefore it is not surprising that most of the SCC test methods discussed at the colloquium related to the

stability of the passive film and/or to its kinetics of reformation if disrupted. The concept that a semi-active/semi-passive condition is required for SCC means that inherently active metals must have a degree of passivating factors built into the environment, such as (partial) addition of inhibitors; on the other hand, inherently passive metals must be subjected to an active environment since the film must now be (partially) broken down. Thus SCC test methods tend to evaluate passive film build up or breakdown, depending on the situation. There is a wide variety of experimental approaches, and the primary aim of the meeting was to convene the espousers of the various techniques.

Parkins pointed out that the problem is further complicated when the cracking environment differs from the bulk, as for example in crevices, under debonded coatings, and as a result of heat transfer, etc. Unfortunately this type of situation is quite common, and indeed, the crack tip environment generally differs from the bulk. A good deal of basic work on SCC has dealt with the question of crack tip chemistry, but this has not substantially assisted the designers. In discussing SCC test methods, Parkins distinguished between situations in which knowledge of the bulk environmental chemistry is sufficient for predictive purposes and those in which the local chemistry in or near the crack must be considered. If one considers that in order for a crack to propagate the rate of dissolution at its sides must be substantially less than at the tip, then as the crack grows, each point along its sides experiences an active-to-passive transition. Thus in SCC testing, Parkins' work has tended to emphasize experimental schemes that delineate the kinetics of the active-to-passive transition. For example, current decay (I vs t) at various fixed potentials, or potentiodynamic sweeps (I vs E) at various potential sweep rates ($\Delta E/\Delta t$) are quite useful. In the latter case, the potential ranges where the polarization curves differ in position may be interpreted roughly as the area of possible susceptibility to SCC. Furthermore, the potentiodynamic experiment accomplishes this in one experiment, whereas the current-decay method requires a series of I vs t runs at various fixed potentials. The application of potentiodynamic polarization methods to ferritic steels was described. Here, it was shown that, although the potential range for SCC can be delineated well enough from measurements on unstrained electrodes, the varying cracking propensity of a series of steels cannot be accurately reflected by the data, so straining electrode tests must be introduced to delineate the kinetic factors. Parkins also noted that allowance must be made for pH changes during constant-strain rate and polarization tests.

When bulk environmental experiments are supposedly insufficient, Parkins suggested that perhaps pursuit of the microenvironment had been overemphasized. It is clear that in order for SCC to occur, the potential must obtain a rather specific and often narrow range and that this typically does not overlap the freely corroding potential. Therefore, from a practical viewpoint, we should try to understand in general how the potential obtains this range.

Touching on purely "paper predictions" for SCC, Parkins outlined the use of potential-pH maps to delineate regions of susceptibility to SCC. Typically, based primarily on knowledge of "species produced" in various ranges, a SCC region will be bounded by the lines representing equilibria for anodic protection, pitting, and general dissolution. Parkins presented some correlations between these kinds of calculations and experimental data that showed quite good agreement. Unfortunately, these methods are not likely to be readily accepted by designers at present.

The other plenary lecture, by M. Keddam (Univ. of Paris, France), considered in detail the mechanical and electrochemical aspects of passive film breakdown, and the various test methods that relate to these mechanistic aspects. He pointed out that all SCC test methods relating to environmental influences can be divided into two groups: those in which the passive film is destroyed by external mechanical action (e.g., scraping), and those in which the film is broken by strain of the underlying base metal. Furthermore, in each case, the film may be disrupted either continuously or discontinuously. This gives a matrix of four types of tests, which may be referred to in abbreviated form as continuous scrape, single scrape, continuous strain, and transient strain. The data accumulated from such tests very often take the form of potential-time (E vs t),

current-time (I vs t), and current-strain (E vs e) data, perhaps at various strain (film disruption) rates. In general, one would like to be able to relate the rate of film destruction to some measure of the rate of reformation (current, potential, etc.) and then correlate this with some model of the deformation and reformation processes. Keddam reviewed various workers' methods for this noting that a wide range of strain rates are used, from very slow up to almost "explosive" including fracture-repassivation studies. In all cases, the straining/scraping method attempts to simulate conditions at the crack tip where it is assumed that there is always some critical relationship between mechanical effects and electrochemical activity. The strain/scrape method produces fresh metal, and the electrochemical activity on this is monitored. Keddam also discussed the various electrochemical techniques that are applicable to SCC evaluation, such as the ring-disc electrode, by which the various components of current in I vs t decay curves can be determined. Keddam, as did Parkin, noted the difficulty in using microelectrode type techniques to monitor the crack tip environment directly, and he discussed some of the specimen designs that have been used in attempts to model the situation.

Beyond the two plenary lectures, the program consisted of research papers dealing with specific test techniques and their application. The relatively short program did not attempt to group papers on the basis of either test method or application area. The major analytical areas covered were 1) various film disruption techniques, including straining and scraping electrodes; 2) various electrochemical monitoring methods; 3) microstructural and surface observations, including metallographic, electron microscopic, and ellipsometric methods; 4) microelectrode studies; and 5) thermodynamic calculations.

In terms of applications, considerable attention was given to ferrous and nickel-base alloys. Several authors considered tests to evaluate the SCC propensity of superalloys and stainless steels in steam generator-type applications, including J. Hickling (Kraftwerk Union AG, Erlangen, FRG), N. Pesall (Westinghouse Electric Corp., Pittsburgh, PA), and C. Buscarlet and co-workers (Ecole Nationale Supérieure des Mines, Saint Etienne, France). In these presentations, attention was given to the predictive capabilities of electrochemically controlled tests of short duration (days) as compared to longer conventional immersion tests (such as U-bend tests) in similar environments. Hickling, using data obtained for Inconel 600 and Incoloy 800 alloys in boiling 50% NaOH solutions, showed how controlled potential U-bend tests demonstrate the strong potential-dependence of SCC and of the mode of crack growth, thus explaining some of the contradictions in published results where potential control had not been used. Hickling's experiments included potential decay (potential vs time, E vs t) from values initially in the passive region; from E vs t curves, one can identify the time points at which significant changes in film structure occur. He also presented correlations between the potentiodynamic experiments and cross-sectional cracking profiles to delineate the mode of crack propagation. Pesall's results for similar nickel-based alloys in 10% NaOH solutions, also showed the dependence of SCC behavior on potential, with maximum susceptibility observed around the active-passive transition range of the anodic polarization curve. His experiments included the development of a family of crack growth curves (crack length vs time, Δa vs t) at various controlled potentials from which one would hope accurately to extract a Δa vs t curve at the natural ("freely corroding") potential, as well as a critical crack depth, ac, for crack growth. Ultimately, the aim is to obtain two essential parameters for predictive purposes, the time to obtain a growing crack and the steady-state crack growth rate.

Although it was not the primary aim of the colloquium, several papers usefully devoted some time to mechanisms, especially in the case of stainless steels: these issues were considered in presentations by D.J. Duquette (Rensselaer Polytechnic Institute, Troy, NY), B. Rosborg (AB Atomenergi, Studsvik, Sweden), D. Desjardins (Université Bordeaux I, France), A. Desestret (Conference co-organizer, CREUSOT-LOIRE, Unieux, France), and others. My comments here will be limited, as was the theme of the colloquium, to revelations about test methods.

Desestret pointed out that SCC of stainless steels is now generally accepted to depend on several factors: (a) mech-

anical deformation at the microscopic scale, (b) chemical or electrochemical dissolution of depassivated unfilmed metal, and (c) repassivation rate. Whether localized corrosion cracking takes place depends on the interaction of these three processes. Process (a) is probably dependent mostly on the physical metallurgy features of the alloy, while (b) and (c) are dependent on the chemical/electrochemical interactions at the metal/solution interface. Thus, one can imagine that the relative kinetics of the three processes determine whether cracking occurs. Desestret suggested that SCC occurrence depends on the modification, by the mechanical deformation processes, of the electrochemical processes. Relative to SCC testing, his point was that electrochemical monitoring methods are therefore the logical way to analyze such modifications. The electrochemical methods he used allow determination of a critical strain rate for depassivation (a parameter with strong dependence on stainless steel composition) and an order of magnitude estimate of crack propagation rates ($\Delta a/\Delta t$). The results have also proved useful in interpreting physical metallurgical effects; for example, for certain ferritic stainless steels in specific environments, the particular deformation modes may cause very strong localized depassivation, and if the repassivation kinetics in the particular environment are not sufficiently rapid, SCC will occur.

Numerous papers have been published on SCC of stainless steels in which the data presentation is in the form of potential-time (E vs t) curves during stress tests to fracture. Desjardins showed that prior measurements of mechanical properties as well as *in-situ* extension measurements (Δa vs t) are useful in interpreting these E vs t curves. A new test, in which a load is briefly applied to the specimen was also described: the potential rises rapidly, then falls off, and the E vs t profile obtained can be correlated with crack velocity in a full SCC test.

A group of papers considered tests for intergranular SCC (IGSCC), particularly for stainless steels. V. Cihal (G.V. Akimov State Research Institute for the Protection of Materials, Czechoslovakia) described a test method based on reactivation from the passive state in a specific electrolyte. The ratio of the charge passed during reactivation compared to that in the active region was taken as the criterion of susceptibility, and the results were compared with standard IGC tests. G. Herbsleb (Mannesmann-Forschungsinstitut, Duisburg, FRG) considered the problem of IGSCC in sensitized austenitic stainless steels and in nickel-base alloys in high temperature (up to about 300°C) waters, through the use of time-to-failure vs potential data which delineate a critical potential for SCC. B. Poulson (ATD Clarke Chapman, Ltd., Gateshead, UK) considered the complexity of the relationship between sensitization (the microstructural condition) and susceptibility to IGSCC (the environmental behavior), showing that although sensitization can be assessed by short-term electrochemical tests, but that this does not always correlate with susceptibility.

Referring to SCC in general, colloquium discussion emphasized that for some alloy systems, it is possible to predict SCC from microstructurally-oriented types of observations, for example by scanning electron microscopy (SEM) or transmission electron microscopy (TEM) examination after etching by the expected environment or during straining of thin foils; these methods are an extension of the classical metallographic methods used to evaluate the intergranular corrosion susceptibility of stainless steels. Also, a number of the papers discussed the utility of various microstructural type observations, including crack path studies.

One of the more sophisticated electrochemical approaches for SCC evaluation was described by A.C. Coates (British Gas Corporation, Newcastle upon Tyne, UK), namely the method of AC impedance. This was used to establish a relation between time constants for passivation and SCC, for low-carbon steel in inhibited and uninhibited carbonate-bicarbonate solutions. By use of automatic frequency-response analysis, he employed the impedance spectra to delineate various time constants for incremental stages of passivation. This method also has great value in mechanistic terms; in the case Coates cited, for example, the findings demonstrate the importance of passivation for the "pre-existing active path" model. In addition an *in-situ* AC-impedance method for monitoring steam generators was described by M.W. Kendig (Brookhaven National Laboratory).

Finally, a few papers on hydrogen assistance to environmental cracking (HASCC) included contributions by J.C. Charbonnier (Institute Recherches de la Siderurgie, Francaise, France), J. Galland *et al.* (Ecole Centrale des Arts et Manufactures, France), and P. Sury (Sulzer Brothers Ltd., Switzerland). In order to predict susceptibility to HASCC, such measures as the constant strain rate method at open-circuit potential and activation pH measurements on scrubbed electrodes were discussed.

In summary, it is clear that there is a wide variety of experimental approaches to the problem of predicting SCC susceptibility. The primary aim of the colloquium at Firminy was to consider and compare these. An ultimate goal of the Working Party is to formulate standard tests procedures, but it is obvious that this will take time. It is not even clear at present exactly how the various techniques (film-destruction methods, potential-scan experiments, ellipsometry, microstructural determinations, microchemistry, etc.) complement each other. There was some evidence that there is a possibility of developing sufficient understanding of SCC processes in the future so as to be able to predict conditions for SCC occurrence without experiment. However, one has the feeling that the design engineer is never going to accept those dotted (theoretical) lines on the environmental map, and that there will always be room for another good SCC test. (Jeff Perkins)

MATHEMATICAL SCIENCES

GRADUATE EDUCATION IN OPERATIONAL RESEARCH IN THE UK

Operational Research (as they call it—we call it Operations Research) was initiated in England in 1940 when several scientists (of whom Prof. P.M.S. Blackett, Nobel laureate in physics, was the most famous) were asked by the Royal Air Force to do research in operational questions involving a new gadget called radar. Of course, some people had been doing this kind of thinking and analysis for a long time (for example, Lanchester in the UK and Edison in the US during WWI), but nobody was listening; this time the recommendations of the OR people made a significant contribution to the winning of the Battle of Britain, and therefore the war, and so a new field was born. The first OR society was in the UK, and while the International Federation of Operations Research Societies, created in 1957, now has almost 30 national societies as members, only one of them is titled "The OR Society," and the field is still better known in the UK than in the US.

The BSc in the UK normally takes three years (although some "Honours Courses" require four), but the entering student's preparation is so much better than that of American high-school graduates (for example, many will have had linear algebra and differential equations) that the BSc's may be considered equivalent. The MSc is normally a twelve-month course. The PhD requires about as long as in the US; it is usually exclusively a research degree—there being no course work—and the requirements for the dissertation may be more severe than in the US. Every graduate of a UK university is subject to examination by "external examiners" from different schools, and, for the PhD in particular, the final decision is made not so much by the thesis director as by the external examiners. While flunking the final defense of a thesis is now almost unheard of in the US, it is not at all uncommon in the UK; perhaps one third of the doctoral OR candidates in the UK are told by their external examiners to go back and do more work (or perhaps to give up entirely). The PhD is not a necessary prerequisite in the UK (as it is in the US) to the academic ladder, and only about half the OR faculty hold it. The much more prestigious DSc in OR is held only by Prof. Samuel Eilon at the Imperial College of Science and Technology (London) (and K.D. Tocher outside academe). Unlike the US, almost all OR faculty members have had practical OR experience.

The principal difference in graduate education in OR is that practice is heavily emphasized in the UK, theory in the US. An American with a graduate degree in OR will surely have studied a lot of math, beyond which he will have had innumerable courses in mathematical techniques of OR (linear and nonlinear programming, queueing theory, etc.)

He will almost surely never have seen a real problem, and in some extreme cases will hardly have seen any textbook problems other than mathematical ones. The corresponding Briton will be weaker on theory, and in extreme cases may use virtually no math on his course; on the other hand, he will have spent a lot of time analyzing OR cases, and in several schools will actually have been out of the university for some months getting his hands dirty in the real world—working on a unique problem that somebody really wants solved, and to which, in all probability, no optimal solution exists. At most schools the project occupies the last three months of the year, from June to September, but at the Univs. of Hull and Strathclyde the project lasts five months and the course work is confined to the first seven—supposedly a "very intensive" course. It seems unlikely, however, that students there can learn faster than those elsewhere.

The effort required to find organizations that have such projects and are willing to have students work on them, to handle the administrative details, and to supervise the students on a one-on-one basis is enormous. At Aston, as an extreme example, credit given to a faculty member for supervising one student on one project is about equal to that given for teaching one course (to many students) for one term (about equal to a US quarter). British faculty are on 12-month contracts (at salaries markedly below those of Americans on 9-month contracts) and so do not get extra pay for summer instruction. The sponsoring organization is usually asked to pay the marginal expenses of the student, and in a few cases the department also assesses a small fee believing that this will ensure a real problem that someone wants solved; most schools refuse such a fee as a matter of principle, feeling that they might otherwise lose control and find that the students were being put to work on unrewarding tasks. Most universities report a considerable amount of repeat business, so there is some evidence that these inexperienced youngsters are able to make a useful contribution, although one cynic (head of OR at a British Corporation and a user of such students) tells me that the real criterion is that they not do too much harm, since the sponsoring organizations, both governmental and industrial, are motivated largely by the eleemosynary desire to aid the educational process.

This use of projects in education is popular in the UK and is not restricted to OR. The Business School at Manchester uses it, as does the Management Science Department at Imperial College for students majoring not only in OR but also in such other fields as finance. That it has not been adopted in the US is probably due primarily to the faculty effort involved, but it may also be related to student attitudes: tuition fees in the UK are low (£800 for a 12-month MSc in OR) and usually financed by government grants; in the US a student paying $4000 to $5000 for 9-month tuition may feel he has a right to be lectured at. Moreover, most US pedagogs feel that the academic environment is most efficiently used in conventional course work, and that the project kind of thing is best performed in apprenticeship on the first job. The major difference between OR instruction in the US today and the only comparable thing, industrial engineering, 30 years ago, is that today's instruction gives the student a strong theoretical background which will presumably make him capable of learning and keeping up-to-date throughout his professional life. Theoretical learning is very hard to come by outside academe, but practical experience can be picked up on the job.

There are always some students who cannot be sent out on real projects (either because a project is unavailable, or he is unsuitable—perhaps because he is a foreign student with communication problems), and so almost all of these schools have some "synthetic" projects that are not unlike most of the theses in the US. Some schools think these synthetic projects are better—because, for example, there is less chance that they will turn out to be insoluble or otherwise totally inappropriate—and are using them almost exclusively, but no one in the UK seems to be thinking seriously of going to the American system of depending entirely on course work.

Another important distinction is that in the US the BSc in OR or something equivalent would normally be required for admission to the MSc, whereas in the UK most of the entering MSc students in OR have had undergraduate majors in other sciences, engineering, or economics, and are assumed to have no OR training. In this sense, there may be no graduate education in OR as such available for the undergraduate OR major other than the PhD. It follows that the UK MSc in OR will have less technical background

than the equivalent in the US; this makes it all the more surprising that it is the UK that has chosen to spend a quarter or more of the year on projects, while the US gives added course work in this period.

There are some 600 institutions of higher education in the UK, in the following order of prestige: (1) Oxbridge (Oxford and Cambridge, the two oldest British universities); (2) the other 45 universities; (3) the polytechnics and the colleges of education; (4) a variety of other colleges and institutes of higher education. Virtually no graduate education in OR, except for isolated courses, exists except in the second category above. Some 10 or 20 of these universities give graduate OR degrees, and there are about 10 chairs in OR. As will be seen, these numbers are hard to pin down. A chair in the UK is synonymous with a professorship, and is a rare and prestigious thing. Not more than 40% of the faculty may hold the three highest ranks (professor, reader, senior lecturer); most of these are senior lecturers who cannot become professor until the chair becomes vacant. But these chairs do not necessarily correspond to graduate degrees. Thus Roger Collcutt holds the OR chair at the Business School of the University of Manchester, but there is no OR degree there; at UMIST (the Institute of Science and Technology at the same University) there is a Department of Management Sciences with six chairs, one of which is in Operations Management and has a strong OR flavor; and a third faculty at Manchester has an OR-related chair of Decision Science. At Imperial, Eilon, who holds the chair in Management Science, supervises a large and prestigious graduate program in OR. At Bradford University, Keith Lockyer's chair in Production Management and Christopher Higgins' chair in Management Information both have strong OR flavors. Lancaster has chairs in both OR and Systems. At City University (in London) the Department of Systems Science has two chairs, with P.K. M'Pherson handling systems and management while L. Finklestein handles instrumentation and control. All of the above have significant programs at the graduate level. In addition, OR is taught by many departments of math, statistics, economics, etc.

Financing of graduate education in the UK is a serious problem. There are many foreign students (along with a few domestic ones) who finance themselves, and others have industrial sponsorship (especially promising young individuals who have been working for a few years and are sponsored by their employers). Many of the domestic OR students have grants from the Science Research Council which pays their tuition and modest living expenses. The grant giving is naturally a complex process, but in general the grants are allocated by the SRC to worthy schools, which then assign them to worthy students. Operational research gets 100 of these grants each year, more than most other fields (more than chemistry, for example), and most of these are given to five large programs at Lancaster, Imperial, Hull, Birmingham, and Sussex.

There seems to be a general feeling that there are too many MScs in OR programs (they average about 20 students) and possibly too many students for the economy to absorb in OR. A large fraction of BSc and MSc graduates in OR obtain initial employment in OR groups, industrial, commercial, and governmental; most eventually move out of such groups, many up and into management. Starting salaries are low by US standards—£3,000 to £5,000 ($5400 to $9000) per year for students with no experience, but these do not appear to be lower than those of other MSc graduates.

There follows a set of subjective impressions of some of these institutions, the length of the discussion bearing no relationship to the size or importance of the program.

The University of London has several autonomous "colleges," two of which have graduate OR programs: LSE (the London School of Economics and Political Science) and Imperial College (which specializes in engineering and the natural sciences).

LSE had the first faculty post in OR, then held by Ailsa Land, who is now a Reader. The OR program, which she heads, has about 30 MSc students, half in a strictly theoretical stream (math techniques) and half in a practical one. Only the latter have projects, and these are all "synthetic." There are also two or three PhDs per year. There are only two lecturers in OR, and so the courses in economics, statistics, etc., are taught as service courses by other departments. For these and other reasons they have recently had no SRC grants, therefore most of the MSc students have been foreign. Imperial has a massive program in management science, admitting about

70 to 80 MSc students each year, of whom about 90% graduate. All do projects, and all receive strong quantitative training as well as emphasis on applications; the large minority who major in OR get a particularly strong dose of mathematical techniques. The program is headed by Prof. Eilon, one of the two incredible achievers on the British OR scene; the other is Prof. K.B. Haley of Birmingham. Each edits a technical journal (*Omega* and *Journal of the Operational Research Society*, respectively), publishes prodigiously, serves as external examiner for other universities, on the SRC, on boards of directors, teaches (and knows all his students), fulfills his commitments on schedule, and always seems to have time.

Birmingham, UK's second city, has two universities, each with a chair in OR. At the University of Birmingham the chair in OR (held by K.B. Haley) is one of three in the Department of Engineering Production, but the OR group, including one senior lecturer, three lecturers, and some research faculty, is largely autonomous. They give undergraduate service programs, have a large group of undergraduate OR majors, and each year give 15-20 MScs and 2-3 PhDs. (One of the current doctoral candidates is a lecturer in the Department; by University regulations not only will he have no course work, he will not even be assigned a major professor until his research is completed—certainly far different from US practice.) While the MSc course is basically quantitative, the emphasis on practice is unusually strong; there is a synthetic miniproject of three weeks' duration (during which the students work in pairs) before the main three-month project, which is never synthetic and is always spent away from the University. Even on the main project the students often work in pairs—a practice different from that of most other universities; Birmingham feels that they can sort out the efforts of the individuals in the pairs (important, because successful completion of the project is a prerequisite for the award of the degree) and have, in at least one case, passed one member of such a pair and failed the other. They charge a fee of £250 for one student and £400 for a pair of students working on a single project.

At the University of Aston in Birmingham the OR chair is held by S.L. Cook. There are two MSc programs with about 20 students each, one in OR and the other in Systems. Both are "softer" than many other UK OR programs; that is, there is less math and more behavioral science, organization theory, methodology, and the like. There is also more emphasis, especially in the systems course, on data processing, and many of these graduates find employment in that area.

At Sussex University the chair is held by B.H.P. Rivett, a young elder statesman who formerly held the first OR chair (at Lancaster). He was a pioneer in setting up industry-sponsored research programs. This University is located in the resort town of Brighton on England's south coast and suffered more than most during the student uprisings of a decade ago. The OR department, with its strong industry connections, was a special target of the radical students, and barely survived. Today it has a strong research program (much of it government-sponsored), nearly 30 MSc students all of whom do projects (many synthetic), a large undergraduate service program, and a few undergraduate OR majors.

The University of Hull's OR department has very heavy emphasis on projects. The 20 MSc students spend one week on the project during December, one day per week from December to April, and full time from May to September. OR has only just received the status of a department, and is headed by a Senior Lecturer, James Morrison, assisted by five lecturers. In spite of having no undergraduate program in OR (they give a few service courses, and are planning an undergraduate major in "Management and Operational Research"), they need so many faculty because of the heavy load of project work. Hull is one of the few places where the MSc in OR includes a full course in accounting.

Lancaster had the first chair in OR and now has two chairs in OR and one in Systems. One OR chair is held by M.G. Simpson (who has given up the post of head of department while he holds the post of President of the OR Society; Michael Chambers is the temporary department head) and the other by Alan Mercer. The OR Department is very large, having a faculty of about 15 in the ranks of lecturer and above. They have about 15 research students (mostly doctoral can-

didates), 36 on the master's course (they award the MA rather than MSc), and 30 "diploma students" who are inadequately prepared in math or English for the master's course, and about half of whom go on to the MA after attaining the diploma at the end of a year. They also have about 25 undergraduate majors. Teaching loads are nominally 12 hours per week of formal lectures during the 28 weeks of the year when lectures are given, but this is reduced by project work and other assignments so that most instructors have about 6 contact hours (these loads are probably typical). All students do projects, and 80% of the organizations that sponsor a project in any one year will be sponsors again the following year. The OR Department at Lancaster is one of the few that has made an organized effort to obtain sponsored research from industry. On the whole this has not been as successful as at many American universities, but it does give some faculty members an opportunity to work on interesting problems and supplement their salaries; graduate students are rarely used on such sponsored research.

Lancaster also has a Department of Systems, headed by Professor Peter Checkland. This was formerly the Department of Systems Engineering, under G. Jenkins, and had a classical engineering outlook. It has now become much softer, with emphasis on organizations, data processing, etc. Master's degree students in this course also do projects.

Warwick University (located in Coventry, some 10 miles from Warwick) has several faculties, one of which is the Faculty of Social Sciences; in this there are several schools, one being the School of Industrial and Business Studies; in this School there are four MSc programs, including one in Management Science/Operational Research. The program, headed by a Reader, Hylton Boothroyd, has six other faculty. There are some 15 students on the MSc program, 2 or 3 PhDs a year, 55 undergraduate majors, and service courses. All MSc students in the school (including those in marketing, for example, as well as those in OR) do projects, mostly in industry but some synthetic. Sponsoring organizations are asked to pay a fee of £300 as well as the students' expenses.

At Bradford there are no departments; each chair has autonomy. The Management Centre is a consortium of six of these chairs, with C. Higgins as Director; OR is taught under two of these, not necessarily under this name. The Management Centre gives a three-year BSc, a four-year BSc, an MBA, a PhD, and considerable post-experience (non-degree) instruction. Much OR is taught in all of these.

At Manchester the only chair in OR is at the Business School. This School was established in 1965 using industrial money in response to the apparent success of US business education. Like almost all other higher-education institutions in the UK, it is now government funded. Everyone in the School gets some OR, but not in separate courses; the same is true of the extensive post-experience courses. The School has perhaps gone farther than anyone else in their projects; all of the MBA's do them, and even on ten-week management courses they have short projects. Among the other faculties at Manchester are Economics, which has an OR-related chair in Decision Theory, and the Institute of Science and Technology (UMIST), where the Department of Management Science has six chairs, one of which, Operations Management (Robert Hollier) is OR-related. OR is also taught in the Math Dept. in UMIST.

Strathclyde University is located in the heart of Glasgow, a declining city (once having had a claim to be the Second City of the Empire, it is now considered by some to be the second city of Scotland). The head of the OR department is Prof. W.A. Donaldson. They take their projects very seriously; the 20 MSc students do 5-month projects after an intensive 7-month course of lectures, which are quite quantitative.

In addition to all the above, there are many post-experience courses, varying from weeks to months in length. Many of these are run by or for the public sector, for example, the National Coal Board through Brunel University, the Department of Health and Social Security through Warwick, and the Ministry of Defence through Lancaster, Sussex, and the Royal Holloway College (another college of the University of London). In addition, the Civil Service has its own college in London. MSc's can be obtained through most of these, and some are oriented primarily toward close collaboration for sponsoring research.

Finally, having lectured at most of the institutions mentioned above, I can add a personal impression about graduate students in OR in the UK. They vary from bright to dull, and from energetic to

lazy; they seem to be more polite than their counterparts in the US; and they are likely to attend lectures only when they believe that they will be examined on the content thereof. (Robert E. Machol)

PHYSICAL SCIENCES

THROWING LIGHT ON THE MATTER—THE INTERNATIONAL LUMINESCENCE CONFERENCE

It seemed entirely proper that the 1978 International Conference on Luminescence should have been held in Paris—the city of light. Because similar conferences have been held previously in such varying locations as Budapest, Delaware, Leningrad, and Tokyo, this conference series has developed a truly international following; at this meeting there were even delegates from Vietnam and China. Professors D. Curie and J. Mattler and their colleagues produced and directed a conference that was unusually well thought out. The meetings were held in various conference rooms of the UNESCO building, with sophisticated features such as simultaneous translation of the formal opening speeches and a microphone at each chair in the audience for questions. Similarly, the Conference dinner on the first level of the Eiffel Tower was a "high point" in my experience of such institutions.

Most conference series develop a personality of their own after a time, this one being no exception. Part of the uniqueness of this Conference is that it concentrates on a property (luminescence) rather than on a material. Since a very wide range of materials luminesce, the conference has a built-in tendency to break into sub-groups covering luminescence in organic materials, or semiconductors, or inorganic insulators. Since the overlap between, say, an organic chemist and a semiconductor physicist is usually small, integrating these various groups into a cohesive conference is a major problem. From the beginning of this series the organizers have worked diligently to reduce the barriers between sub-groups and to attempt to educate the participants broadly as well as to allow them to follow their own research area deeply. To this end there were many longer invited talks without competition from parallel sessions. Even when parallel sessions could not be avoided, there was a surprisingly large crossing over of scientists from one sub-group to another.

Another facet of these conferences is the lively, but courteous, discussion. A number of the senior people seemed to try especially hard to use the discussion period to make suggestions, spur the speaker to think even more deeply about his results, or to clarify for everyone the significance of what had been presented. There was a sense of "critique" in much of what was said; perhaps that quality in discussions may be worthwhile attempting to develop in other conferences.

Before really getting into the meat of the Conference, I would like to comment on the introductory sessions, which one can usually leap over in a single bound when reporting. There was a strange initial series of obituaries for giants in the field who had died since the last meeting. Luminescence is an old field, and perhaps its practitioners carry along more than most some of the courtesies and respect for elders that graced an earlier time.

Finally, the Conference was opened by Prof. A. Kastler who gave a passionate plea for an end to the arms race. This was no bland collection of cliches. With equal fervor he criticized the US for furthering the arms race by developing the neutron bomb, the USSR for its lack of freedom of speech and freedom to travel as shown in the Orlov case, and France for its reluctance to end nuclear weapons explosions. This larger political militancy among French scientists was also evident in the distribution of a statement signed by many in which the signers promised to work actively in their professional contacts to make evident their displeasure at the Orlov affair. See *ESN* (32-8:285) for a more detailed description of this development.

Among the many themes of the Luminescence Conference, I shall concentrate only on two. The first of these is the attempt to understand various dissipative or nonradiative processes that reduce the luminescence efficiency. The second is the study of the details of optical processes occurring in very short times after a pulse of exciting radiation falls on a material.

In a wide ranging opening address, P.T. Landsberg (Southampton University, UK) discussed luminescence and statistics. He emphasized the role of nonradiative transitions in the many processes of semiconductor luminescence. Since free and bound excitons are frequently involved in luminescence, the creation of these from free electrons and holes, their deexcitation by an Auger interaction with free charges (to be discussed in more detail later in this article), their luminescent recombination at appropriate traps, and their thermal dissociation lead to somewhat complex equations. An interesting development of these equations occurs if the free electrons and holes are allowed to multiply by impact ionization. In practice this could be controlled by applying a varying electric field to a semiconductor that luminesces. Landsberg points out that the resulting equations have the character of a phase transition with the sudden switching between two types of solution. He suggests that electroluminescence be examined from this point of view. A further complication of the kinetics to include two impact ionization processes could lead to luminescence oscillations in time that are like the autocatalytic reactions that have received much attention in recent studies of chemical and biological nonequilibrium phase transitions. While such oscillations in luminescence are sometimes seen, their occurrence has been ascribed to thermal effects rather than to these complex autocatalytic effects, but here again a review of the experiments might be rewarding.

M.H. Pilkuhn (Univ. of Stuttgart, FRG) pointed out that silicon may be considered as a "model material" for nonradiative recombination since the luminescence efficiency is small, the luminescent centers and transitions are well understood, and the material control is not excelled by any other material. In silicon the Auger effect accounts for recombination without radiation. If we consider intrinsic luminescence in silicon, that is the recombination of free electrons and holes, the indirect band gap in silicon requires the assistance of a phonon for the recombination to occur. By transferring the recombination energy to a free electron or hole (the Auger effect), the recombination may occur without radiation while the highly excited electron or hole dissipates the energy in collisions. As a result, measured lifetimes are not influenced by the intrinsic radiative transition but are determined by the Auger effect.

Another source of luminescence in silicon comes from the recombination of excitons trapped at an impurity. Here, too, the radiationless process involves an Auger transition with the electron or hole at the impurity itself. In this case the bound exciton lifetimes are much shorter than the radiative lifetimes derived from the absorption oscillator strength. For an exciton bound at In the observed lifetime is 2.7 nsec; the expected radiative lifetime would be 128 msec. Recently, theoretical analyses of these transitions have yielded excellent agreement with actual lifetime data and their dependence on the ionization energy of the impurity. As a result the bound exciton decay in silicon appears to be the first case of complete qualitative and quantitative understanding of a nonradiative process in a semiconductor.

Another theme that has attracted wide attention is that of "hot luminescence." This term describes luminescence from the excited state of a center immediately after excitation and before the center and the surrounding lattice have relaxed to their new equilibrium positions for the excited state. It is from this relaxed state that "ordinary luminescence" appears. In addition to the hot luminescence seen at very short times, Rayleigh and Raman scattered light could appear. The tasks are to determine experimentally what processes occur and dominate in various cases and be able to relate these observations to theory.

K.K. Rebane (Institute of Physics of the Estonian SSR, Tartu, USSR) reported calculations of the shape of the luminescence spectrum as a function of time going from hot to ordinary luminescence. Direct measurements are difficult since they would require picosecond measurements; Rebane showed an ingenious alternative set of data taken from time-dependent Mössbauer experiments. As predicted these showed the Mössbauer line becoming narrow as time progresses and the oscillating wings of the line first appearing and then disappearing.

Two different kinds of Raman scattering were described by M. Balkanski (Univ. P. and M. Curie, Paris) in an attempt to distinguish between resonant

light scattering processes and hot luminescence. In the case of GaSe, a lamellar semiconductor, scattering with the creation of phonons of a single frequency is seen. It appears to be a clear-cut cascade inelastic light scattering in which exciton recombination takes place in successive steps each involving a single longitudinal-optical phonon. Data were presented for scattering involving 1, 2, 3, and 4 phonons. The theoretical development of excitation line shapes showed beautiful agreement with the relatively complex distributions found experimentally.

A different kind of scattering is seen for materials such as $GaAs_{0.2}P_{0.8}$. In this case, there is structural order, but the randomness of the As and P atoms produces a compositional disorder. Experiment shows that resonant light scattering involves a repetition of the whole first order Raman spectrum at intervals corresponding to one or more longitudinal optical phonons.

The optical properties of CuCl were reported on by M. Ueta (Tohoku Univ., Sendai, Japan) who used pulsed laser excitation. In this material both Raman scattering and luminescence are seen in the same spectral region. Empirical ways of separating them have been developed. The Raman line widths are related to the line width of the exciting light; the width of the luminescence lines are independent of excitation. Also, the energy of the Raman lines shifts with the energy of the excitation; the luminescence is not shifted. The same system was studied using picosecond spectroscopy by S. Shionoya (Univ. of Tokyo, Japan) and a large collaborative group consisting of 9 other workers. They developed a tunable laser that could operate between 312 and 450 nm with a peak power of about 300 kW. The time resolution of the system is about 20 psec and a high sensitivity television camera is used to record the data. They were able to show that the Raman spectra followed the laser pulse closely in rise time and decay. On the other hand, the onset of luminescence was delayed and the luminescence had a decay out to 200 psec.

Shionoya also reported on the emission from very high excitation densities in the direct-gap semiconductors CdSe, CdS, and GaAs. His group were able to fit the data by assuming that an electron-hole plasma is formed and that the emission seen was stimulated. They feel certain that the electron-hole plasma in these materials is not condensed to form a liquid or drops but is spread out in the crystal. It seems likely that in direct-gap materials the lifetime of the electron-hole pairs created is shorter than the time necessary for the spatial condensation, so that a high density plasma exists only in a transient state.

The Conference proceedings will be published as an issue of the *Journal of Luminescence*. (Clifford C. Klick)

A RED, BLUE, AND GREEN CHRISTMAS ON OXFORD STREET

This Christmas UK and foreign London shoppers on Oxford Street were greeted with powerful laser beams overhead reportedly a Christmas decoration first. This interesting and expensive project was undertaken and fully funded by the Oxford Street Association (OSA), an association of 105 owners of shops, restaurants and hotels on Oxford Street. Mr. Harry Shepherd, president of the OSA, described the display along with some difficulties presented by the Westminster City Council at the last minute.

Six lasers were purchased and mounted in five positions. One green beam was directed down Oxford Street from D.H. Evans Department Store as far as the top of Burton's at St. Giles Circus, a distance of ½ mile. A reflector on top of Burton's sent the beam back along Oxford Street where it eventually struck a building. A red beam originating from a different location also traveled along Oxford Street and was reflected back from a reflector atop Burtons. Other lasers had their beams split into a fanned array and were sent across Oxford Street diagonally where they intersected the sides of buildings.

The OSA hired a group of Germans under the direction of Horst Baumann, who works for a company called Communication Design, to set up the display. Baumann has previously developed small-scale laser displays in Germany. The project had an international flavor as the lasers were made in the US, the optical beam dividers were made in Switzerland, and the display was installed and operated by Germans for the London group.

On the day before "switch on" Shepherd ran into a problem with the Westminster City Council over safety considerations. Originally, the fanned arrays were to be scanned to provide a dynamic display. However, the Westminster City Council, under advice from health and safety officials, banned the use of the lasers as they felt there was a risk of eye damage. In order to satisfy the environmental health requirements, the display had to be modified rather hurriedly. No dynamic operation was allowed, that is, the fanned arrays had to be static. In addition all beams had to terminate on the surface of buildings or other nonreflective surfaces so that no observer's eye could possibly be exposed to either a direct or reflected beam. All of the modifications were successfully completed early in the morning of 11 November and the display was turned on at 6 p.m. that day.

Only some weeks later after masking of a large number of windows and other surfaces in office buildings and department stores so that no one would be in a direct beam or reflected one was scanning of the fanned laser beams finally permitted on November 30th.

A representative of Spectra Physics described the lasers. There were 4 Ar-ion lasers producing about 9-W continuous wave (cw) on several lines in the blue and green between 4570 and 5140 Å and 2 Kr-ion lasers with about 4.6-W cw power operating on the 6470- and 6760-Å red lines. Ion lasers are notoriously inefficient, and each laser consumes up to 38 kW of electrical power.

A laser display such as this, costing £150,000, might seem to be rather expensive. However, Shepherd pointed out that the Oxford Street businesses brought in about £1.7 billion last year. An expenditure of less than 0.1% of the total business for such an attraction is probably quite reasonable and could be very profitable if the laser display attracted an even larger number of shoppers. (Vern N. Smiley)

ONRL REPORTS

See the back of this issue for abstracts of current reports.

PSYCHOLOGICAL SCIENCES

CONFERENCE ON PRACTICAL ASPECTS OF MEMORY

The 175 experimental psychologists who attended the International Conference on Practical Aspects of Memory, 4-8 September 1978, performed in the standard fashion of presenting research papers to each other, oblivious to jokes of the press about memory experts wearing name tags so they could remember each others name, or about the memory expert who forgot where he parked his car. The Conference, sponsored by the Welsh branch of the British Psychological Society, was held at the University of Wales Institute of Science and Technology, Cardiff, and was managed by M. Gruenberg and R. Sykes (both of University College of Swansea, Wales), and P. Morris (Lancaster Univ., Lancaster). As the title of the conference indicates, the theme was uses of research on memory, which contrasts with the usual memory conference where uncommitted basic science is featured.

Most memory research is not useful, at least not yet, so most of the research reported was laboratory work that may be useful. The research that is useful, and proved in everyday life, concerns memory aids (some call them mnemonic devices) which are techniques to give a high capability for remembering certain kinds of material. Experimental psychologists, with their modern interest in memory, did not discover memory aids but they are doing research on them, and they are verifying and refining them. The Conference had a symposium on memory aids, and it was the liveliest symposium of all. R. Rawles (Univ. College, London) reviewed the history of memory aids, P. Morris examined modern research on memory aids, and K. Higbee (Brigham Young Univ., Utah), who has written a book on memory aids (*Your Memory and How to Improve It*, Prentice-Hall, 1977), discussed "pseudo-limitations" of memory aids. Memory aids have been criticized, and the criticisms, which Higbee regards as invalid, were the subject of his presentation. A review of standard memory aids is a useful preface to a discussion of the criticisms.

R. Rawles reminded us that Aristotle had something to say about effective methods of memorization and recall, but

it is Cicero, writing in *De Oratore*, a treatise on rhetoric, who is most widely cited as the first advocate of memory aids. By citing the story of Simonides, that ancient Greek who used spatial imagery to remember the names of dinner guests who were crushed beyond recognition when the roof fell in, Cicero established the Method of Loci, the oldest of memory aids (Cicero saw it as a way of remembering the points of a speech in the days before notes). Long lists of objects or events can be remembered by assigning them to locations in a mental image that is spatially distributed and familiar, like your office or living room.

The Pegword Method, like the Method of Loci, relies on imagery. A jingle is memorized, e.g., "One is a bun, two is a shoe, three is a tree," etc., and this jingle provides the mental pegs on which to hang lists of items. Suppose the first word of a list to be remembered is DOG. Visualize the image of a dog sitting on a bun. Suppose the second word is HOUSE. Visualize the old woman who lived in a shoe and used it for a house. And so on. At recall, a covert recitation of the jingle produces recovery of the words in proper order.

Some memory aids are based on verbal association rather than imagery. We are all familiar with these: "Thirty days hath September...," "Cooking rice? Water's twice," and "Men Very Easily Make Jugs Serve Useful Nocturnal Purposes," the last being a device for remembering the ordering of the planets from the sun. Not all verbal aids need be formally learned. Idiosyncratic verbal associations are useful also. If I need to remember a grocery list of dog food, meat, and bread, the arbitrary sentence "The dog prefers meat to bread," is helpful. Other techniques are rehearsal, grouping of items into subgroups, preferably meaningful ones, and rhyming.

Memory aids have a proved usefulness, but some analysts have leveled criticisms at them. There have been five main criticisms. Higbee refuted each of them.

1. <u>They are not practical</u>. This criticism stems from the arbitrary situations that are often used in laboratory research on memory aids. Some find it hard to see the relationships between laboratory work and real life. Notwithstanding, there are a variety of applications for memory aids. They are useful for learning a foreign language vocabulary. Those who deal with many people and must remember many names can use memory aids to advantage. Memory aids have been shown to be useful for children, including mentally retarded and educationally disadvantaged ones.

2. <u>They do not help with understanding</u>. Memory aids work for rote tasks but are of little help for understanding and reasoning. Apart from some evidence that they <u>do</u> help understanding, Higbee's main reply is that memory aids were never intended for understanding. There is plenty of rote learning and recall in this world, and we need all the help we can get.

3. <u>There is more to remember</u>. One must not only remember the items but also the memory aid and how to use it; there is a larger memory chore with the aid than without it. The answer to this criticism is that remembering is work, and a memory aid is supposed to make remembering effective, not easy. However, those who train themselves in the use of memory aids say that their use is not burdensome.

4. <u>They are a crutch</u>. We come to depend on memory aids and may not be able to perform without them. Higbee does not take this criticism seriously. What is wrong with a crutch, like the use of eye glasses to improve poor vision? A telescope to bring distant objects near?

5. <u>They are a trick</u>. The memory expert mystifies us with his accomplishments, like the magician, so he is performing "tricks." Actually, he is doing no more than using known mechanisms of learning and memory, but he is using them <u>very</u> well. Like so many acts of impressive skill, the discrepancy between lay and masterful performance is so great that the layman stands in awe.

When it comes to the practical aspects of memory, memory aids are about as much as psychology has to offer at this time, and it cannot take credit for their discovery at that. What psychology can take credit for is research evidence that memory aids work, research that refines the way that a memory aid is defined and used, research on new uses of memory aids, and analysis, as Higbee has made, that lays unreasoned criticisms to rest. (Jack A. Adams)

IMPORT OF PSYCHOLOGICAL THINKING ON LAW IN GREAT BRITAIN

Trinity College, Oxford, was the setting for a meeting on law and psychology in which about 45 individuals from England, Scotland, and Wales participated over a three-day period in late September 1978. Included in this number of participants were the 16 who offered prepared papers for discussion and criticism. The setting and the fact that all were in residence at Trinity College induced quite a bit of stimulating discussion both during, between, and after the talks. The bulk of the participants came from various categories of psychology and the law, for example, clinical and social psychology and circuit judges, professors of law, barristers, and solicitors. There were also a few psychiatrists and sociologists. The seminar was initiated and developed by the Socio-Legal Institute, Wolfson College, Oxford, with the support and sponsorship of the Social Science Research Council.

A wide variety of subjects received attention in which psychology and law do, or could have interactions. The comments that follow reflect the author's observations, though these were tempered by much discussion with the participants over the course of the sessions. Several ways in which psychology could play a role in assessing evidence and confessions occupied several sessions on one full day. The theme running through the sessions on evidence and confessions related to identification problems. The question of old people and young children as witnesses received attention. Various studies on memory and recall of older people were discussed and reviewed. While in an unconditional sense memory and recall tend to diminish with age, the parameters under which recall is attempted can have quite an influence on the amount of recall. For example, older people can recall words or sentences given to them in an experiment, but when the older person is then permitted a free-wheeling discussion of any number of things subsequent to the delivery of these sentences, there is a sharp drop, usually almost to zero, in recall. Some data on rather aged people were presented that were quite interesting. It appeared that recall diminished until the age of 70, but then improved for those in their 80s and 90s. There seems to be a selectivity factor operating which suggests that those with diminished recall performance correlate very highly with those individuals who die earlier. The survivors are those whose recall is good all along, save for some natural impairment of memory. This has interesting implications for new retirement legislation in the United States, especially in California, which now has no chronological age for retirement and where performance on the job is the only index for continuation.

One of the speakers, Circuit Judge Brian Clapham, referred to a case reported in the *Criminal Law Review:* "Cluster Analysis in Court," by Bryan Niblett and Jillian Boreham (1976, p. 175-180) in which a rather sophisticated statistical technique was employed in a murder trial to decide whether documents matched. In this recent case, a cluster analysis was applied. The jury was informed that a similarity matrix had been computed, after which a single linkage nearest neighbor clustering algorithm was employed to produce the dendrogram from which conclusions were rendered. It is intriguing that such sophistication would be permitted and not be considered prejudicial because of the confusion it would place in the jurors' minds. In this case the defendant was acquitted. A much more primitive example of this occurred during the Dreyfus court martial in France in the last decade of the 19th century. One of the expert witnesses for the Army informed the seven judges of the court martial that he had performed a frequency count for the letters of the alphabet in all the words used in the documents presented in evidence as having been passed to foreign countries. He had then compared these frequencies with the modal values of the letters of the alphabet employed in French literature which had been compiled by the French Academy. In this situation there was quite a deviation between the frequencies for each of the letters and the conclusion was that therefore the documents had been prepared in code to avoid discovery.

Another interesting paper in the sessions on evidence related to the use of voice identification. The problems that could occur in identification of voices by another human or through the use of electronic signatures were developed. This subject can be compounded by the considerations of the use of another electronic device that would actually attempt discrimination between

two voice signatures developed by electronic devices or a voice and an electronic signature. There are a number of reliability problems here which make suspect the use of such procedures for the development of evidence in a courtroom. Perhaps improved technology will change this.

Still another interesting problem arising in identification to be subsequently used in evidence is the selection of a putative felon from a police line-up or, as it is called in Great Britain, an identity parade. There are some interesting statistical and probabilistic problems here. Should the individuals in a line-up be seen sequentially? Even in that case, should the selection procedure stop when an individual has been identified or continue until all have been inspected? Should one be allowed to review individuals who have passed through once and not been identified? Should the complainant be allowed to see the entire line-up as a group and then be permitted to select one? Should two line-ups be concocted, one of which contains the suspect? If this were done so that the complainant looks at only one line-up at a time, and then, of course, also, in different ways, such as suggested above, what are the implications?

The issue of confessions was given a good deal of attention. There are obviously psychological issues in confessions or in extracting information in general. Experiences from Vietnam suggest that physical torture was not as useful in obtaining information as permitting the individual to, in some way, depending on the individual, maintain his dignity. In criminal cases, confession may be more easily obtained by a policeman who is quite interested in the individual and his family and in the circumstances that led to the crime, rather than the overbearing, brutish interrogator. Another area of study here is the question of forensic hypnosis in extracting information or confessions. Some examples were given in which hypnosis permitted a defendant to recall events of great importance in developing innocence in criminal trials, that is, events which could be subsequently checked independently and which could preclude the defendant from any involvement in the crime.

Sex law reform, pornography law reform, decisions affecting the welfare of children, and subjects that deal with violence in the family were given consideration during the meeting. Legal and psychological perceptions of gambling also received discussion, and this topic has been heightened by the very recent Report (July, 1978) of the Royal Commission on Gambling chaired by Lord Rothschild. In the latter situation, the Government is faced both with permitting something that the public wants, and yet not letting it get out of hand. There is now almost 15 years of experience with current gambling regulations in Great Britain, and the Rothschild Commission Report is intended to serve as a basis for additional legislation by Parliament, if it deems it necessary. The Report presents the odds on all gambling games permitted, and has an interesting section that develops their computation. In a sense, this can provide a basis for consumers' protection legislation.

The Report itself does not go in great detail into the psychology of gambling but instead co-opts another volume prepared on this subject: "Gambling—A Review of the Literature and its Implications for Policy and Research," by D. B. Cornish, Home Office Research Study No. 42, 1978. There are obviously various subjects for study. Participation in gambling as related to sex, age, social status, propinquity to gambling places; economic motivation; use of psychological theories such as learning theory to account for persistent gambling. There is, in addition, the fact that gambling is not a unidimensional variable but of various kinds, such as casino gambling, football pools, horse racing, etc. The reader may also be interested in an article in a previous issue on this subject (see *ESN* 32-10; 357).

The meeting at Trinity College is the first of two to be held in this academic year; another is scheduled in the spring of 1979. The proceedings of this meeting will be published in a volume although the publisher is not yet known. At an initial meeting held about a year ago by the same group, a number of papers were prepared and these will be issued shortly in a volume to be published by Macmillan. (Herbert Solomon)

SPACE SCIENCES

EUROPEAN SYMPOSIUM ON PHOTOVOLTAIC GENERATORS IN SPACE

The European Space Agency (ESA) recently sponsored the first European symposium on space applications of photovoltaics. The papers presented provided a comprehensive review of the photovoltaic programs under the direction of ESA as well as national programs. Over 100 participants representing 10 countries and several international organizations were in attendance. Eight sessions covered the broad topical subjects of the evolution of photovoltaics, solar cell technology, solar array technology, and solar power satellites (SPS). The overall flavor of the papers was that of European participation in an SPS program and there was a 3-hour round table panel discussion devoted to the subject. Panel members represented ESA, the Commission of the European Communities, universities, solar cell manufacturers, the aerospace industries, and power boards. Topics treated included competing sources of energy, timeliness of the implementation of an operational SPS system, environmental impact of microwaves, and other solar energy conversion systems. The consensus of the panel was that Europe must become independent of imported energy sources and that the SPS might be instrumental in accomplishing this goal during the first quarter of the 21st century. The view of the power board representative was that breeder reactors are in operation now and could accomplish the energy independence goal well before the year 2000 and more economically. The proponents of nuclear fusion expressed the view from the floor that operational fusion reactor systems will be available in the same time frame as the SPS system. The SPS proponents disagreed with this viewpoint. The solar cell manufacturers and aerospace industry representatives assured the audience that solar cell and space station technology to accomplish an SPS system by the year 2000 was available now and only funding is in question.

The entire feasibility of assembling an SPS system depends upon the evolution of the US Space Transportation System (STS). Since this question as well as that of a US SPS system is still under consideration, the European community is directing its efforts toward assessing potential contributions to a US system that could also be used for Europe. Two of the more serious considerations are the number and size of the satellites to be incorporated into the system and what part of the total energy requirement the SPS system should provide. It is generally accepted that whatever configuration the SPS takes, it will be assembled in space from basic components and that the ultimate power stations will be developed through a staging process. Thus the European organizations involved in solar array technology as well as advanced technology solar cell development are concentrating their efforts on the development of large hybrid arrays involving solar mirror concentrators of various types and modular in nature.

Two papers of particular interest depicted the evolution of a space power station utilizing the STS for assembly. The first was presented by P.R.C. Gillett (British Aerospace) describing utilization of wing or planar arrays, with the work being carried out under ESA sponsorship. The second describes a family of modular solar generators—MOSGEN—with the concept being developed by J. Ruth and W. Westphal (Technical University of Berlin). The generators consist of hexagonal modules employing mirror concentrators. Gillett presented an examination of future solar arrays in relation to several Shuttle launched missions expected to occur during the next decade and also addressed some scenarios for providing space solar power in the 1990s. The mission scenarios are shown in Table 1. They indicate a strong exponential nature for future space photovoltaic opportunities. The first four scenarios are aimed at extending the current on-orbit duration of

TABLE 1. SPS Evolution Scenarios

SCENARIO	POWER*	TIME
Orbiter/Spacelab array	6 kW	1982/3
Free-flying pallet array	6 kW	1983
Orbiter Integral array	20 kW	1982/3
Power Module	55 kW	1983/4
Space Platform	250 kW	1987/8
Pilot Power Plant	2 MW	1990
Space Power Station	10 GW	1995

*Beginning of life

the STS/Spacelab mission and to provide increased power to Spacelab users. The latter scenarios are geared to examine the development, testing, and operation of a space power station in geostationary orbit.

The Orbiter/Spacelab array (Orbiter connotates a Shuttle which remains in orbit with its payload) would be mounted within the Shuttle cargo bay and deployed on orbit to provide additional power for the Shuttle payload. It would remain attached to the Shuttle and could be flown on missions of up to 30 days duration over a five-year period with about one mission every six months. The Free-flying pallet array would be similar to the Orbiter/Spacelab array in design and power except that it would be deployed on orbit, carry batteries for power during eclipse periods, and be used for long duration experiments which must be away from the Orbiter environment. Both systems would consist basically of two wings, each comprising two flexible solar cell blankets, supporting structure, cushion blanket, storage drums, and the necessary deployment and orientation mechanisms.

The 20-kW Orbiter Integral array and the 55-kW Power Module are extensions of the above arrays, the former providing a method of increasing the Orbiter on-orbit stay-time and the latter increasing on-orbit time as well as providing more power to payload instrumentation. The 20-kW array would provide power to both the Orbiter and its payload supplying all or part of the power requirements during sunlit phases, with fuel cells being used during eclipse periods. The 55-kW Power Module is envisaged to operate in three modes: A sortie support mode with the Module berthed to the Orbiter; An Orbiter storage mode, a quiescent situation in which the Module is unattached to any payload; and A free-flying mode with the Module docked to a free-flying satellite which might be a payload deployed from the Orbiter. Again, the array concept for both arrays is the two wing concept described earlier.

As the power level enters the 250-kW range, the ESA study envisages space platforms rather than arrays, and construction in space enters the picture. Various configurational concepts have been studied for such a platform, with the trade-off between the amount of assembly work required in space and the level to which stored volume should be minimized for transportation being a prime consideration. The European interest in such a program at this stage is heavily slanted towards solar cell technology and solar array module technology development with the intent of letting the US handle the assembly problems. Once a space platform has been accomplished, attention can be turned towards programs for establishing large power stations of the 2-MW Pilot Power Plant (PPP) or 10-GW SPS variety. It is possible that the Space Platform could become the PPP for the SPS depending upon the methods of technology advancement. The main objectives of the PPP will be to demonstrate the various aspects of construction of a power station and of space-to-ground power transmission. The PPP would be constructed in low earth orbit and then either operated there or in geostationary orbit depending upon the tests to be undertaken. One key factor relating to the technology requirements for the solar arrays of the power station is whether a level of concentration of the incident radiation onto the cells is adopted, and the paper by Ruth and Westphal which will be discussed later treats this subject. Solar concentrators have not been considered in the lower power deployed arrays since silicon solar cell efficiency drops rapidly with an increase in operating temperature thus requiring larger and heavier structures to provide either more cells or a heat sink. Gallium arsenide cells respond more favorably at higher temperatures and are more resistant to the charged particle radiation in space. However, it is not expected that these cells will be available until the late 1980s. For these reasons, research is being carried out at several institutions in Europe to perfect GaAs cells and improve silicon ones. While testing will no doubt be carried out with reflectors on smaller arrays, they are not expected to be economically feasible until the large power stations are implemented.

The ESA study recommends a European strategy for participating in an SPS that acknowledges three developmental factors. The first is the natural near-term progression of developments required for moderate increases in power required to support the early Shuttle era. Second is the potential of long-term space solar-power programs to swamp any near-term requirements if given a go-ahead, and thus these near-term programs should

be regarded as stepping stones to the ultimate solar-power development program. Finally, significant strides may be made in terrestrial photovoltaic developments owing to higher investments and quicker economic payback, and this condition might result in a reverse spin-off effect such that technology capabilities developed in the terrestrial programs may be used directly or adapted to the space photovoltaic programs. Solar-array technology development in Europe must evolve in the light of the above aspects, keeping options and applications open. The study recommends a future strategy which focuses on one principal objective—building up a firm experimental data base upon which decisions of high-level investment can be founded.

Whereas Gillett describes a philosophy for evolutionary development of large photovoltaic power stations in space, the Ruth and Westphal paper on MOSGEN treated a specific solar generator module with concentration mirrors which can be attached in space to provide the required power eventually agreed upon for the satellites in an SPS system. The multiplication of these modules requires finding the best relationship between module size, number of modules required, and the functional behavior of the entire system. The following considerations of a modularized system were taken into consideration by Ruth and Westphal in defining the optimum module: reduction of mounting procedures; decreasing manpower, tools and construction time in space; high maintainability; high variability of system configurations; early qualification of an operational system; and series production with a low number of different series and a high number of equal parts per series. Their conclusion after considering several options was that a hexagonal configuration with flat concentrating mirrors appears to be optimum. The structural stiffness achieved by this configuration helps avoid much of the supporting structure which is characteristic for most other SPS concepts. Moreover, the power distribution system can be integrated into the supporting structure linking the back sides of the modules. Figure 1 illustrates an individual module while Fig. 2 is an artist's conception of a Shuttle deployed integrated system.

About four years would be required to prepare for the first operational MOSGEN generator. During this time solar cell types would be selected and

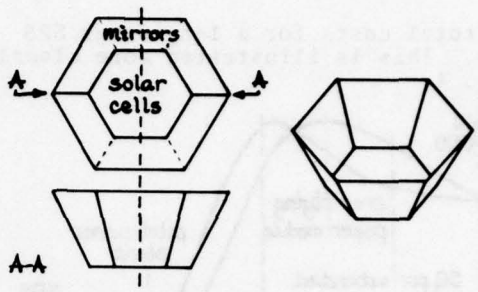

Figure 1. Concentration ratio about 2. Relatively stiff structure. Completely functional. Easy handling.

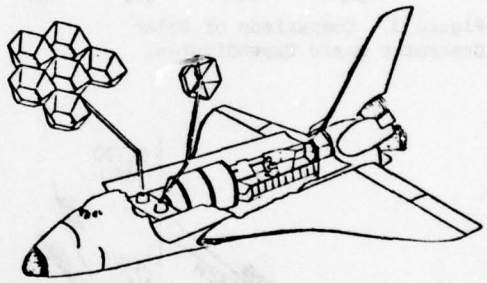

Figure 2. Integration of a 16-kW Solar Generator.

tested and a preliminary constructive optimization performed. In 1984, a Shuttle would carry up to 10 complete functional modules into low earth orbit where they would be assembled by extra vehicular activity in about a day. The power provided by this first generator is estimated at 16-kW. The next milestone in the MOSGEN program would be a free-flying generator producing about 40-kW assembled in orbit about 1987. If the concept and assembly procedures prove successful, an 8-GW SPS is envisaged by the end of the century.

It is believed by the authors of the MOSGEN paper that the modularized design concept combined with evolutionary development of an SPS should represent a significant long range cost savings relative to the separately developed generator (SDG) concept in which nonmodular generators are optimized along the way for specific missions. Figure 3 illustrates a cost comparison showing higher initial costs for the MOSGEN but

lower total costs for a long-range SPS system. This is illustrated more clearly in Fig. 4.

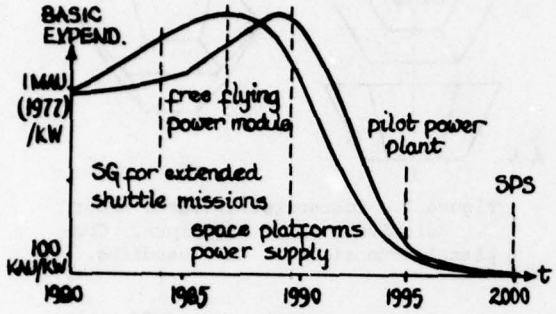

Figure 3. Comparison of Solar Generator Basic Expenditures.

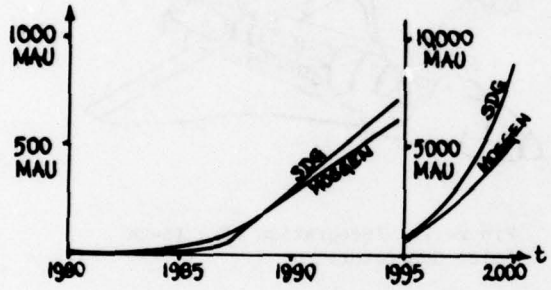

Figure 4. Comparison of Cumulative Basic Expenditures in the Development of Solar Generators.

The conference clearly demonstrated the European interest in keeping abreast of and advancing the state-of-the-art of space photovoltaic technology on a scale commensurate with expected economic return. This interest exists in both government and industry, each sector anticipating significant participation in any future solar power station. (Robert W. Rostron)

NEWS & NOTES

MEETINGS

European Undersea Biomedical Society 4th Annual Scientific Meeting

One hundred twenty participants attended a Congress on the Medical Aspects of Diving Accidents, held in Luxembourg 12-13 October 1978. It was sponsored jointly by the Mines Safety and Health Commission of the Commission of the European Communities, the European Undersea Biomedical Society, and the Medical Committee of the European Diving Technology Committee.

The Congress consisted of 20 scientific papers divided among 4 sessions, with panel and open discussions from the floor following each session. There were 2 "invited" general review papers leading each session, followed by anywhere from 2 to 5 "submitted" papers. Simultaneous translation of all papers into 4 languages was provided.

The first session was concerned with "Unconsciousness of the Diver in the Water," and an extensive review was followed by several papers on the various approaches to the problem of rescue and resuscitation of the unconscious diver. Session Two was entitled "Diagnosis of Decompression Illnesses" and largely dealt with different methods and results of ultrasonic detection of gas in the body. The third session concentrated on the "Treatment of Decompression Illnesses." Two excellent review papers, one on drugs and the other on the use of pressure and oxygen, were the high points of the morning. The final session on Friday afternoon was called "Coincidental Injury or Illness While at Raised Environmental Pressure." A very complete review of anesthesia in the hyperbaric environment was followed by a paper on the priorities for management of ill divers in an offshore pressure chamber. Case histories, both clinical and pathological, were also presented in two other papers.

A detailed review of this Congress, as well as other selected items of interest to the underwater medicine community, can be found in ONRL Report C-6-78. (LCDR R.F. Goad, MC USN, Exchange Officer, Underwater Medicine, Institute of Naval Medicine, Alverstoke, Gosport, Hampshire, UK)

The following briefs on two international meetings are based on recent information provided to ESN by Dr. R. Bhattacharyya, Guest Professor at the Technical Univ. of Denmark at Lyngby.

The 15th International Towing Tank Conference (ITTC)

The 15th triennial ITTC was held 3-10 September 1978 in the Hague, the site of the first conference in the series held in 1933, when the ITTC was known as the International Conference of Tank Superintendents. Twenty-three delegates, representing 10 European model basins in 9 countries attended that first meeting. At the 15th one, sponsored and organized by the Netherlands Ship Model Basin (NSMB), there were about 200 delegates representing 65 basins in 35 countries including the People's Republic of China. In this connection it is particularly worthy of note that the ITTC continues to represent and foster a very high spirit of international cooperation between scientists and engineers.

The main objective of the ITTC is to stimulate and support the development of experimental methods for the prediction of the hydrodynamic behavior of ships. Over the years this objective has been expanded to include other marine structures. Emphasis on the experimental approach follows from the fact that full-scale ships and structures are major economic investments, while the hydrodynamic theories for bodies moving in, above or below the water are complicated, with the result that model testing plays a very significant role in the determination of optimum forms for powering, seakeeping, sea worthiness, and maneuverability.

The ITTC is governed by an Executive Committee consisting of eight members representing various geographical areas, under whose guidance various technical committees function and report to the Conference on developments during the preceeding three years. Membership of these committees is primarily from facilities with adequate support and capability to pursue the technical issues involved.

General topics chosen at the 14th ITTC for emphasis at the 15th meeting were flow around the hull, motions of the hull, towing tank systems and techniques, propulsion, and ocean engineering. Technical Committee reports covering Resistance, Performance, Seakeeping, Maneuverability, Propeller, Cavitation, and Presentation and Information were available in advance to the 15th ITTC delegates as Vol. 1 of the Conference Proceedings. These reports were discussed to develop acceptable recommendations for future committee activities. Reports from the ITTC's Ice and Ocean Engineering Panels were treated similarly and the activities of both of these panels were raised to the status of Technical Committees. In addition a new High Speed Vessel Panel was established.

All contributions from the participants, general assembly recommendations, and the like, will be available in a second Volume of the Proceedings to be published by NSMB in the near future.

Among the more important recommendations of the Executive Committee were the following:

a) The technical committees were asked to take note of the most recent development in the theoretical methods for ship prediction, although at present there may be a tendency to overestimate the usefulness and accuracy of these methods in certain applications.

b) With the increase in size of oil carriers "shallow water" effects on resistance, trim, squat, wake flow, etc., have become more important and should be considered in future committee reports.

c) More attention should be paid to ship behavior prediction and correlation with full-scale measurements.

d) Exchange of information on the application of computer programs should be further stimulated.

In the closing ceremony the outgoing chairman Prof. J.D. van Manen, Director of the NSMB, announced that the 16th ITTC will be sponsored and organized by the Krylov Institute (under the chairmanship of Prof. G.A. Matveyev, the Director) and held in Leningrad in 1981. It will be the first to be held in a Communist country. It was also announced by delegates from the Bulgarian Ship Hydrodynamic Center that it is intended to hold a Technical Symposium prior to the 16th ITTC so that Conference participants may have the opportunity of visiting the major ship experimental facility built in recent years.

The International Maritime Association of the East Mediterranean First International Congress

The International Maritime Association of the East Mediterranean was founded at Trieste, Italy in June 1977. To date, three countries are participating, Italy, Yugoslavia, and Turkey, but it is expected that more from the area will join in a united effort aimed at widening their influence in shipping and shipbuilding. Turkey took the initiative under the leadership of Dean Teoman Özalp of the Technical University of Istanbul in organizing IMAEM's first International Congress which was held at the Technical University, 25-30 September 1978.

In his opening speech the President of IMAEM, Prof. A. Servello (Univ. of Trieste, Italy), paid tribute to the maritime tradition and its great influence on the history of the peoples of the Eastern Mediterranean. Discussing the diverse evolution of maritime craft, he credited the Phoenicians, who were exceptionally capable mariners, for conceiving the idea of multiple banks of oars, probably to utilize the increased freeboard they had added to their ships for better seakeeping qualities. He also cited Constantinople (now Istanbul) as historically the leading place in the shipping and shipbuilding activities in the whole Mediterranean. He concluded by stating that 3,000 years of history have inspired the association to organize its first Congress in Istanbul, a jealous custodian of ancient traditions.

In the parallel technical sessions some 40 papers were presented in the fields of naval architecture, marine engineering, and ship production as well as on general topics related to shipping and shipbuilding. They covered such diverse subjects as ship design; off-shore structures; marine transportation systems; marine engineering; ship hydrodynamics; the role of international regulatory bodies; shipyard and production techniques; ocean engineering wave mechanics; ship stability and safety; and model experimentation. Twenty-six of the papers were given by invited participants from seventeen countries. A large number of Turkish scientists and engineers alongside 43 foreign guests took part in the presentation of papers and the following discussions. The Congress was valuable to the foreign participants in providing an opportunity to learn of the fast-growing Turkish shipbuilding industry and of the high standard of educational research and experimental activities being carried out at the Technical University of Istanbul. It was particularly heartening to note the efforts young faculty members of the Technical University are making in the research and development work for naval architecture, marine engineering as well as ocean engineering, and that most of them have had experience in academic pursuit in foreign countries, such as West Germany, the UK, and the US.

Preprints of papers were supplied during registration, and a bound volume containing all the papers as well as the formal and informal discussions will be available in near future. Those interested should contact Dean Teoman Özalp of the Technical Univ. of Istanbul.

ONRL NEWS

Dr. Herbert Solomon, our Chief Scientist has been awarded the Navy's Distinguished Public Service Award for his accomplishments in the field of mathematical sciences. The award which was presented by Dr. David E. Mann, Assistant Secretary of the Navy for Research, Engineering and Systems on 13th November, is the highest award that the Secretary of the Navy can confer on an individual not employed by the Navy. RADM Albert J. Baciocco, Jr., chief of Naval Research, read the accompanying citation to the assembled group from the DOD, government agencies and universities. Dr. Solomon received the award in recognition of services performed at Stanford University where he was the principal investigator for research in mathematical statistics and probability and applications in Department of Defense problems. He is serving in ONRL as Chief Scientist while on leave of absence from Stanford.

Staff Changes. Just before Christmas, we bade farewell to four of our staff members, two of whom were Liaison Scientists and two, Naval Applications Officers. Dr. Jack A. Adams (Psychology) has returned to the Univ. of Illinois, at Urbana-Champagne, where he is Professor of Psychology. Dr. Clifford C.

Klick (Physics) has returned to the US where in January he plans to retire. LCDR John D. McKendrick (Ship Systems and Military Oceanography Officer) has been transferred to the Naval Oceanographic Command, Bay St. Louis, MS, and LCDR David C. Rummler (Command, Control and Communication Systems Officer) has been assigned to the Naval Material Command in Washington, DC. We wish all of them success and smooth sailing.

In November, we welcomed aboard LCDR Clayton H. Spikes, who reported in from Commander in Chief, Atlantic Fleet, Norfolk, VA. He has taken up the post of Ships Systems and Military Oceanography Officer.

PERSONAL

Dr. C.B. Blakemore, Lecturer in Physiology and Fellow of Downing College, Univ. of Cambridge, has been elected Waynflete Professor of Physiology at the Univ. of Oxford from 1 October 1979. He will succeed Professor D. Whitteridge, who is retiring.

Mr. P.H. Gore, Reader at Brunel Univ., Uxbridge, has been promoted to the Personal Chair in the Department of Applied Chemistry at that University.

Dr. T.H. Pennington, Senior Lecturer in Virology with honorary consultant virologist status at the Western Informary, Glasgow, has been appointed to the Chair of Bacteriology at the Univ. of Aberdeen.

Prof. Vincent Reddish has resigned as Director of the Royal Observatory, Edinburgh, after a dispute with the Science Research Council over the program of work and staffing of the establishment. Since 1975, he has held this post, which carries associated appointments as Astronomer Royal for Scotland and Regius Professor of Astronomy at Edinburgh Univ. He was responsible last year for having a British infrared telescope, the largest ever built, shipped to the Pacific for use in Hawaii. Reddish said that he is leaving science altogether next September, when he intends to retire to his home in the Scottish Highlands.

Mr. William Shepherd, Reader in Electrical and Electronics Engineering at the Univ. of Bradford, has been appointed to the Chair in Electrical Power Applications at Bradford.

OBITUARY

Prof. Herbert Dingle, the well-known philosopher of science, critic of relativity, and lover of English literature died on 4 September shortly after his 88th birthday. Formerly Professor and Head of the Department of History and Philosophy of Science at University College, London, a position to which he was appointed in 1946, he had previously spent more than ⅔ of his academic life at Imperial College of Science and Technology. At Imperial, Dingle specialized in Spectroscopy and became head of the Spectroscopy Section in 1935 and Prof. of Natural Philosophy in 1937. However, despite personal student memories of one of the editors, he will be remembered primarily as a writer on the philosophy of science and particularly so in the US which he visited for two lengthy periods in the thirties. As a critic of relativity, his onslaught on special relativity was not solely destructive for he attempted to develop further the Swiss physicist W. Ritz' "ballistic" theory of light emission. Two of his books demonstrate his appreciation of English literature, particularly poetry, and his beautiful literary style—*Science and Literary Criticism* (1949) and *The Mind of Emily Bronte* (1974).

ONRL REPORTS

R-8-78 AN OVERVIEW OF ELECTRONICS EDUCATION IN POLAND AND ROMANIA by D.K. Cheng

To promote mutual understanding and exchange scientific ideas, the US National Academy of Sciences has established exchange programs with Eastern European countries. This article reports some factual information and personal impressions of the engineering education in general and electronics education in particular after a month-long trip to Poland and Romania.

R-9-78 NATIONAL HEALTH SERVICE AND MILITARY MEDICINE IN GREAT BRITAIN by P.F.D. Van Peenen

This report describes similarities and differences between US and British military medicine, with emphasis on preventive medicine. British National Health Service has apparently had remarkably little effect on the mission, organization, and practice of military medicine in the United Kingdom. The major problem for the British military medical services is identical to that for the US: recruitment and retention of physicians.

-10-78 SOME ELECTRICAL AN[illegible]CTRONICS ENGINEERING ACTIVITIES IN THE USSR by T.G. Berlinc[illegible]rt

This report covers visits made to scientific and technical institutes in the USSR and to the Popov Society Congress during 12-28 May 1978. Institutes visited were the Krenkel Central Radio Club (Moscow), Institute of Radioengineering and Electronics of the Academy of Sciences (USSR), A.A. Baikov Institute of Metallurgy (Moscow), Institute of the Problems of Transfer of Information (Moscow), All-union Electrotechnical Communications Institute by Correspondence (Moscow), Television Center (Moscow), TV Tower, Moscow State University, Ulyanov (Lenin) Electrotechnical Institute (Leningrad), and the Institute of Cybernetics (Kiev).

C-11-78 FOURTH INTERNATIONAL BIODETERIORATION SYMPOSIUM BERLIN, WEST GERMANY, 28 AUG-1 SEPT 1978 by E.C. Haderlie

This is a short account of the Fourth International Biodeterioration Symposium discussing briefly the aspects of biodeterioration covered. A complete list of papers presented is included, however, as proceedings are to be published within six months, no papers are discussed.

SUBJECT INDEX FOR VOLUME 32, ESN ISSUES 1 THROUGH 12, 1978

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