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(10) Aubrey W. Pryce
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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 members of the staff of ONRL, with certain articles prepared by, or in cooperation with, members of the scientific

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

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Aubrey W. Pryce and Victoria S. Hewitson

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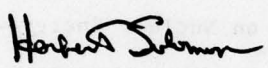

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AEROSPACE

BALLOONS ARE STILL FASHIONABLE IN FRANCE

France has had a strong national interest in space science and technology since the late 1950s. In 1962, with the creation of its national space agency, Centre National d'Etudes Spatiales (CNES), these interests took on a structured nature with definite goals. CNES is nationally responsible for all civil French space programs and works closely with the European Space Agency (ESA) in various joint international programs. The French have launched over a dozen nationally produced research and technology satellites on their own launch vehicles from their Kourou, Guiana, space center. In cooperation with the Germans, they have succeeded in building the first European telecommunications satellite (US launched) and have continuing cooperative programs underway with the US and the USSR. The current national budget for civil space programs is over $250 million of which about 63% is allocated to ESA. A large portion of the total budget is supporting satellite and launch vehicle programs such as Spacelab, SPOT (a national earth observations satellite), and the Ariane launch vehicle (Atlas-Centaur class).

Apart from these extensive spacecraft programs, CNES has continued to place heavy emphasis on space and atmospheric study projects using balloons as experimental platforms. These programs have involved the launching of over 1500 balloons from France, Antarctica, Argentina, Brazil, Iceland, Norway, Sweden, and the USSR. Owing to this emphasis, France remains the only active balloon-launching country in Western Europe. All scientific experiments using balloon platforms launched in France are organized by CNES. In many cases launches in other countries are coordinated by CNES, and these services may be provided on a no-charge basis if CNES has an interest in the experimental program. In general, however, French and other national experiments are launched on a cost reimbursable basis. Proposals for balloon support are submitted to CNES headquarters in Paris.

The main research facilities of CNES are located in the south of France in Toulouse, which serves as the home for almost the entire French aerospace industry. The two balloon-launch facilities are also located in the south, the primary site being in the town of Aire-sur-l'Adour. The secondary site is to the east near Gap-Tallard and is used mainly during June and July when the prevailing stratospheric winds are east to west. The main facility has several special purpose buildings for testing and integrating payloads, inflating superpressure and special purpose balloons, telemetry recording, tracking, and maintenance. Its small meteorological station is complete with teletype and facsimile machines for receiving the most recent weather data. A team of 20 people is responsible for the tasks mentioned above, as well as data and payload recovery. For the latter function a small aircraft and Land Rover are used.

A typical launch is performed in a somewhat different manner than in the US and the payloads are generally smaller. Instead of hoisting the payload rig by a truck-crane and maneuvering it under the rising balloon (a sometimes tricky operation), it is immediately attached to a small tetrahedral balloon that is attached to the same cable as the larger main balloon. As the main balloon rises, the smaller balloon lifts the experimental payload until the cable is vertical. The smaller balloon is then mechanically separated and the main one takes over. This method is very simple and reliable in winds up to 14 m/sec and where small launch areas must be utilized. Europe's political boundaries, mountains, and water areas do not lend themselves to long-duration balloon experiments. Trajectories must be closely watched if the experiments are to be recovered in an accessible and dry area. Flight durations, under good conditions, average 6 to 8 hours on east-to-west flights and may be half those values on west-to-east flights because of stronger winds. There is, however, another long-flight launch site that was successfully tested in August 1977. In cooperation with Italy and Spain, CNES launched two 350,000 m^3 stratospheric balloons from Sicily. These traveled across the western Mediterranean and were recovered in southern Spain. Both flights exceeded 20 hours, attaining altitudes of 40 km. An expanded campaign is planned for July and August 1978 with, eventually, much larger payloads.

The current emphases in balloon R&D and balloon oriented experiments at CNES are in several areas. A continuing program prevails in the development and testing of stratospheric balloon materials and manufacturing techniques. The FGGE experiment [First GARP: (Global Atmospheric Research Program) Global Experiment], for example, will involve the deployment of super pressure balloons, containing internal instrumentation, over the Indian Ocean at low altitudes. Wind vectors will be determined as in a French program conducted in the Southern Hemisphere in 1974. Another program, the Venus Project, is being conducted in cooperation with the Soviet Union. In this experiment CNES will eject and inflate from a spacecraft an 8-m-diam. balloon into the atmosphere of Venus. The launch and subsequent balloon deployment is scheduled to commence in 1983, and the experiment will measure the atmospheric constituents and other parameters of Venus. CNES is currently sponsoring tests of materials and adhesives for the balloon.

CNES would like to undertake new efforts in the study of high-altitude tethered balloons. Tests were conducted with such balloons in the early 1970's from Guiana, South America, without complete success. The balloon, a standard stratospheric type, was launched on the coast and tethered to the winch of a ship in the harbor. The low reel-out speed of the ship's winch and the weight of the cable precipitated the partial failure of the experiment. In new efforts with tethered balloons, an improved cable weave would be used.

The Zodiac-Espace company in Toulouse has for many years been prime contractor for fabricating all of the CNES high-altitude, superpressure, and special purpose balloons. A second balloon R&D/manufacturing facility, Brochier-Espace, has recently been established in Lyon, France. This company works with CNES and Zodiac-Espace in developing and manufacturing new and more efficient balloon materials.

Several types of balloons are manufactured for CNES. Natural shape, free stratospheric balloons are routinely manufactured with volumes up to 350,000 m^3 of 25-μm thickness polyethylene film, sealed by tape heat-welded to the balloon sections. These balloons can reach altitudes of 34 to 43 km (5.9 to 2.0 mbar) carrying a 350-kg payload. The relatively small payload size is dictated by safety restrictions imposed over high population and air-traffic density areas of France.

Tetrahedral balloons are also manufactured routinely in quantity. Two types are currently being produced. The first is the small auxiliary balloon used in conjunction with the main stratospheric one. The size may vary in order to allow a lift slightly exceeding the gondola weight. The second type is larger, having volumes up to 87,000 m^3, and is constructed of 25 or 50-μm thick polyethylene film. These easily produced, inexpensive balloons are used as free stratospheric balloons but carry maximum payloads of only 200 kg.

Superpressure balloons are made for special programs such as GARP, FGGE, and EOLE. EOLE was the 1974 French Southern Hemisphere program referred to earlier in which balloons were released and tracked for an average of 111 days to determine atmospheric winds from 1- to 16-km altitude. Such balloons are produced in sizes varying from 1.0 to 4.4 m in diameter, up to 45 m^3, from 50-μm laminated polyester film.

France is singular among the nations of Western Europe in its ability to manufacture and launch high altitude and advanced technology balloons for scientific payloads. Despite the Shuttle and Ariane, CNES plans on increased exploitation of this capability in the future.
[MAJ. David T. Newell (EOARD) and Robert W. Rostron]

MORE ON SPACE FROM BRITISH AEROSPACE COMPANY

In the 31 December 1977, issue of *ESN* (*ESN* 31-12:514) an article on satellite technology at British Aerospace (BAe) mentioned the four corporations or corporation segments from which the nationalized company was formed—namely, Hawker Siddeley Aviation, Hawker Siddeley Dynamics (HSD), Scottish Aviation, and British Aircraft Corporation (BAC). Nearly all of the satellite orientated programs of BAe are concentrated in the Electronic and Space Systems Division of the Dynamics Group which is composed of similarly titled divisions of the

former Hawker Siddeley Dynamics Space Division, located at Stevenage, and British Aircraft Space Division, located at Bristol. The terminology is still rather difficult to sort out, and both BAC and HSD are continuing to operate in a rather autonomous fashion pending further reorganizations. For example, each of these entities are members of separate competing European consortiums. HSD tends to bid on contracts involving primarily spacecraft bus development and systems integration, and BAC tends to bid on those involving prime power sub-systems, scientific payloads, attitude and orbit control, and data handling. This situation is dictated partly by the nature of the consortiums and partly by the funding policies of the UK government. This article will focus on some of the past and present programs of the BAC division and highlight two rather innovative projects.

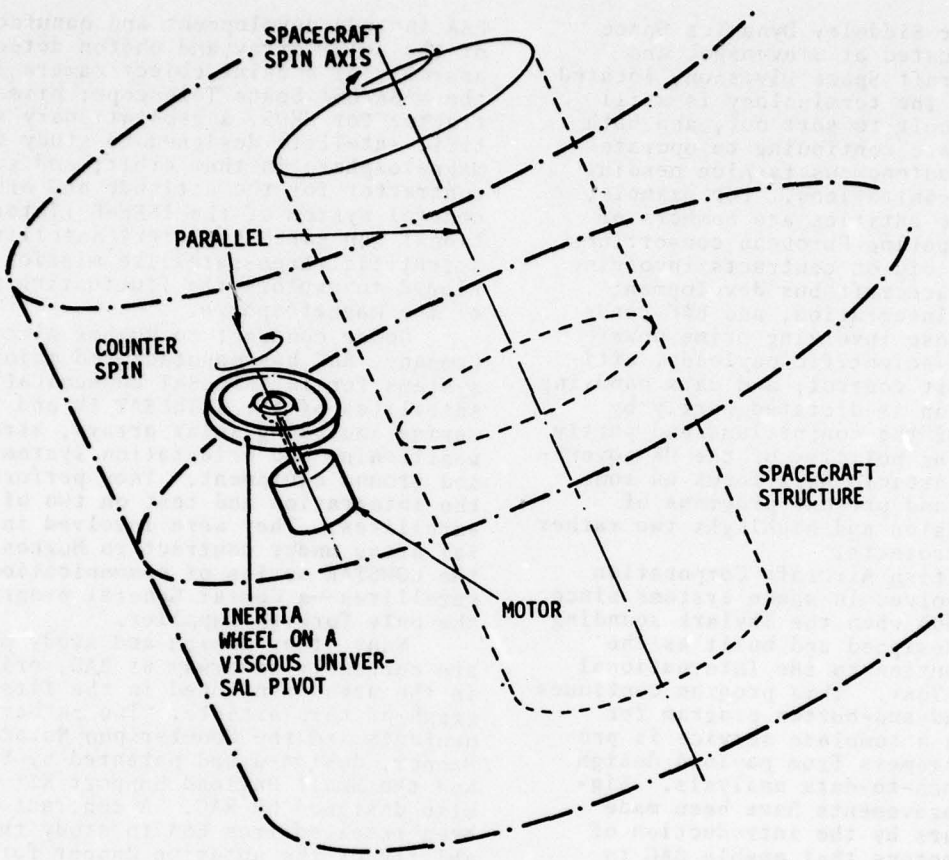
The British Aircraft Corporation has been involved in space systems since the late 1950s when the Skylark sounding rocket was designed and built as the UK's contribution to the International Geophysical Year. This program continues to be a bread-and-butter program for BAC in which a complete service is provided to customers from payload design through launch-to-data analysis. Significant improvements have been made over the years by the introduction of new rocket motors that enable BAC to offer a capability across the entire spectrum of sounding rocket research. The most recent version, Skylark 12, will lift a 140-kg payload to 800 km. Some 365 Skylarks have been launched to date from ranges around the world.

The second major national program in which BAC has been and continues to be involved is the UK or Ariel series of scientific satellites. Of this series of six satellites, BAC has had various responsibilities ranging from experimental package contractor through subcontractor to prime contractor. The mission of these satellites has included x-ray astronomy, radio astronomy, ionospheric measurements of electron and ion temperature, density and composition, and measurements of micrometeorite fluxes.

BAC is continuing to participate in international programs through the European Space Agency (ESA), INTELSAT (International Telecommunications Satellite Consortium), and Comsat General Corporation. Current contracts with ESA include development and manufacture of the solar array and photon detector assembly of a faint object camera for the NASA/ESA Space Telescope; prime contractor for GEOS, a geostationary scientific satellite designed to study the magnetosphere in that orbit; and subcontractor for the attitude and orbit control system of the ISEE-B (International Sun Earth Explorer) satellite—a scientific three-satellite mission designed to explore the fluctuating nature of the magnetosphere.

Under contract to Hughes Aircraft Company, BAC has manufactured major subsystems for 16 INTELSAT communications satellites of the INTELSAT IV and IVA series including solar arrays, structures, positioning and orientation systems, and ground equipment. They performed the integration and test on two of the satellites. They were involved in similar areas under contract to Hughes in the COMSTAR series of communications satellites—a Comsat General program—as the only foreign supplier.

Many other design and study programs are currently underway at BAC, primarily in the areas mentioned in the first paragraph of this article. Two rather novel projects are the Counterspun Nutation Damper, designed and patented by BAC, and the Small Payload Support Kit SPSK—also designed by BAC. A contract has been received from ESA to study the suitability of the nutation damper for future ESA spacecraft. This device will provide the "fine tune" stabilization for a spinning prolate spacecraft in place of conventional active control systems, despun platforms or passive dampers—that is, it will remove the small nodding periodic motion (nutation) experienced by a spin-stabilized spacecraft. The device consists basically of a drive motor spinning about an axis which is parallel to the spacecraft axis but with the spin in the opposite direction, and with a compliantly-mounted flywheel on the motor shaft. Energy dissipation is associated with flexing of the compliant mounting. (See diagram on the following page). In the current BAC model of the device, the compliant mounting consists of a viscously lubricated ball-joint between the flywheel and the motor shaft. Other methods of compliant mounting are under study. The model is of sufficient size to damp the nutation of a spacecraft 44 cm in diameter and about 1.0-m long, weighing about 100 kg. Development of



DAMPER ESSENTIALS

a device to stabilize a spacecraft with a moment of inertia of several hundred kg m^2 is proceeding.

BAC envisages the damper being used for several applications including: Stabilization of spinning sounding rockets during coast; stabilization of spinning geostationary satellites during transfer orbit when they are destined to be 3-axis stabilized; stabilization of spinning upper stages launched from the space shuttle during delay before firing; stabilization of spinning launcher stages during prolonged coast; and stabilization of spinning variable-geometry satellites during transition from prolate to oblate or vice-versa. Although the damper was designed to stabilize a prolate spacecraft, it can also be designed to stabilize an oblate one or make a spherical one spin about a preferred axis. Thus it can be fitted to a variable-geometry satellite and still operate continuously.

The Small Payload Support Kit has been designed to assist experimenters utilizing the low cost, small, self-contained payloads offered by NASA on the Space Shuttle. The NASA packages are defined to weigh under 200 lbs, (mass of 91 kg) have a volume less than 5 ft^3 (0.14 m^3), and require no Shuttle services such as power and data storage. They will be carried for a nominal cost and permit scientists operating on small budgets to carry out experiments in space utilizing the unique environment of weightlessness, hard vacuum, a synoptic view of the earth and its atmosphere, and of direct exposure to solar, stellar, and cosmic phenomena. BAC has reserved space for prospective users on the

earliest available Shuttle flight. The SPSK is a container which can be mounted in various places on the Shuttle. In addition to the container, optional components include a high energy power pack, high capacity tape recorder, a thermal control system, and a sealed box for equipment not suited to hard vacuum. The main container has a mass of 13 kg, an internal capacity of 0.12 m^3, is unpressurized, and will maintain a temperature between 0°C and 50°C by a heater/radiator combination. The power pack has a mass of 11 kg, a volume of 0.0058 m^3, a capacity of 1000-W hr and will operate from lithium cells at an output of 28 V. The tape recorder has a mass of 3 kg, a volume of 0.0044 m^3, and a capacity of 144 megabits, and will require 2 to 4 W of power. The sealed box will vary in size from a volume of 0.014 m^3 and mass of 6 kg up to approximately the maximum size stipulated by NASA cited above. It will be hermetically sealed at 1 atm.

The kit is designed so the user can install his own experiment in his own laboratory with BAC providing technical support, if required, to ensure acceptance by NASA as to safety and interface verification. The kit components themselves will be NASA approved so that for experiments involving nonhazardous components, NASA acceptance is expected to involve little more than inspection of the completed payload.

The facilities for integration and test of scientific payloads, spacecraft sub-systems and entire spacecraft are extensive at the Bristol facility. Many of these are remnants of the INTELSAT IV program, particularly the spacecraft assembly building which was constructed in 41 weeks and is the largest of its type in Europe. The assembly area is adapted to standard clean-room conditions and contains a vibrator, dynamic balance equipment, and an rf-screened room. An environmental test laboratory, containing a comprehensive range of equipment for providing simulated climatic conditions and vibration environments, is available for testing components or completed systems. A large anechoic chamber is well equipped for antenna pattern analysis. Unfortunately many of these facilities are idle because of the realignment of projects between BAC and HSD and a lack of contracts. Some of them are being revamped to support work in the power system and orbit control areas for which BAC does have contracts.

The continuing problem with the overall British space program is that there is no central control agency and support comes from three primary sources: Science Research Council, Department of Industry, and Ministry of Defence. This situation continues to frustrate the space-oriented companies. The establishment of a national authority would be a most welcome event to these organizations. (Robert W. Rostron)

ENERGY

MAKING DECISIONS ON NUCLEAR ENERGY—BRITISH WAYS

Over a period of a year Great Britain will have possibly made three important decisions with regard to nuclear energy. The first is past. A decision has been taken to proceed with production of two more advanced gas reactor (AGR) power stations for the late 1980s rather than switch to another type. A second decision is nearly complete. This article is being written just as the House of Commons, on its first test, has voted overwhelmingly to support the establishment of a thermal oxide reprocessing plant (THORP) at Windscale. The third decision lies ahead; its substance is whether the British should proceed with the development of a commercial fast breeder reactor or not.

We feel that it is appropriate to review in this note not only the substance of the decisions that have been made but also the paths that have been followed in reaching them.

Energy supply in Great Britain is currently less critical than for many other countries. The oil crisis of 1973 and the subsequent sharp increase in the cost of oil and of energy generally has left its mark on the UK consumer. One result has been that the demand for electrical energy has fallen and can now be readily met by existing generating facilities.

North Sea gas deposits are being heavily exploited replacing coal gas for domestic and industrial uses and powering some generating stations. North Sea oil is beginning to appear reducing the British need for imported oil which had earlier in the 1960s, as in much of Western Europe, substantially replaced coal as the primary fuel. Large coal deposits exist and represent a substantial reserve for the future, the demand on which has decreased substantially in recent years despite an active mining industry. There is also a well-established nuclear energy industry. For a number of years 10% of the UK's electrical energy has come from nuclear stations, very largely from its first commercial program of 9 Magnox reactor stations [some experimental and prototype reactors also supply power to the grid, a steam generating heavy water reactor (SGHWR), an AGR, and a prototype fast reactor]. This figure will grow to more than 20% as 5 AGR stations ordered under a second program and now coming into operation are completed. It is in this complex and in many ways particularly favorable energy background that the UK is making its nuclear energy decisions and concurrently exploring other alternative non-fossil fuel energy sources such as solar energy and wave power. (See *ESN* 31-10:396, *ESN* 32-4:124, and *ESN* 32-4:128.)

At the end of January 1978, the Secretary of State for Energy, Mr. Anthony Benn, announced a government decision to order two more AGR power stations for the nation and to provide financial support to develop the detailed plans necessary to carry a pressurized water reactor (PWR) station through the planning and safety clearance stages necessary before a firm order for a PWR station could be placed.

This ended, temporarily at least, an intense battle between advocates of various reactor systems, or of no reactor system at all, each anxious to see his view prevail concerning the selection for the UK's third commercial nuclear power station program. Although an earlier government decision of July 74 in regard to this third program favored the SGHWR, principal recent candidates have been the AGR and the PWR. Only Britain builds the AGR, the first of which has had little more than a year of operation with about 30% of its expected output in that time. There have been construction problems and the necessity for some redesign. They are also said to be more expensive than the PWR that is an American design and is the predominant nuclear power plant throughout the world.

The preamble to this decision has in many ways been reminiscent of a Wagnerian opera, if not the complete Ring. It has involved a complex range of technical, industrial, political, economic, resource, environmental impact, and safety considerations, not necessarily in that order of priority, and all perhaps tempered a little by considerations of national prestige, but all significant to the making of such an important national decision. Factors have included the nuclear industry's need for orders to sustain itself and to build a base for overseas sales in a highly competitive market. The Central Electricity Generating Board has wanted experience with both kinds of reactor before deciding how future orders are to be placed. Some manufacturers have wanted to produce the PWR for local and world markets. It has been argued that starting from scratch, the PWR would take several years longer than building an AGR, while there have been questions of safety. The decision trail has been beset by frustrating periods of indecision but, more unfortunately, by decision reversal and reexamination. Facets of this trail have been covered in earlier articles by contributors fascinated in part at least as much by the UK's search for a decision process as by the technical and other questions. (See *ESN* 29-7:308 and *ESN* 31-3:306.)

The final decision arrived at within the government and offering a degree of compromise has followed wide consultation, intensive lobbying, and extensive and protracted airing of conflicting views and interests. The Press and other news media watching from the outside have rendered opinions and reported the diverse views. Individuals, national organizations, government agencies, and many others have been deeply involved. Public discussion has been organized and has developed in unexpected fora. (See, for example, *ESN* 31-4:150.) Select Committees on Science and Technology of the House of Commons have inquired into the subject and have reviewed, reported, criticized, and recommended. Particular details have been subjected to exhaustive technical examination. But the decision itself has been internal to the government.

With this decision now made, earlier questions in some parts as to the safety of the PWR have been frozen, put on ice, or committed for resolution depending on how individuals will choose to interpret the additional technical knowledge that is unravelled prior to a final decision as to whether to go ahead, or otherwise, with a PWR.

The second decision has concerned the request by British Nuclear Fuels Limited (BNFL) for planning permission to create a "plant for reprocessing irradiated oxide nuclear fuels and support site services" at their Windscale Works in Cumbria. There already exists a plant at Windscale to process fuel elements from nuclear reactors of earlier design. A new plant would separate plutonium and uranium from spent AGR fuel elements. In addition, the plant is planned to be large enough so that half of its capacity could be used to process fuel elements from countries that have nuclear power plants but do not have reprocessing facilities. A large public outcry concerning the possible implications of the creation of such a plant led the government to establish a Windscale Inquiry to study the matter. Mr. Justice Parker, a High Court judge chaired the inquiry; he was advised by two experts in the nuclear field, Sir Edward Pochin and Sir Frederick Warren.

A normal local planning inquiry would concern itself with elements of safety and the effect of the plant on the local community. Justice Parker enlarged the scope of the inquiry at the outset. He proposed that three questions should be asked:

"1. Should oxide fuel from United Kingdom reactors be reprocessed in this country at all, whether at Windscale or elsewhere?

"2. If yes, should such reprocessing be carried on at Windscale?

"3. If yes, should the reprocessing plant be about double the estimated size required to handle United Kingdom oxide fuels and be used, as to the spare capacity, for reprocessing foreign fuels?"

The Windscale Inquiry conducted in the nearby town of Whitehaven, opened on 14 June 1977 and closed on the hundredth day of hearings, 4 November 1977. It was, in the meantime, something of a National Town Meeting between proponents and opponents of an increased reliance on nuclear energy in the 21st century. Justice Parker heard 146 witnesses and accumulated some 29 feet of documents. Most of the major groups immediately concerned with the inquiry were represented by legal counsel. Witnesses not only testified but were subject to cross examination by opposing counsel and direct examination by Justice Parker. In addition Justice Parker ordered that some tests be carried out during the inquiry to bring in evidence on points that were in dispute concerning the safety of the present Windscale plant. These tests included analysis for tritium in seaweed, soil, scallops, and potatoes from the Isle of Man, airborne radioactive contamination in a nearby village, and whole body monitoring of fish eaters for cesium.

Justice Parker presented his report of the inquiry to the Secretary of State for Environment, Mr. Peter Shore, on 26 January 1978; It has since been printed as Volume 1 of "The Windscale Inquiry" and is available from Her Majesty's Stationery Office at a cost of £3.75. Its 90 pages of very readable analysis include discussion of the nuclear weapons proliferation question, terrorism and civil liberties, the need for reprocessing of oxide fuel, financial aspects, risk of accidents and risk from routine plant discharges, size of plant, public hostility, and conventional planning issues. It recommends that THORP be approved. Justice Parker argues that the long term storage of unprocessed fuel is more dangerous than processing it. On the proliferation issue he argues that a refusal to process foreign fuel "...would put pressure on non-nuclear-weapon states which could lead them to produce their own plutonium long before they could receive any from THORP." It is, of course, in this judgement that the report differs most significantly from the stand taken by the US Government.

One can ask what was accomplished by the Windscale Inquiry and the large funds spent on both sides to conduct it. Perhaps the ultimate gain was the process itself. Here was a broad public forum to collect evidence, analyze arguments, and arrive at judgements on issues in which there are important long range consequences and current passionate disagreements. To quote Geoffrey Taylor of *The Guardian*, "...the democratic process, in France, Germany, Sweden, and the United States is what ultimately counts, and it is probably to Britain's credit that the process has been significantly improved by the pilot project at Whitehaven."

The public inquiry, the inspector's carefully reasoned public report, the debate in the House of Commons, and a Commons vote on the issue all contrast strongly with the first case where most of the action was behind closed doors and a decision was simply announced by the government. We commend Justice Parker's report to all those interested in the subject and, indeed, to those interested in the decision process in an area of very considerable technical complexity and major public concern.

During the Windscale Inquiry, Justice Parker asked that the government declare whether a public inquiry would be held if there is an application to build Britain's first commercial-scale nuclear breeder reactor. He felt that some issues concerning the fast breeder reactor should be pursued at the Windscale Inquiry if a separate public inquiry were not to be held.

The government finally gave assurance that it would do so. No date has been set for such an inquiry at this writing, but there is speculation in the press that it may occur within a year of the other nuclear decisions. In any event, it will have been a busy year of decision on the nuclear front for Britain. (Clifford C. Klick & Aubrey W. Pryce)

ENGINEERING

UNINTENDED JAMMING

While the subject of electromagnetic compatibility (EMC) includes a wide range of problems, such as explosions of combustible materials due to nearby or powerful radio transmitters and biological damage induced by such radiations, the majority of its applications are subsumed under the rubric *unintended jamming*, which can afflict not only communications but also control systems. The importance of EMC is reflected in the adoption of a number of national and international standards in this field and in the holding of Britain's first EMC Conference, sponsored by the Institution of Electronic and Radio Engineers (IERE) 4-7 April at the University of Surrey in Guildford.

In the keynote address, Dr. C.G. Bradshaw (Superintendent, Radio Division, Royal Signals and Radar Establishment, Malvern, Worcs.) pointed out that legislative and contractual EMC requirements can be very helpful but are not in themselves sufficient to insure operation without unacceptable degradation of or by the electromagnetic environment. Frequency management—allocation by international conventions, allotment, and assignment by national bodies—can merely alleviate the problems, he said; equipment must be designed to avoid EMC problems from the start rather than being fitted afterward with palliative devices.

The high point of the program was the paper presented by Prof. Daniel N. March (Montana State Univ., Boseman) concerning the threat posed to rural radio and TV reception by a new 500-kV power line. March and his team anticipated the problem, got the power company to support field surveys both before and after energizing the line, corrected difficulties caused by faulty house wiring and TV antenna connections, and found the public highly pleased with the surveys and with the results. (They were not told who financed the work.) British EMC people were quite impressed with American enterprise and with this success story, though new problems could be anticipated when wet weather leads to corona discharges from the line.

In another excellent paper F. Harlen (National Radiological Protection Board, Harwell, Didcot, Oxfordshire) discussed protection standards for biological effects of radio waves (cf. J.B. Bateman, *ESN* 31-11:433, 32-3:85, and C-14-77), pointing out that Soviet standards are far more stringent than those of the US, while the level of microwave radiation beamed at the US Embassy in Moscow fell somewhere in between. He indicated that the widely accepted upper limit of 100 W/m^2 may have to be revised downward, possibly because of focusing and long-term effects occurring within the human body, and it may have to vary with frequency. Since people may be working in the near field at VHF, separate limits must be adopted for the electric and magnetic fields.

The number of applications of EMC is so large that only a small part of the total can be mentioned here. The

electrically crowded environment aboard a ship or aircraft gives rise to many EMC problems, especially when new construction materials such as glass-reinforced plastics are used, which offer reduced electrical shielding. Even the use of glass fibers for information transmission does not entirely eliminate EMC problems, as the light pulses are handled in electrical form at the ends of the fibers, and these ends must be supplied with power by wires that can carry interference in and out along with the power. In one of the many anecdotal discussions, the fuel-injection control circuitry of a police car was reported to have caused the vehicle to slow down every time the radio transmitter was energized, and in another a cardiac pacemaker was said to have been stopped by a 20-mW transmitter.

A large number of industrial processes make use of electromagnetic radiation—from biscuit baking to the case hardening of metal and welding of plastics. These uses, as discussed by R. Colley (Strayfield Ltd., Reading, Berks.), seem destined to grow on account of their high efficiency and ability to control moisture content, thus presenting EMC problems that will require attention.

Some of the principles of EMC emphasized during the Conference were: Tying all ground leads to a common point in a star arrangement in order to avoid interactions due to the resistance and inductance of the wires, keeping bypass capacitor leads similarly short, and making circuit bandwidths no larger than necessary. It was noted that, on an airplane, cabling should avoid the edges of windows, where the EMC field caused by an outside source is maximum.

During their month-long Easter vacation British university students are asked to empty their dormitory rooms (apart from one locked compartment) so that they can be rented to visitors, and in this way very convenient, pleasant facilities were made available to the participants in this Conference and in a dozen others taking place during the same week at Surrey University. This institution received its Royal Charter as a technological university in 1966, but it originated in London in 1894 as the Battersea Polytechnic Institute. It completed its move to Guildford in 1970. Thus, the buildings, which occupy the northern slope of Stag Hill below the Guildford Cathedral, are, like the latter, very new and comfortable. The University has 3500 students, and its 2700 undergraduates are divided equally among science, engineering, and other practical fields (hotel catering, tourism management, economics, languages, psychology, home economics, music, and philosophy), the BSc generally taking four years with the third devoted to gaining industrial or professional experience outside the University on the "thick sandwich" principle.

While all of the papers at the EMC Conference were presented sequentially, with a half hour for each, they had competition from three excursions during one afternoon, and the participants could then visit the National Physical Laboratory in Teddington, Middlesex, the Royal Aircraft Establishment in Farnborough, Hampshire, or the Electrical Research Association Ltd. (ERA) in Leatherhead, Surrey, to see some of the work reported at the Conference. I chose the last of these, which turned out to be an organization with about 250 employees that is heavily supported by government contracts in the field of EMC. It also offers help to industry with thin- and thick-film technology, explosion hazards, and computing, as well as EMC. One of their investigations, carried out by Gerald A. Jackson and Andrew Williams, dealt with the production of intermodulation (IM) by nonlinear effects in a coaxial cable through which two strong signals are passing, i.e., the production of other signals whose frequencies are the sums $m_1f_1 + m_2f_2$ and differences $m_1f_1 - m_2f_2$ of multiples of the frequencies f_1 and f_2 of the original signals. It was found that odd-order IM products (with $m_1 + m_2$ odd) are stronger than those of even order ($m_1 + m_2$ an even number) and that they strengthen with increasing f_1 and f_2—probably because of the skin effect, which confines current to a thin layer near the surface, the thickness of which decreases with rising frequency, thus reducing the effective area of contact of the connectors. However, it was not determined what nonlinearity at such junctions is responsible for generating the IM products nor even whether their source lies mainly in the end connections or in the cables themselves.

Another ERA study reported by Jackson and by N.A. Ferrett (Civil Aviation Authority) involved interference with the radio compass (automatic direction finding) by a pocket calculator aboard

an aircraft. This problem will arise particularly in small planes where distances are short and there is very little shielding. The calculator may be a specialized one for aircraft operation or, on a larger plane, a simple one for international currency conversion when duty-free goods are being sold. The effect is easily observed if any pocket calculator is brought close to any AM radio. The interference falls off at frequencies above the AM broadcast band, but it can adversely affect the frequencies from 190 to 1800 kHz used for radio direction finding.

Again the exact source of the problem was not determined, but it appeared to vary directly with the current consumed by the display, and a calculator with a liquid-crystal display caused negligible interference, while one with a green display produced the greatest noise. A member of the audience (Peter S. Excell, a doctoral candidate at the University of Bradford, West Yorkshire, who had himself given an excellent talk on the performance of long dipoles as unintended receiving anntennas which might yield sparks igniting combustible substances) suggested that this may be due to the 150-volt inverter powering the fluorescent gaseous-discharge display.

This was a thoroughly British conference, only about a dozen of the 275 participants and less than a tenth of the 36 papers having come from abroad. A permutation of EMC yields ECM for electronic countermeasures, a form of electronic warfare (EW) that exploits the weaknesses of electronic equipment. Thus, the field is of great interest to the Ministry of Defence and, indeed, half of the papers came from UK government agencies with many of the rest supported by government contracts, but there were only one or two passing references to EW, recommending spectrum spreading for communication in a hostile environment. Among the government agencies was the Home Office, which is somewhat like the US Department of Justice but has among its responsibilities the licensing of transmitters and assignment of frequencies to avoid overlapping spectral and spatial coverage. Both the Radio Regulatory Department and the Radio Interference Branch of its Directorate of Radio Technology supplied speakers for the Conference. In particular, Robert J. Harry discussed the objective assessment of TV receiver susceptibility to inference, with a phototransistor looking at the picture-tube screen.

It was announced that the second IERE Conference on EMC is likely to be held in March 1980. The 316-page *Proceedings* (no. 39) of the present (first) Conference were distributed in advance to all registrants and are available to others from the IERE, 99 Gower St., London WC1E 6AZ, at a cost of £16 plus approximately £1.50 for overseas packing and postage. It is interesting that, while these Proceedings include many references to the 1977 Second EMC Conference in Montreux, Switzerland [G.H. Hagn, *ESN* 31-8:312], and to other publications, there was not a single citation of the *IEEE Transactions on EMC*, although that journal has been published for twenty years and is well known in the UK among EMC people. Perhaps the explanation lies in the much more experimental, less analytical approach generally taken in Britain, and, indeed, only 5 out of the 275 participants and 2 out of the 36 papers came from universities. The Conference offered a number of very good papers in addition to these two and served to underline the importance of minimizing electromagnetic interference in a wide variety of applications as well as suggesting means for its measurement and alleviation. (Nelson M. Blachman)

MATERIAL SCIENCES

COPPER ALLOYS IN THE MARINE ENVIRONMENT

A two-day conference entitled, "Copper Alloys in the Marine Environment" was held from 8-9 February at the Institute of Marine Engineers in London. Of the 100 or so attendees (about 15 from outside the UK), there was quite a good mix between materials people, ship designers and fabricators, licensing, insurance, and government experts, and representatives from specialty organizations such as the Copper Development Association, the Welding Institute, International Nickel Company, and the National Corrosion Service. These last-named interest groups often provided a narrow, but usefully focused view of marine-related

problems. Such a combination of expertise is often sought for its hoped-for synergistic benefits, but these are usually not realized because of seemingly insurmountable technical language and vested interest barriers. However, in this particular case it seemed to work quite well, possibly because so many common problems existed that cut across traditional specialty areas.

Some 12 papers were presented, with ample time allowed for specific and general discussion. Access to the preprints prior to the talks was as usual very helpful notwithstanding any personal guilt feelings associated with not having read all the papers beforehand.

There were two major thrust areas considered in depth: One was the expanding use of copper alloys for the well-developed application of condenser and heat exchanger tubing, and the other was an increasing emphasis (to be sure, put forward mainly by copper and nickel metal producers) on the possible large scale applications of copper-based alloys for protection against corrosion and biological fouling of ship hulls, rudders, and other relatively large sea-water systems. There were also papers dealing with the use of copper alloys for offshore oil and gas wells, but these will not be discussed in this brief summary. Those interested in these areas and in more detailed expositions on shipboard applications are directed to the Conference proceedings available from the Institute of Marine Engineers, probably late in 1978.

The use of copper alloys in heat exchanger and condenser tubing has been common practice for probably a hundred years. B.A. Weldon (Inco Europe Ltd., UK) traced the development of different alloys for the following desired properties: (1) Resistance to impingement attack and erosion in flowing seawater. (2) Resistance to pitting in stagnant seawater. (3) Resistance to product corrosion, e.g., from ammoniated condensate. (4) Resistance to stress corrosion in seawater and ammoniated condensate. (5) Ease of production as tube. (6) Reasonable strength and ductility. (7) Good thermal conductivity. (8) Resistance to marine biofouling, the build-up of marine organisms on metal surfaces in contact with flowing seawater, with a concomitant reduction in heat transfer and flow rate. (9) Galvanic compatibility with adjoining tube-plate and water-box materials.

Weldon traced alloy development from the early use of copper and brass (70% copper-30% zinc), both of which are readily attacked by sea water, to aluminum brass (66% copper, 22% zinc, 2% aluminum) now widely used although still susceptible to stress corrosion cracking from the ammoniated condensate, to the highly corrosion resistant but expensive copper-nickel alloys, ranging up to 16% nickel. Final material selection is based on the often used concept of a trade-off between cost and performance, weighted to the anticipated service life and criticality of the application. He suggested that on balance 90/10 cupro-nickel provides the best compromise as to cost, resistance to corrosion, and importantly to bio-fouling. The last property results from the high copper content of the alloy.

Dr. M.B. Levens (Shell International Marine Ltd.) further discussed corrosion problems associated with heat exchangers and condensers, for both the salt water and steam sides of the system. With the former, problems of erosion, corrosion, and biofouling are encountered. While material substitution can be effective, e.g., replacing aluminum brass with cupro-nickel, other approaches have also been used. For example, iron rust deposited on the interior walls of the tubes can be used as a cathodic inhibitor. This can reduce the localized corrosion precipitated by erosive damage caused by high velocity, highly turbulent, sea-water flow. The iron can be provided either by direct injection of ferrous sulphate into the salt water, or by electrolytic plating using an impressed current, and either an iron-containing organic binder or a soft iron anode as the source of the metal. Along with the use of ferric hydroxide as a corrosion inhibitor, nylon inserts at tube inlets, where erosive damage can be most severe, are also used.

Fouling by marine growth is a parallel problem in that it not only restricts flow but leads to the establishment of local corrosion cells and subsequent pitting even in the relatively immune copper-nickel alloys. Careful alloy selection as well as the use of electrochlorination to "poison" the biological organisms are prescribed remedial pro-

cedures. For the latter, during slow steaming of a ship injection must often be done on a daily basis, an expensive and—notwithstanding assurances to the contrary—an ecologically unsound procedure.

For the steam side of the main condenser system, Levens discussed the three major problems that can be encountered: a) Ammonia corrosion resulting in either stress-corrosion cracking or condensate corrosion, b) fretting, and c) erosion by inlet steam.

Considering these problems in reverse order, erosion is a quite common phenomena accounting, by Leven's estimate, for up to 20 or 30 tube failures per ship over 10 years. Material upgrading or the use of baffle plates to prevent direct impingement is a commonly used remedial solution. Fretting is an infrequent but troublesome problem as it leads to leakage and a diminution of water quality. Since the problem is exacerbated by vibration, mechanical stiffening to reduce freedom of movement of piping is often prescribed. Stress-corrosion cracking, precipitated by the presence of ammonia, is now relatively easily controlled by prior heat treatment of aluminum brass tubes to remove the residual stresses that are a necessary component of the cracking process. On the other hand condensate corrosion, in which the protective Cu_2O surface film is converted by ammonia and oxygen to the non-protective CuO, is the most serious of the above problems, particularly in modern high-pressure steam ships. Remedial solutions include reducing the ammonia content by controlling the hydrazine additions to the boiler, the use of a film forming amine compound to protectively coat the outside of the tubes, and of course material substitution, again using the more resistant, but more expensive cupro-nickel alloys.

A series of papers then considered the feasibility of extensive use of copper alloys to protect structural parts of the ship, particularly the hull, from corrosion, erosion, and bio-fouling. The alloys used or proposed are invariably rich in nickel, to the point where several attendees suggested that a more appropriate title to the Conference would have been cupro-nickel alloys in marine environments; this suggestion did not make Inco representatives unduly unhappy.

T.J. Glover (Inco Europe Ltd., UK) pointed out that the billions of pounds Sterling reputed to be lost from corrosion and fouling of ship hulls results not only from costs owing to drydocking, cleaning and repainting of the hull, but also from increased frictional drag caused by surface roughening and bio-fouling. This aspect becomes more important as fuel costs continue to escalate. He suggested that up to 50% of time lost at sea could be directly attributed to increased surface roughness. To illustrate the losses attendant to this problem he estimated total annual fuel costs for a large container ship of $6 million compared to $60,000 for a four-day drydock. Thus even modest fuel savings far outweigh the cost of drydock.

Traditionally control of roughening problems has been by the use of corrosion resistant and anti-fouling paints. Their supposed inability (disputed by some attendees) to provide reliable long-term protection has, he claimed, led to a reassessment of the use of copper-based alloys for sheathing the wetted surfaces on ships' hulls, in particular the use of 90/10 cupro-nickel which combines adequate mechanical strength, fabricability, anti-fouling properties, and corrosion resistance to both flowing and stagnant sea water.

While attractive in its properties, any decision to sheath the hull (the use of a solid cupro-nickel hull is completely unfeasible, both economically and technically) must be based on comparative costs between this procedure and regular maintenance of the traditional hull material, steel. Such analyses were carried out both by Glover and by I.C. Brookes and N. Whittier of the BNF Metals Technology Centre, UK. Both analyses used as their base formula the costs of the cladding material plus fabricability, minus operational benefits and recovery value of the cladding at the end of the service life of the ship. Both agreed that the additional cost is dominated by the copper-based material itself, being of the order of 200 £/m^2. Cladding itself is usually done by hot roll or explosive bonding. While these technologies are reasonably well established, the costs and possible problems associated with large scale production have yet to be accurately established, they were estimated to be about 35 £/m^2. Taking into account the savings in the cost of the steel, the final cost for using cupro-nickel cladding ranged from 212 to 290 £/m^2 (the differences coming from the two groups considering different material thicknesses and alloy contents).

How does this compare with potential recovery savings from lower maintenance and fuel costs? These are, of course, much harder to estimate since they are so strongly dependent on ship performance etc. Glover cited one study of large vessels, considering a 20-year lifetime, in which the maximum permissible extra cost for cladding for general-purpose vessels and oil tankers was about 140 £/m^2, while for high-speed, high-cost liquefied natural gas and chemical tankers and container ships in which sustained high-speed operation is needed, this cost increased to 300-500 £/m^2. Brookes and Whittier suggested similar although somewhat lower allowable increases.

These comparative figures make it clear that, in terms of cost-benefit, the use of cladding can only be justified and then usually only marginally for sophisticated vessels such as container ships. In discussion, it was pointed out that even this application may be unrealizable. Principal buyers of new container ships are now planning on a 5-10 year service life. While the ship may in total be used well in excess of 20 years, it is implausible to believe that the primary buyer would pay the additional cladding cost when the short service life promises relatively maintenance-free performance with conventional hull material.

Interestingly, small ships such as fishing vessels or patrol boats may provide a more viable market. Glover cited the case of a hull-cladded shrimp boat working alongside traditional vessels off the Nicaraguan coast. Return-on-investment calculations have shown that the capital cost of the cupro-nickel hull is recoverable in about seven years, quite a short time-period in the life of this type of vessel.

In summary, copper alloys, especially cupro-nickel, have well-established maritime uses, particularly for in-board condenser and heat-exchanger systems. Expanded use to large tonnage applications such as ship hulls is, at the current state of technology, more a hope than a reality. Vested interests like INCRA (International Copper Research Assoc.) and INCO (International Nickel Co.) persuasively argue the merits of such applications, but to date they appear to be depending mainly on their prophecy becoming self-fulfilling, rather than on responding to an obvious need. (I.M. Bernstein)

DOING MORE WITH LESS WITH SURFACE COATINGS

Where's the action? Generally speaking, it's at the surface. At least that is the case when we speak of materials and such phenomena as friction, wear, corrosion, catalysis, lubrication, and adhesion. In the continuing struggle to improve such properties of surfaces while using a minimum of costly material and still have structural strength and toughness, surface coatings are the answer. It is the drive for more effective surfaces using less of the costly coating materials that has brought forth recent rapid advances in surface coating technology.

"Advances In Surface Coating Technology" was the title of an International Conference held in London on 13-15 February and sponsored by The Welding Institute. Although billed as an international conference, 20 of the 30 papers presented were from the UK, while the US presented 3, and 7 were by representatives from continental Europe. Two-thirds of the 170 people in the audience were also British. The aim of the Conference was to survey the state-of-the-art (often the "black art" familiar to all metallurgists) of the various techniques for applying coatings. Naturally there were liberal references to the various electronic analytic tools (and their acronyms) used by surface scientists, but the emphasis was on methods of applying coatings. Those interested in understanding what is happening at an atomic level at the interface of applied coatings had little offered to them. (Readers interested in this subject are referred to *ESN* 31-6:241, "ISSC 3—The Status of Surface Science" which provides a short review of the Third International Surface Science Conference held in March 1977.)

The Conference was organized into six sessions: Thermal spraying, chemical vapor deposition and sputtering, nondestructive testing and quality control, ion implantation and ion plating, other coating methods, and surface treatments. The following remarks about a few of the more significant papers should provide the reader sufficient insight to the content of the Conference to allow him to decide whether to write to The Welding Institute, Abington Hall, Abington, Cambridge, England, for a copy of the proceedings.

After a most useful keynote address by J. C. Anderson (Imperial College of Science and Technology, London) in which he used a video tape to portray examples of many of the various coating techniques currently being applied, R. T. Smyth (Metco, USA) got the industrialists in the audience thirsting for more information with the first paper in the thermal spraying session. His topic was "Thermal Spraying—A New Approach to Thick Film Circuit Manufacture." In the manufacture of hybrid electronic circuits, the current cost of standard 96% pure alumina substrates accounts for half the expense of producing the circuit. He described the success his firm has had in plasma spraying alumina powders to form a coating on a metal substrate. The alumina coating then provides the substrate for the application of the thick film ink. In addition to reducing the need for costly high-purity alumina, the metal base provides a more rugged structure, a better heat sink, and a possible ground plate. The development effort has concentrated on finding an ideal base material that is chemically stable over a wide temperature range, and on obtaining an alumina coating with a smooth finish, high dielectric strength, good thermal stability, high reliability, and good bonding. Smyth claimed that they have overcome feeding difficulties for fine alumina powder and are now producing pilot-scale batches of reliable substrates on Kovar® as the base metal at about one-fourth the current cost for totally alumina substrates.

During the discussion period following the thermal spraying session, A. R. Moss (Royal Armament Research and Development Establishment, Fort Halstead, Kent, UK) gave a brief description of their unique hyperbaric chamber for deep-water simulation of arc plasma investigations to a simulated depth of 400 m. The chamber incorporates all the arc plasma equipment and instrumentation needed for study of development problems involving safe use of high-power electricity in arc-based processes for welding, cutting, and plating. With the increasing exploitation of ocean resources, this facility could prove a valuable tool.

A. J. Perry (Berna AG, Olten, Switzerland) presented his own paper on chromium carbide coating on steel by chemical vapor deposition (CVD) and also a paper by H. E. Hinterman (Laboratoire Suisse de Recherches Horlogeres, Switzerland) entitled "Chemical Vapor Coating of Surface Bearings." Hinterman's paper perhaps was the more significant in that it described a TiC coating that gives a harder surface than CrC. Both CVD processes are influenced by sensitivity to the same parameters: Temperature, pressure, gas composition (which tends to vary during the reaction), flow pattern, load density, and geometrical arrangement of the load in the reactor. Furthermore, clean oxide-free substrate surfaces are required (this was mentioned as a requirement for success with most coating processes) to obtain a strongly adherent coating. The successful operation of TiC-coated ball bearings in ultrahigh vacuum at very high speeds without a lubricant was mentioned as a significant application. Hinterman also reported that lubricants do not degrade when used with TiC-coated bearings thus indicating that essentially no wear products are generated from the bearing surfaces to react with the oil or grease and initiate decomposition of the lubricant.

There is substantial need for a nondestructive testing method to determine imperfections in the bonding of coatings, especially thermally sprayed but nonfused coatings. The audience showed avid interest in a paper on the use of ultrasonics for such testing by W. Francke (Metaalinstituut TNO, Apeldoorn, The Netherlands). Francke's research evaluated interface echo, backwall echo, and transmission ultrasonic techniques. To test the three methods, he prepared various layers with different bond strengths by oxidizing grit-blasted substrates at 900°C for differing times prior to spraying. He then evaluated bond strength ultrasonically by all three methods using water as the acoustic coupling between the transducers and workpiece. The actual bond strength was then obtained by applying glued blocks to both the substrate and the coating and testing tensile strength at the bond interface. Based on his research to date, Francke concluded that backwall echo and interface echo techniques are unreliable and have little likelihood of success, but the transmission method using dual transducers with 5-MHz crystals yields positive results. He noted that calibration diagrams must be made for each new combination of

coating and substrate, but he is hopeful that such diagrams made using flat plates will be useful irrespective of the shape of the workpiece to be tested.

Ion implantation has become a widely adopted method for fabricating semiconductors but it can also be considered as an alternative to applying a coating for the protection of a component's surface, particularly when it is important to avoid the potential weaknesses of an interface. G. Dearnaley [Atomic Energy Research Establishment (AERE), Harwell, UK] described the application of ion implantation to metallic surfaces to create surfaces resistant to wear or corrosion. By varying the kinetic energy of the ions (range 10-500 keV), the depth and concentration of the injected ionized atoms can be controlled. To minimize scattering and neutralization of the ion beam, a vacuum of $\sim 10^{-5}$ Torr is desirable. Because the practical maximum concentration of implanted atoms is limited by sputtering (the kinetic ejection of material under bombardment) to levels well below 50 at.%, it is not surprising that the implanted ions proving most useful in low concentrations have been those which have historically been successful as alloying agents; e.g., Cr in steel for corrosion resistance and N in steel for wear resistance. Dearnaley stated that surface atomic vacancies, vacancy clusters, and other dislocations produced by the ion bombardment appear to play an important role in the resulting surface property. Surfaces of ion-bombarded metals resemble in many ways a cold-worked metal or a surface which has been hardened by shot-peening—in this case, shot-peening on an atomic scale! For those sceptical about the long-term wear resistance of a necessarily very thin layer of nitride in a nitrogen ion-implanted steel, Dearnaley suggests that inward migration of the implanted nitrogen evidently takes place during wear thus maintaining the nitrided surface. At present, only prototype ion implantation facilities have been built, but AERE hopes to maintain a high momentum in this field and effectively to transfer the technology to industry.

Overcoming the suggestion by some of the audience that surface heat treatment using a 2-kW CW CO_2 laser was just "expensive flame hardening," C. Courtney (Imperial College of Science and Technology, London) described the results of his statistical approach for determining the relationship of laser-incident power (P), traverse speed (V), and incident beam diameter (D_b), with depth of hardening. Although there are some other variables such as surface reflectivity and substrate thermal properties when working with a given steel, the depth of hardening appears linearly related to $P/\sqrt{D_b}V$. Courtney listed the four principal advantages of laser heat treatment of steel components as cleanliness (the method introduces no impurities), low thermal load on the component, the treated area can be precisely the area needing treatment, and no special atmosphere is required. He suggested that for many components, these advantages are worth the cost.

There were a few papers that reported on surveys of the literature for some of the surface coating techniques. J. A. Cross (Univ. of Southampton) presented "Advances in electrostatic coating techniques" with special emphasis on innovations that have improved application of powders. R. S. Sethi (Plessey Company, UK) gave a most impressive survey of electrocoating from molten salts. His paper included 109 references. His conclusion was that some progress in understanding the mechanisms of electrodeposition processes from molten salts has been made, but that many questions remain. Still requiring investigation, for instance, is the influence of small quantities of complex ion additives on the rate of deposition. Judging from the reaction of the audience, the potential for applying thinner (thus less costly) coatings without suffering such flaws as pinholes (porosity) or pitting of substrates offers strong incentives for growth in electrocoating from molten salts.

Without doubt, the economic force driving efforts to obtain better surface characteristics at less cost has resulted in considerable action in the surface coating field. (CAPT L. Roy Patterson)

MEHR LICHT, MEHR LICHT!—SEMICONDUCTOR LUMINESCENCE RESEARCH AT PHILIPS

Goethe's final words on his death bed—"Mehr licht, mehr licht"—were a European rallying cry during the nineteenth century. In our own more blasé and materialistic world they could be reinterpreted as the motto of a group of scientists at the Philips Research Laboratories (Eindhoven, The Netherlands) who have been working steadily to improve the luminescence efficiency of semiconductor materials.

Such materials are finding ever increasing uses. Both semiconductor and laser diodes are light sources for optical communications by way of optical fibers—a technology that is fast approaching widespread use. Watches that flash time at the wearer in the dark also use these devices. There are even aesthetic applications now: The pointer on my FM tuner makes its position known by beaming crimson light upon the operator.

As with any other device, the producer would like to get more for less. In this case the question is how much light can be received from a given power input before fundamental limitations block further advances. In some devices the fundamental limitations are easy to assess, but this is less clearly the case for semiconductor luminescence where electron-hole recombination without luminescence is the *bête noire* to be avoided.

On my visit to the Philips Laboratory, Drs. A.T. Vink and C.J. Werkhoven discussed their work on some of the newer semiconductor materials. The application of interest to them is the production of green and yellow light-emitting diodes using epitaxial layers of GaP or similar gallium compounds in which up to 20% of the phosphorus is replaced by arsenic. Their principal research effort has been on GaP prepared on GaP substrates. Vink, Werkhoven, and their collaborators have a strong program to study the parameters that affect efficiency. They have established that the minority carrier lifetime is a direct measure of the influence of radiationless transitions and that this can be evaluated directly in the luminescence decay time over some ranges of that decay. Ideally, the decay would occur only by emission of light; additional recombination mechanisms would make the decay of the number of minority carriers, and therefore the luminescence, faster.

By careful experiments they have been able to separate the effects and importance of various possible radiationless recombination mechanisms. Diffusion of the minority carriers to the surface where radiationless recombination occurs has been shown to be an important problem, especially for thin films. By taking a single film and thinning it down in steps, the effect of surface proximity can be separated from the other parameters and analyzed quantitatively. Even with films that are five times as thick as the minority carrier diffusion length, the effect of recombination at the surface is important.

The presence of dislocations in the thin epitaxial layer is also important. Dislocation distribution in a film can be determined by etching in special solutions and then photographing the surface at high optical magnification: The dislocations can then be identified by the etch pits that form at them. Using the same film, another picture of the layer can be made by using a scanning electron microscope to sweep a raster of electrons across the film and recording the luminescence intensity as this is done. The resulting picture shows the luminescence sensitivity of the layer. By comparing pictures of the dislocation distribution and the luminescence sensitivity, it can be shown that the dark spots in luminescence coincide with dislocations. However, the dark areas around the dislocation lines are quite large—about 0.5 μm in radius. Thus the view is that a dislocation line is surrounded by a cylindrical space, and if a minority carrier is found in that cylinder or diffuses to its surface, recombination with the majority carrier occurs without luminescence. The exact process of recombination is unknown; one speculation is that point defects may tend to congregate near dislocations and that recombination occurs at these defects. Measurements of luminescence decay time as a function of dislocation density in many films have allowed a quantitative evaluation of the effect of dislocations on recombination. It is apparent that dislocations are the major problem in these films and that an improvement in efficiency by a factor of two might be obtained if their influence could be eliminated.

It is possible to prepare bulk GaP that does not show dislocation lines when observed with the etch-pit technique. It was hoped that the use of such materials as substrates in devices would produce a major breakthrough in efficiency. Films are formed on such substrates by covering the surface with a thin layer of liquid gallium and heating it so that some of the GaP goes into solution. On cooling, the GaP deposits on the substrate once again. It was a disappointment to find, however, that films formed on dislocation-free substrates show no improvement in their luminescence properties when compared with films formed on ordinary substrate material. On examination it became apparent that although the substrate material did not contain dislocation lines, it did contain closed loops of dislocations. Redissolving the surface of the material broke some of these loops so that dislocation lines now appeared at the new surface. These lines propagated into the newly deposited layer, and as a result the films had a normal dislocation density.

To make really substantial improvement, it appears that substrates are needed with a low concentration of both dislocation lines and loops. Such materials have occasionally been made, and with their use the decay time of luminescence is increased substantially to about 700 nsec from the normal 400 nsec. The problem now is to learn how to prepare these superior substrates in a reproducible way. Once this is done, an increase of a factor of two in the efficiency of light-emitting diodes can be expected. That is a substantial improvement, of course, and well worth working for. Still larger efficiencies will probably require much more fundamental changes in the materials or configurations of the luminescent devices. (Clifford C. Klick)

ONRL REPORTS

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

PHYSICISTS TACKLE ORGANIC SOLIDS AT THE UNIVERSITY OF STUTTGART

Solid state physics has traditionally been concerned with metals, semiconductors, and inorganic solid insulators. Organic solids have been largely ignored. This impression is buttressed by thumbing through the indices of some of the prominent introductory texts in the field of solid state physics; one looks in vain for an entry labelled "organic" somewhere between "order-disorder parameter" and "orthogonal-plane-wave-method." Somehow, especially in the United States, organic solids is a field that most physicists are content to leave to their colleagues in the organic chemistry department.

The situation in Europe is less one-sided. At the Conference on "Optical Techniques in Magnetic Resonance Spectroscopy" in Dublin, August 1977 (*ESN* 31-12:508), papers on studies in organics were given by representatives from nine different European laboratories with the majority of these coming from West German universities.

One of the oldest and largest groups doing solid state physics in organic solids is that headed by Professor H.C. Wolf at the University of Stuttgart in Germany. It was a stimulating experience to visit there and to learn how far studies have progressed in this field. Much of the program will be discussed later in this report, but consider briefly here what sort of things are known. Electron and hole mobilities have been measured. Trap depths of dopants have been determined and can be derived quite well by comparison with properties of the free molecules. Donor-acceptor or charge-transfer complexes are being studied. Impurity concentrations as low as 10^{-12} can be detected by photoconductivity. Singlet and triplet excitons have been studied, their diffusion coefficients determined, luminescent properties measured, the cross sections for capture by traps evaluated, and the detailed structure of the traps obtained. Solid state lasers have been made from suitably doped organic solids. Chlorophyll has been studied in solutions, and some of this knowledge can be extended to the analysis of similar material in bacteria and algae. This seems to me to be an impressive list of accomplishments and suggests that the solid state physics of organics is already in a period of rapid growth.

It is generally accepted that in organic semiconducting molecular crystals, such as anthracene, conduction occurs in a narrow valence and a narrow conduction band separated by a large band-gap of several eV in energy. Crystals can be made pure enough so that conduction is not dominated by trapping processes, and in these cases the mobilities of charge carriers are found to be of the order of 1 cm^2/Vsec. Narrow bands and small mobilities imply that the carriers are rather localized at the individual molecules of the lattice which is a consequence of the fact that in pure Van der Waals crystals the intermolecular interactions are weak. This, on the other hand, suggests that the energy levels for electron and holes caused by the introduction of organic impurities can be derived from properties of the organic molecule in the gaseous state or from the properties of a solid composed of the impurity alone. A convincing case is the substitution of tetracene (four benzene rings) in anthracene (three benzene rings). The measured hole trap depth is 0.42 eV. This compares very well with the difference between anthracene and tetracene ionization energies in the gas (7.42-6.91=0.51 eV) and the difference of the same quantities for pure crystals (5.75-5.30=0.45 eV). This suggests that relatively simple concepts are helpful in thinking about the origins of traps.

Recently, interest has concentrated on a new class of highly conducting organic compounds: radical-ion salts, an intermediate between Van der Waals and ionic crystals. This class includes charge-transfer complexes in which a high lying occupied level of a strong donor molecule is at about the same energy as the relatively low lying unoccupied level of a strong acceptor molecule. By the transition of one electron from the donor to the acceptor, an ionic ground state is formed with quasimetallic conductivity in a half-filled band. At lower temperatures a phase transition is observed, splitting this band into two separate bands and giving rise to a semiconductor. It is in this class of materials that it has been suggested that a high temperature superconductor might be found. N. Karl and J. Ziegler in Wolf's group have studied the charge-transfer complex anthracene-pyromellitic-dianhydride and are able to measure the temperature dependence of the photocurrent quantum yield and of the electron and hole mobilities. From these data much can be inferred about the mechanisms of charge transfer and the eventual complete separation of electrons and holes in this class of materials.

In addition to charge transport, energy can be transferred by excitons in organic solids as seen by fluorescence studies. Singlet excitons, related to the singlet excited state of the organic molecule, recombine quickly into the ground state. Triplet excitons, however, have a much larger lifetime which allows for the use of electron spin resonance (ESR) and electron nuclear double resonance (ENDOR) techniques to gain very specific information on the nature and orientation of the triplet states. H. Dörner and D. Schmid have recently completed a careful ENDOR study of naphthalene (2 benzene rings) doped with 2-fluoronaphthalene which has a fluorine atom substituted into the naphthalene molecule. Earlier studies at this institute using optical spectroscopy had shown that "X traps" for the triplet excitons were introduced with impurities and that these traps were not the impurities themselves but host molecules perturbed by the presence of the impurities. Dörner and Schmid were able to nail all of this down with the kind of absolute finality that is typical of successful ENDOR experiments. They could also decide which of two possible orientations of the impurity was causing the X traps to be formed; it was not the one which had intuitively been picked earlier from geometrical considerations.

In other recent work A. Braun, H. Pfisterer, and D. Schmid have studied the kinetics of the fluorescence of naphthalene crystals doped both with deep and shallow trap molecules. Experimentally the crystals were excited with a 1-nsec light pulse obtained by frequency doubling the output of a nitrogen-laser-pumped dye laser. The onset, rise, and fall of fluorescence for both the host and impurity molecules were measured as a function of temperature. The primary quantity obtained experimentally from this time-resolved spectroscopy is the energy-transfer rate. It is generally accepted that singlet exciton motion at room temperature is most adequately described in a "hopping model" in which the mean free path is on the

order of a lattice constant and the exciton hops incoherently through the lattice. At low temperatures, however, it is conceivable that the exciton moves coherently over several lattice spacings before it is scattered. According to theory these two modes of exciton motion have different temperature dependencies. The conclusions from these studies are that the trapping radius or the deep traps are about 60 Å ard are 10 Å for the shallow traps. Also, at temperatures below 40 K in naphthalene, a partially coherent exciton motion can be inferred; above 40 K the singlet exciton motion appears to be purely incoherent.

A new technique to study coherent exciton effects is being pursued by N. Karl, who has found laser emission from anthracene molecules substituted into host crystals such as fluorene and 2,3-dimethylnaphthalene. A nitrogen laser is used to pump the system. Work on this technique is in the early stages of development.

The problem of photosynthesis is also receiving attention in Wolf's group, and some of the techniques that have been used to unravel simpler organic materials are also being applied to more complex ones such as chlorophyll. The chlorophyll pigment molecules participate in at least three steps of the photosynthetic process: the so-called light harvesting, the transfer of the absorbed energy to the reaction center, and the actual charge separation. It has been suggested that the different roles of the chlorophyll molecules in the photosynthetic process are induced by different environments or by formation of complexes containing the pigment molecules.

In order to help find a solution to this question, work is underway to study the ESR of chlorophyll a and chlorophyll b in their metastable triplet states at various concentrations in both polar and nonpolar solvents. It is the purpose of this work to investigate the influence of the environment and the concentration on the molecular properties of chlorophyll a and chlorophyll b. Parallels between these properties and those found in *in vivo* systems may help to find models for the chlorophyll configurations occurring in *in vivo* systems. The first results of these studies are being prepared for publication.

To be significant for photosynthesis, experiments and understanding must eventually be referred to living things as is being done in the group. A completed study had to do with the luminescence of green algae. The temperature dependence of the fluorescence spectrum for both prompt and delayed emission was measured for temperatures down to 4.2 K. In addition a linear dependence of the delayed emission intensity on the excitation intensity was found at low temperatures; this supports the idea that a one-quantum-mechanism is responsible for the delayed light production.

One reason for the recital of progress given above is to illustrate how much is being learned about a variety of organic solids from the application of theory and experimental tools that are familiar to solid state physicists. Perhaps organic solids should be more widely considered as an area of opportunity than currently seems to be the case. Certainly there are many processes that are now poorly understood. One that intrigues Wolf is: How does it happen that a quantum yield of 10 or 20 is sometimes found for the polymerization of organic molecules on exposure to light? His hope is that the ESR studies on systems undergoing light-induced polymerization may help to unravel the problem.

Organic solids, anyone?
(Clifford C. Klick)

MECHANICS

STABILITY STUDIES AT THE UNIVERSIDAD AUTONOMA DE MADRID

Located in Canto Blanco (Madrid) in the Physics Department of the Universidad Autónoma de Madrid, a Group in the Physics of Fluids and Biophysics (GPFB) is pursuing some interesting problems in the convective instability of thermally driven flows and the stability of chemical and biochemical reactions. The work is under the direction of Prof. M.G. Velarde, who holds the chair in Statistical Mechanics at the University and who, in addition to the foregoing,

is exploring some features of the Ising Model of lattice structures.

Velarde's work in convective instabilities was stimulated by contact with Prof. I. Prigogine's group at the Center for Statistical Mechanics and Thermodynamics (CSMT) of the University of Texas at Austin and has been carried out partly on a joint basis with researchers there. Velarde also engages in joint activity with the Service de Physique, Centre d'Etudes Nucléaires de Saclay (France) and the Laboratoire de Dynamique et Thermophysique des Fluides, Université de Provence, Marseille (France).

It is remarkable that the Bénard problem (stability of a fluid layer heated from below) has been studied since 1900 (though natural convection has been observed since the time of Archimedes in approximately 213 BC), and yet it is so open-ended that it continues to attract ever increasing activity. The aspects of the problem initially studied were the stability properties of the liquid layer with respect to linear (infinitesimal amplitude) disturbances. Even the linear stability problem associated with a thin liquid layer of infinite extent is many-faceted; the upper and lower boundary conditions whether free surface or solid interface, or finitely or infinitely conducting, along with variable surface tension effects due to temperature dependency present many distinct problem variations. The variation of transport coefficients with temperature and the influence of instabilities in the superimposed fluid (on top of the upper, free surface of the liquid layer) make for still further complication.

The problem of thermal diffusion and convective linear instability in a two-component fluid layer was studied some years ago by Velarde and R.S. Schechter of the CSMT following an initial investigation by Schecter, Prigogine, and R. Hamm. The two-component fluid considered was of such composition that when heated from above, the components were thermally driven to separate from each other and, strangely enough, a buoyancy-driven instability resulted even when the overall density gradient favored stability. The theoretical results agreed with experiment.

More recent work on the Bénard problem with rigid solid boundaries indicated that for a weak dependence of viscosity on temperature, no instability exists at a lower Rayleigh number than the critical one predicted by linear theory even though a sub-critical nonlinear instability may exist for the case of a sufficiently strong dependence of viscosity on temperature.

The coupling of chemical processes and hydrodynamic stability is exemplified in the study of the stability of an interface between two immiscible, chemically reacting liquids. Inhomogeneities at the interface can cause surface tension tractions that will induce motions at the interface and within the bulk phases. The motions will occur in Bénard-like interchange (convective) patterns. The inhomogeneities may originate in connection with chemical reactions at the interface with inhomogeneities, reactions, and motions all mutually coupled. Because the problem considered concerns a single interface between two semi-infinite liquids, the resulting instability is of the Rayleigh-Taylor type. The formulation of the problem and its solution represents a cooperative effort involving the relevant centers in the University Autónoma, University of Texas, Université de Provence, Danish Technical University at Lyngby, and Université Libre de Bruxelles. The same problem generalized to the case of an interface in a spherical geometry presumably to represent a reacting droplet has since been investigated by Velarde and J.L. Ibañez. Of course, in a more realistic analysis, they would have to account for the effect of the reaction products separating the reactants at the interface and inhibiting the reaction process.

Most recently, Velarde, along with C. Normand and Y. Pomeau of Saclay, was involved in a review article on convective instability for the *Reviews of Modern Physics* in which linear theory including variational principles, nonlinear theory, energy method, perturbation (power series) expansion, subcritical instabilities, bifurcation theory (fashionably referred to as catastrophe theory), and transition to turbulence is expounded through to the present state of understanding. It should be noted here that for the case of convectively unstable Taylor-Couette flow, the "turbulent" state seems highly ordered as observed by Frank Mobbs of the University of Leeds.

Besides the research on convective instabilities of the Bénard and Rayleigh-Taylor class, the GPFB is studying the stability of chemical and biochemical

reactions. Given a particular chemical reaction, the reaction scheme (including chemical kinetics) can be modeled in terms of a timerate generation (or depletion) equation for each species that includes the effects of the concentrations of all and their diffusion through each other. In this manner, various types of chemical reactions that include built-in process inhibiting mechanisms can be studied for time and space variations of reaction rate. The chemical reaction can even be designed to simulate the respiratory and metabolic processes of a bacterial culture. Accordingly, Velarde and co-workers have developed theorems regarding the evolution of solutions of the coupled families of partial differential equations in phase-space and the related stability properties. In addition to the stability of an initially uniform state, the problem of the stability of dissipative structures for the diffusion-reaction problem has been tackled. Somehow, this has taken on an appearance analogous to large-scale, coherent structures in ordinary turbulent flow.

In all, the program at the GPFB is in touch with important centers of research activity and is actively contributing in its own right. Its level of proficiency is remarkable, particularly in view of its small size and its level of support. (Martin Lessen)

FLUID MECHANICS AT THE ESCUELA TECNICA SUPERIOR DE INGENIEROS INDUSTRIALES DE TARRASA

The Escuela Tecnica Superior de Ingenieros Industriales de Tarrasa (ETSIIT) is one of a number of component institutions of the Universidad Politecnica de Barcelona. In the Spanish tradition, Industrial Engineering covers all engineering with industrial applications and hence encompasses the usual Civil, Electrical, Chemical, and Mechanical Engineering fields. Further as the city of Tarassa, located on the outskirts of Barcelona, is an important textile manufacturing center, a large part of the teaching and research program of the ETSIIT is devoted to textile technology. In addition to the ETSIIT, the Polytechnical University of Barcelona has other higher technical schools in Telecommunications Engineering; Road, Canal, and Harbor Engineering; and Industrial Engineering within the city of Barcelona as well as lower level technician programs in Technical Architecture, Agricultural Engineering, Industrial Engineering, and Mining Engineering.

The program in Fluid Mechanics at the ETSIIT is the substantial one in the Barcelona area, and so I was happy to be able to visit and discuss it with Professor Luis Virto Albert who occupies the Chair in Fluid Mechanics and Fluid Machinery. Virto explained that undergraduate students specializing in Mechanical Engineering take Fluid Mechanics in their third year and Turbomachinery in their fifth and last year at the ETSIIT. The Doctoral program in Fluid Mechanics consists of three full-time and two part-time (external) students.

Virto and his students have a number of interesting investigations under way that combine the usual fluid mechanical considerations with those of neighboring disciplines such as thermodynamics, combustion, and rheology. An example of such a problem being studied is the design and parametric representation of a heat pipe of arbitrary conductance. A heat pipe is a device that provides low resistance transport of heat. It consists of a hermetically sealed tube partially filled with a liquid that develops capillary forces with respect to a porous structure also contained in the tube. The liquid is such that it vaporizes within the temperature interval over which the heat pipe operates. If the heat pipe is placed between a heat source (high temperature) and a heat sink (low temperature), the liquid at the high temperature end evaporates and the resulting vapor is condensed at the low temperature end. The porous structure serves to transport the condensed liquid continually toward the high temperature end. The heat, however, is transported by the vapor from the heat source to the heat sink. The heat pipe apparatus at the ETSIIT consists of a 4-cm i.d. to 5-cm o.d. tube, 1 m in length. The porous structure inside the tube is composed of a stainless steel mesh; the mesh wire diameter and spacing are varied in the course of the studies. Various fluids such as ammonia, methane, and water are being studied inside the heat pipe which was purposefully made large enough for pressure, temperature and other instrumentation to be introduced. The study of the effect of the presence

of a noncondensing gas either mixed with the working fluid or separated from it by an interface is projected. Virto mentioned the use of the heat pipe for solar energy applications, but the actual geometry of the proposed installation was not clear.

Another area of investigation at the ETSIIT is the study of internal flow in a 2-stroke cycle internal combustion engine for a motorcycle. The objective of the research is to optimize the delivery ratio (volumetric efficiency) of the engine by varying the air induction and exhaust configurations so that the engine "breathes" as freely as possible. The volumetric efficiency of an engine is the ratio of the air actually inducted (at external conditions) per induction cycle to the engine displacement. Much work has been done in the past in the development of resonating induction and exhaust systems with the intent of maximizing volumetric efficiency (and performance), but the beneficial effects are only present over a very narrow engine-speed range. For a motorcycle (or a racing car) many transmission gears have to be included in the installation so that the engine intake and exhaust operate at close to resonance. Virto and associates are having a new look at an old problem, and we can only wish them success.

Some basic research on the distribution of droplet size in a fuel spray is under investigation. An application is in the design of combustors for jet engines. Knowledge of the properties of the spray will permit the minimum length design of the primary combustion chamber for complete combustion at close to stoichiometric conditions in order to reduce the formation of nitrogen oxides. The mixture of primary combustion products with secondary air then lowers the temperature to that permitted in the turbine. The effect of a more uniform droplet size as opposed to a distribution in size is also being pursued. Virto felt that the closely related problem of water droplet cooling in air conditioning systems (only under very dry atmospheric conditions) would benefit from the research. It is indeed a pity, however, that nature is so uncooperative; where climates are sufficiently dry for water droplet cooling, water itself is scarce.

Other investigations in progress concern the flow of suspensions through porous (filtration) beds and the resulting gradual modification of the permeability of the beds with progressive flow, and the generation of noise in low-speed fluid flow through piping systems. (Martin Lessen)

PHYSICAL SCIENCES

LASER SOUNDING IN THE STRATOSPHERE AT APPLETON LABORATORY

Appleton Laboratory, located in Slough, 22 miles west of London, was established about 1923 as the Radio Research Station. The Science Research Council took over in the mid-sixties, and for the next ten years the institution was known as the Radio and Space Research Station. Since 1973 it has been called the Appleton Laboratory with very active UK and worldwide cooperative satellite programs as well as space research conducted from rockets, balloons and aircraft. Other interests include astrophysics (see *ESN* 30-8:346); radio astronomy; radio propagation in the troposphere, as well as the upper and lower ionosphere; solar physics; uv astronomy; and studies of composition and structure of the upper atmosphere.

Laser investigations from the ground are carried out in order to determine the concentration and movements of various constituents of the upper atmosphere. Indeed, the very first lidar measurements of Na vapor by resonance scattering of dye-laser radiation in the upper atmosphere [M.R. Bowman, A.J. Gibson and M.C.W. Sandford, *Nature* 221, 456 (1969)] were obtained by the Laboratory. Lidar work will be the only topic discussed in this report.

I first met with Dr. W.C. Bain, a senior administrator, who briefly described the history of the laboratory and explained the organizational structure. I then met Dr. L. Thomas, who works for Bain and has charge of the lidar work. I also talked briefly with Dr. R.J. Emery, from a different group, who is conducting ir-transmission measurements in the atmosphere from sub-mm to 10-μm wavelengths.

The first measurements of Na in 1969 and 1970 were made with a flashlamp-pumped dye laser tuned to the D_2 line of Na (5890 Å) with a laser linewidth of about 7×10^{-2} Å and output energy of 150-300 mJ per pulse. These first measurements were important as they established the fact that it was possible to measure, from the ground, very low-level gaseous concentrations at altitudes exceeding 90 km. During the period July 1969 to July 1970, Gibson and Sandford at a field station at Winkfield, Berks., made measurements of the sodium layer. Data were recorded on 60 clear nights during all seasons of the year. Intense background noise, even though a narrow-band filter is used in the receiver, makes it very difficult to make daytime measurements. The results of these observations showed that the column content of atomic Na reached a maximum during winter of 12×10^{13} m^{-2} and a minimum in summer of 2×10^{13} m^{-2}. These seasonal variations in content were accompanied by a lowering of the height of maximum concentration in both summer and winter. This has been interpreted as an increase of Na from below in the winter and a loss from the top of the layer in summer. The maximum number density of Na observed in January was 1×10^{10} m^{-3} and the minimum summer value was 2×10^{9} m^{-3}.

The group has used the same technique to measure K in the upper atmosphere at a wavelength of 7699 Å. A near-ir dye, 3,3′-dimethyl-2,2′-oxatricarbocyanine iodide dissolved in ethylene glycol, was used in the laser. The dye cell was 50-mm long and 10-mm in diameter and pumped longitudinally by a Q-switched ruby laser. Two Fabry-Perot (FP) etalons and a third solid etalon (used as the output reflector) were used for tuning the laser. The output energy was 40 mJ and linewidth was 0.1 Å. Since the concentration of potassium was expected to be the order of 1% of the sodium concentration and a weaker laser was employed, a larger receiver was required. Sandford, in collaboration with F. Felix and others from the University of the West Indies, Kingston, Jamaica, used the very large receiver of the Mark II laser radar at Kingston which has a collecting area of 15 m^2. They obtained a resonance scattering profile on 27 January 1973 at heights between 75 and 100 km and estimated a column number density of 9×10^{11} m^{-2}. Other investigators have since made more detailed K measurements by laser radar (see *ESN* 31-12:510).

More recently the group has developed a mobile van-mounted lidar system with a steerable beam that was used at Skibotn, Norway to track sodium clouds at altitudes between 130 and 175 km which had been released by rockets from the rocket range at Andenes. Winds were determined from the lidar returns as a function of altitude during an auroral substorm. Strong eastward and southward wind components with maxima of 150 m/sec were observed.

The steerable-beam lidar was used in 1975 to demonstrate that on occasion horizontal structure exists in the sodium concentration. During one such set of measurements a vertical differential of about 2 km was found for a horizontal separation of 15 km. In addition the time dependence indicated that there were vertical motions in the opposite sense. The layer structure appeared to be oscillating with a period of about 20 minutes. It is not as yet possible to tell if this is a horizontally moving structure or the action of a gravity wave.

Other investigations are being conducted in the uv over the wavelength interval 2970-3080 Å. The laser for this application uses a flashlamp-pumped dye whose output is frequency doubled by an ammonium dihydrogen phosphate (ADP) crystal. The output energy is 0.2 mJ per pulse with a 2-Å linewidth. The purpose of these measurements is to investigate the effects of aerosols, clouds, haze, ozone, and other absorbing gases in this spectral region that are important in regard to biological effects. Some preliminary measurements were made in 1975. They showed a 10:1 ratio between the transmissions (two-way) at 3080 Å and 2970 Å for heights below 5 km. Interpretation of the results at different wavelengths is inconclusive, but Gibson and Thomas believe that it is probably due to absorption by water vapor in the 0-5 km region. Since accurate absorption cross sections for water vapor are not known yet for this wavelength range, it is difficult to analyze the data. They hope to continue this work with a more powerful laser so that certain gases can be monitored by resonance scattering or fluorescence.

Another recent activity of the group is the determination of characteristics of cirrus clouds by taking lidar meas-

urements at different elevation angles. At Winkfield they made measurements on cirrus at 10-12 km on otherwise clear nights in August through October 1976. The data showed a directional dependence on the ratio of backscatter to extinction coefficient. Backscatter signals were obtained at 90° elevation and 30° elevation. Comparison of signals with respect to expected Rayleigh scattering from clear regions above and below the cloud layer permit the determination of the apparent optical thickness,

$$\tau(\theta) = \int \beta_{ext} \operatorname{cosec}\theta \, dh$$

and integrated backscatter coefficient,

$$B_{int} = \int \beta_{\pi\,\circ\circ} \operatorname{cosec}\theta \, dh$$

β_{ext} = attenuation coefficient

θ = elevation angle

h = height above surface

$\beta_{\pi\,\circ\circ}$ = volume backscatter coefficient.

This assumes no horizontal variation in the atmosphere or cloud layer. For one particular night they obtained values at 30° of $\tau(\theta) = 0.115$ and $B_{int} = 2.0 \times 10^{-3}$ while for an elevation angle of 90°, $\tau(\theta) = 0.047$ and $B_{int} = 2.7 \times 10^{-3}$. If the particles were spherical or randomly oriented, the values at 90° (calculated from the 30° values) should have been 0.058 and 1×10^{-3} respectively. They deduce from those results that the crystals were elongated in shape and oriented predominantly in a horizontal plane.

This group has done some very important work in remote sensing of the atmosphere particularly in early work with resonant scattering determination of Na. One factor that Thomas feels is reducing current productivity is a lack of enough scientific talent which is preventing more projects being undertaken. (Vern N. Smiley)

TERMOLOGIA AT THE UNIVERSIDADES DE SEVILLA, VALENCIA AND BARCELONA

In Spain the term Thermology is used to denote the study of classical thermodynamics, irreversible thermodynamics, and statistical mechanics. Three Universities in Spain are linked by a faculty-teacher-student relationship in this field, hence the research activity at the institutions is constructively related. The senior program is located at the University of Barcelona under the direction of Professor José Maria Vidal Llenas, Chairman of the Department of Thermology in the Faculty of Physics.

A large part of the research activity at Seville, Valencia, and Barcelona involves the use of heat flux calorimetry. The basic instrument, developed at Seville, measures heat flux directly and consists of an array of thermocouples on the surfaces of a known thermal resistance. The thermocouples are then calibrated to read the heat flux directly through the thermal resistance. For some applications, the thermal resistance is a copper plate. Although the thermocouple readings are directly interpretable as a heat flux in the case of steady heat flow, the correct interpretation of transient readings requires a convolution integral to yield transient heat fluxes. A related problem illustrating the necessity for the use of convolution techniques involves the sampling of a fluid of varying constituency through a long cannula. When the flow in the cannula is laminar and the effect of laminar diffusion is negligible, the varying constituency of the fluid at the entrance of the cannula propagates along the cannula with the flow velocity of the fluid in the cannula. Since the velocity within the cannula is a quadratic function of radius (for Poiseuille flow), the entrance conditions are smeared out at the exit but can be retrieved from the exit information by a convolution procedure. In like manner, the flux meter apparatus can be characterized as a "black box" and the relevant "black box" parameters evaluated for various processes.

Thus, at Barcelona, calorimetry is used to study the fast reaction kinetics of chemical reactions with enzymatic catalysis. Since the enzymes degrade rapidly, the calorimetric measurements must be made within minutes. The time

evolution of the heat dissipation in the metabolism of drosophila is studied in this way. Heat flux calorimetry is also used in connection with microbiological measurements of the metabolism of mixtures of bacteria from the sea, in order to obtain the time evolution of the heat dissipation as an identifying signature for the bacterium. In this way it is possible to recognize on the thermogram profile whether the bacteria came from great or small depths in the ocean because the aerobic and anerobic behavior of the bacteria is conditioned by the availability of oxygen in its natural habitat. It has been observed that the thermogram of heat dissipated with time for a given sample of bacteria exhibits a coherent oscillatory structure that seems to be uniform over the sample. It is probable, that for a sufficiently large sample, there exists a corresponding space structure that would indicate a wavelike propagation phenomenon of fluctuations in metabolic rate. The work in calorimetry at Barcelona is under the direction of Prof. Vicente Torra Ferre.

At the University of Seville, the Department of Thermology in the Faculty of Sciences is under the direction of Prof. D. Manuel Zamora Carranza. It is curious that this University is housed in what formerly was the first tobacco factory in Europe; it is supposedly where Carmen enticed Don José in what became the theme of the opera by Bizet. Zamora and associates are studying the properties of ferroelectric materials. A ferroelectric is a solid that has a spontaneous electrical polarization as opposed to a piezoelectric that attains a polarization only with a mechanical stress. When a ferroelectric is raised to its Curie temperature, it loses its spontaneous polarization and becomes a simple dielectric. The approach used at Seville to obtain the relevant ferroelectric properties of a single crystal involves the application of an electric field at constant entropy, and then a thermal fluxmeter is used to obtain the time-integrated heat flux necessary to return the specimen to its initial temperature.

Heat flux calorimetry is also being used in Seville in the study of Bénard type hydrodynamic instabilities. Since the Bénard instability is thermally driven and convective in nature, the heat flux it transports can be related to its modal structure. Therefore, if the heat flux is plotted as a function of the temperature difference driving the instability, the changes in slope of the curve can be interpreted as bifurcations between disturbance modes. This work is being carried out in cooperation with P. Bergé and M. Dubois of the Service de Physique Théorique, CEN de Saclay, and M. G. Velarde of the Departamento de Física, Universidad Autónoma de Madrid. Since theoretical studies were carried out for a rectangular parallelepiped cavity of 3 cm × 10 cm × 1 cm high, this is being studied initially in the Seville experiments. However, it would seem that with these particular dimensions, one could hardly expect to observe an instability but rather a forced or secondary type flow. In view of this, the Seville studies will also include an 8.5 cm × 12 cm × 1 cm high cavity and a circular cavity of approximately 10 cm dia × 1 cm high. In all cases, the upper and lower boundaries will be of very high thermal diffusivity in order to maintain the thermal boundary conditions as uniform as possible.

At the University of Valencia, the Chairman of the Department of Thermology is Prof. Vicente Gandia Gomar, who also is the acting Rector of the University. Since the well-being of the orange crop is of great importance to the region, Gandia has a research program in the micrometeorological prediction of frost conditions. Thermistor sensors are placed in the orange trees, on and under the ground, and in balloons, and the observations correlated with local climatic and pollution states and used on an empirical basis to indicate the possibility of frost. Ground frost is controlled by a ground-cover planting. Experiments are in progress to determine whether a water spray can control frost in the trees themselves (the heat of fusion of the water raises the temperature of the air).

Prof. Emilio Rojas Blasi at Valencia is active in thermal flux calorimetry. Rojas has worked with Vidal of Barcelona and Zamora of Seville and is interested in the techniques to study thermoelectric energy conversion using liquid metals near their melting points. He has studied mercury-indium, mercury-thallium, mercury-cadmium, and mercury-zinc systems experimentally. In connection with solid-state thermoelectric-energy conversion, he

has also studied the gallium-phosphide system over a temperature range from room temperature to 500° C. (Martin Lessen)

PSYCHOLOGICAL SCIENCES

HUMAN FACTORS AND THE FIGHTER AIRCRAFT COCKPIT OF THE 1990s

"Human factors," "ergonomics," "human engineering," and "engineering psychology" are terms that English speaking analysts give different shades of meaning but interchange freely nevertheless to describe the consideration of human variables in the design and use of man-machine systems. In West Germany, "anthropotechnik" is the label most commonly used, and the recommended translation is "human engineering." The Anthropotechnik Department, Military Aircraft Division, Messerschmitt-Bölkow-Blohm GmbH, in Ottobrunn (just outside of Munich), is headed by A.R. Seifert, a psychologist. MBB, as the company name is mercifully abbreviated, has a work force of 20,000, with many projects, and the Anthropotechnik Department that serves them is a busy group. They have a professional staff of 13, composed of psychologists, physicists, engineers, mathematicians, and MDs. Their biggest project in recent years has been inputs to cockpit design of the Tornado fighter, the European multi-role combat aircraft (the MRCA), for the West German Air Force and Navy, Britain's RAF, and the Italian Air Force. The Tornado will be operational soon, and so it occupies less time of the Anthropotechnik Department than before, although final design matters still arise. The MBB human factors effort for a major system like Tornado does not stop with cockpit design. A Training Department devises the personnel training plan, and a Logistics Department specifies the personnel manning table.

An aircraft company worthy of survival in the competitive commercial world will be looking at systems-to-be, and MBB is already planning Tornado's successor in the 1990s. The Anthroptechnik Department is giving part of its effort to the concept of the cockpit for that next fighter, and the reliance on computer technology will make it a quantum departure from cockpit conceptions of the past. A modern cockpit like that of the Tornado is a mix of old electromechanical instruments and their controls, new computer-based displays and their controls, and the head-up display, but the cockpit of tomorrow will be dominated by the computer.

The big human factors problem for contemporary fighters is aircrew workload, and this problem has been most visible in the debate over one- vs two-place systems that has been active for about 30 years. Everyone acknowledges that a fighter pilot is a busy man in certain phases of a combat mission, but the advocates of a one-place system argue that the cockpit can be designed efficiently enough for one man to do the job. Supporters of a two-place system, on the other hand, argue that one man is overloaded and that some duties should be assigned to a second man. As a result of this unresolved controversy, fighters since World War II have been a mix of one and two-place systems, depending on who was momentarily dominating the debate. The debate was deserved because its ramifications are far-reaching for cost, equipment complexity, personnel, and system effectiveness, but no resolution was possible because the technology of the time did not have significant new ways of handling human workload. If workload could be substantially reduced by automation, there would be no question that a one-seat fighter could do the job. Seifert contends that the debate is over because the presence of onboard computers will make one pilot more effective than a two-man team ever was.

Except for a few old-style electromechanical instruments for standby reliability if the computers fail, all cockpit information of the future fighter, as Seifert conceives it, will come from computers and be displayed on cathode-ray tubes and on a head-up display that will combine a view of the outside world with computer-generated symbols. Seifert's human factors principle, which is not new, is "unburdening," i.e., the use of machines to ease the responding of the human operator, thereby freeing him for functions that he does best and

that machines do less well. Which functions to assign man and which to assign machines is an old argument in engineering psychology, but Seifert sees it as no problem. Assign any function to a computer that can be reasonably assigned without seriously affecting the cost and complexity of the system, and the more the better. The human operator should be freed as much as possible to perform those high-level intellectual and perceptual functions in which he excels. The human mind can be awesome in its resolution of complex uncertainties and interpretation of complex sensory patterns. Machines will not rival these capacities of man in your time or mine.

One of the biggest workload demands on a pilot is visual scanning and interpretation of the panel. Electromechanical instruments are always present in today's aircraft, commanding visual attention, but there is no need for the continuous presentation of information when computers process it; data can be presented as required. Some data will be needed continuously, as flight control information; some will be needed according to the phase of the mission, as in the attack phase; some will be needed on request, as when the pilot wishes to check his fuel supply; and some will appear only when system circumstances force it, as in an emergency, like loss of power. The result is a reduced load for the pilot. Other uses of onboard computers would be calculation of navigation and fire-control problems, or perhaps prediction in which the future state of the system would be estimated on the basis of the present state and possible pilot inputs—e.g., the pilot could obtain the consequences of various attack maneuvers and determine the one with the highest kill probability. Control functions could benefit from analogous unburdening. Complex motor movements to accomplish complex aircraft maneuvers could be reduced to simple movements with computer intervention.

All of these possibilities are technologically possible or are rapidly becoming so, and the anthropotechnik scientists of West Germany are sensitive to them. The realization of details remains to be worked out, but the 1990s are a distance in the future, and time enough remains to do it. With the present thinking and planning, the fighter of tomorrow will be a better balance of human and machine capabilities than we have ever had, and it should have a better combat capability than ever before. (Jack A. Adams)

HOW PILOTS ARE SELECTED IN WEST GERMANY

If Lufthansa German Airlines and the West German armed forces can be said to have the majority of professional pilots in the country, then two groups of psychologists are responsible for selecting them for training. One group is the Psychology Department, Institute for Aerospace Medicine, German Aerospace Research Establishment (Institut für Flugmedizin, Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt e.V.), located at the municipal airport in Hamburg, which selects candidates for Lufthansa flight training. The other is the Center for Research in Aviation Psychology, Air Force Weapons School (Zentrale Fliege-Psychologische Unter-Suchungsstelle/Waffenschule der Luftwaffe), located in Fürstenfeldbruck near Munich, which selects pilot candidates for the military.

The main body of the Institute of Aerospace Medicine is housed in Bonn-Bad Godesberg, although there is a Biophysics Department quartered in Frankfurt in addition to the Psychology Department at Hamburg. The Institute has a staff of 75, of which 33 are scientists. The scientific cadre is dominated numerically by MDs, as befits an institute of aerospace medicine, with the other scientists being engineers, physicists, biologists, mathematicians, and psychologists. Of the six psychologists, five are in Hamburg giving most of their time to Lufthansa pilot selection.

As a result of an effective advertising campaign, the prospect of an airline captain's status and pay, and a week in Hamburg compliments of Lufthansa, the psychologists have a large pool of applicants from which to choose the few that the airline trains each year. In 1976, 1696 young men (women are not considered) requested information, 557 were tested, 33 were selected for flight training of which 30 graduated to

Lufthansa aircrews. The minimum education requirement is high school graduation. After preselection for such routine variables as height, age, and weight, the candidates are subjected to five days of testing, during which a candidate can be dropped at the end of any day. Day 1 is a battery of printed tests, covering mental abilities, general and technical knowledge, personality, and the English language. Day 2 is a battery of psychomotor tests that are behaviorally complex, like two- and three-dimensional tracking. Day 3 is a flight trainer (an old Curtiss-Wright Dehemel Duplicator), and sports. After 20 minutes of familiarization in the trainer, the candidate has a 40-minute session in which he flies three maneuvers that are scored for accuracy. The sports tests are common athletic activities like running, ball games, and swimming, by which the candidate is rated for skill, aggressiveness, competitiveness, and courage. Day 4 is a one-hour interview by a selection board comprised of a retired airline captain, a current airline captain, an engineer, and two psychologists. The interview is a test of sorts where the candidate may be asked additional information about his background, or he may be asked to elaborate a topic covered in a printed test. The board then evaluates all of the performances of Days 1-4, and makes an overall decision about the candidate. The few candidates that pass Days 1-4 must then pass a medical examination on Day 5 and, if they pass it, they are on their way to flight training.

The military psychologists of Fürstenfeldbruck test about 700 pilot candidates a year for the Air Force and Navy, and the number will rise to about 1000 when Army pilot selection is added. Although it appears that quotas are met, the prospects of military flying apparently are not as attractive to young men as Lufthansa flying. To increase the candidate population, the military casts a wider net by having lower educational requirements than Lufthansa. A candidate is considered with less than high school graduation, although he is encouraged to continue his education on a part-time basis alongside his military duties if he is accepted. The testing is in three stages, and moving to the next stage is contingent on passing the previous one. About 15-20% of the candidates are washed out by the tests, and another 10% are dropped in flying school.

In Stage 1 the recruiting office administers printed tests, such as intelligence, to the applicant to see that he has the general qualifications of an officer. Stage 2 is printed and psychomotor tests, not unlike those of the Lufthansa battery. Stage 3 uses a light plane as the selection tool, and gives an 18-hour training program. Those who pass it enter military flight training. At present the testing does not include flight trainers, although by 1980 there will be four Singer-Link GAT-1 trainers in Stage 3. The trainers will reduce the light plane flying to 3-5 hours, according to present plans. The expectation is that measures of flying skill can be obtained in the trainer, with the airplane being used to obtain evidence of fear of flying.

These West German pilot selection programs distinguish themselves from US and UK programs in two ways. One way is that they are more elaborate. Such items as flight trainers, light aircraft, and sports would be considered excessive for a mass selection program in the US and the UK; the Germans seem to put more effort and money into pilot selection than the Americans and the British, and they reason it is cost effective to do so. The cost of flight training is higher for West Germany than for the US and UK, with both Lufthansa and the military sending their trainees to the US for basic training to take advantage of the better weather in the US (Lufthansa trains in Phoenix, AZ). Because the cost of training overseas is high, it is cost effective to put a big effort into pilot selection and minimize selection mistakes. A pilot trainee who washes out after months of training in the US is a costly mistake.

Validation is the extent to which the test battery predicts Pass-Fail in flying school, and only the Fürstenfeldbruck psychologists calculate it for their military battery (the validity coefficient is 0.60). The Hamburg psychologists have never checked the validity of the Lufthansa battery (this is another difference between West German selection procedures and those of the US and UK—the psychometric traditions of the latter two call for meticulous concern with validation). Nor can the Lufthansa battery be validated. Almost everyone who

is selected passes the Lufthansa flight training program, which means that there is no Pass-Fail to discriminate and no correlation to compute.

Does this mean that the Lufthansa battery is worthless? No, because some of the tests used by Lufthansa are also used by the West German, US, and UK military who have shown a degree of validity for them. Actually, not very much validity is required for the Lufthansa battery to look good. If only the top few performers out of hundreds given the battery are chosen for a flight training program whose criteria for success are not excessive, then almost everyone will pass the flight training course and the test battery will be splendidly effective; the battery has done the selection job assigned to it. If, however, this same test battery had to select hundreds of trainees each year, as the West German military does, it would make more mistakes than it does. The requirement for a large number of trainees means that many with less than top test scores would have to be admitted, a region of uncertainty is entered where selection mistakes are made, and the validation power of the battery is truly challenged. The Lufthansa battery pays its way by doing the job that Lufthansa asks it to do, but there is an illusion of the battery being better than it is because almost everyone selected by it succeeds in pilot training. (Jack A. Adams)

NEWS & NOTES

SYMPHONIE EXPERIMENTS

Europe took its first steps in communications satellite technology in 1969 with the development of the Symphonie experimental satellite. The project was a joint French-German effort culminating in the launch of the first three-axis stabilized geostationary communications satellite in 1974. A second Symphonie satellite was launched in 1975, and since that time many experiments have been carried out utilizing the 300 two-way circuits to transmit television programs and telephone conversations. In an effort to expand this experimental program and in line with the recently signed agreement between the EEC and China to expand trade, the French and German governments have agreed to allow China to use the Symphonie system for test transmissions. This agreement is the first joint research project that China has concluded with Western countries. It allows China to transmit radio, telephone, and television signals at no cost for the next six months via both Symphonie satellites. (R.W. Rostron)

WAVE POWER—THE COCKERELL RAFT AT SEA

In our last issue (*ESN* 32-4) a series of three articles addressed the topic of wave power. As we go to press, first sea trials of a 1/10 scale model Cockerell Raft in the multiple-pontoon wave-energy device developed by Sir Christopher Cockerell, inventor of the Hovercraft, have commenced in the Solent following promising tank tests by the British Hovercraft Corporation. The model in the Solent is expected to generate about 1 kW as compared with full-scale rafts of a surface area 100 m × 50 m in the Atlantic which might generate 2 MW. The National Press indicate that Cockerell, who in the past has fought long battles with the UK establishment, is highly complimentary of the government scientists of the Energy Technology Support Unit at Harwell (More kudos for Harwell!). Alex Eadie, Parliamentary Under Secretary of State at the Department of Energy who has ridden the raft in the Solent, reiterating that wavepower probably offers a greater potential for the UK than any other natural renewable energy source, expressed the view that the sea trials "will show people that wave power is not just a boffin's pipe dream but a tangible credible proposition." Skeptics remain however.

The sea trials are particularly important as the time approaches when the wave power program will necessarily have to move into a very substantially more expensive phase if it is to be pursued and when decisions will have to be made between various device approaches. (A.W. Pryce)

PERSONAL

Dr. R.G.C. Bathhurst, Reader in the Department of Geology at the University of Liverpool, has been given the status and title of professor.

Dr. William J. Jones, Research Fellow at Trinity College, Cambridge, has been appointed to the Chair of Chemistry at University College, Aberystwyth, Wales. He succeeds Professor John M. Thomas, FRS, who is taking up the Chair of Physical Chemistry at the University of Cambridge.

Dr. Tony McDonnell, Reader in Space Science at the University of Kent in Canterbury, has been selected to design one of two British experiments on the first scientific mission of the NASA Space Shuttle. The Science Research Council has awarded a grant of £36,773 for the project, which is designed to detect very small meteoroids.

Dr. T.N.L. Patterson has been appointed Director of the Computer Centre at the Queen's University of Belfast.

Gérard Piketty, an Engineer with the Chief of Mines, has been appointed President-General Manager of the Centre National d'Exploitation des Oceans - CNEXO (National Ocean Exploitation Center) at Brest, France, as the replacement of Yves La Praire.

Dr. K.G. Stephens, Reader in the Department of Electronic and Electrical Engineering, University of Surrey, has been promoted to a personal Chair in Electrical Engineering in the Department.

Professor J.H. Wilkinson, FRS, of the UK's National Physical Laboratory, has accepted a one-third time appointment in the Computer Science Department at Stanford University. He will be spending one term each year at Stanford.

OBITUARIES

Professor Rowland S. Benson, Professor of Mechanical Engineering at the University of Manchester Institute of Science and Technology since 1962, died 30 March at the age of 53. He was internationally renowned for his researches on internal combustion engines and radial turbomachines. With a ten-year industrial experience behind him, he became a Lecturer at the University of Liverpool in 1953, and became Reader in 1961. At the age of 37, he was appointed to a chair at UMIST, where he started and developed the Division of Thermodynamics and Fluid Mechanics, bringing it to a level second to none in academic reputation and experimental facilities. He published well over 100 substantial papers and two notable books. Benson received several major prizes from the Institution of Mechanical Engineers (London), the American Society of Mechanical Engineers, and other bodies for his papers. He was Academic Vice-Principal of UMIST, 1971-73, and among other appointments, he was Chairman of the Aeronautical and Mechanical Engineering Committee of the Science Research Council.

Sir Stewart Duke-Elder, one of the greatest oculists in Britain, died on 27 March at the age of 79. He was Surgeon Oculist to King Edward VIII, King George VI, and to the Queen. During a brilliant career, he achieved an outstanding reputation as a research worker, a clinician and perhaps above all, for his reputation as a research worker. His earliest papers were on the nature of the intra-ocular fluids. From 1932 to 1954, he wrote and published the great Textbook of Ophthalmology in seven volumes. Upon its completion he felt that parts of it needed revision. Instead of producing a second edition, he decided to completely rewrite it as the System of Ophthalmology in no less than 15 volumes, the first of which was published in 1958 and the last in 1976. For a few volumes of the work he did have some co-authors, however, he did all the final editing and revising. He also found time to write The Practice of Refraction (8th ed., 1958), Recent Advances in Ophthalmology (4th ed., 1951), Parson's Diseases of the Eye (16th ed., 1969), as well as to contribute a steady flow of papers to many ophthalmic and scientific journals. He was Editor-in-Chief of the *British Journal of Ophthalmology* and of *Ophthalmic Literature*. He received many honors and medals during his lifetime.

Dr. John Ieuan Harris, a leading research worker in the field of protein chemistry and a founder member of the Medical Research Council's Laboratory of Molecular Biology in Cambridge, died 2 April at the age of 53. After his PhD work at the National Institute of Medical Research, he spent five years (1950-55) as a postdoctoral fellow

in the US and Denmark. In the Laboratory of C.H. Li at the University of California, he first became interested in studying amino acid sequences in proteins. In 1955 he joined the staff of the Medical Research Council in the Department of Biochemistry at Cambridge and moved his group to the new MRC Molecular Laboratory in 1961. His work has always been characterized by a logical scientific approach, extreme accuracy, and reliability of experimental results.

Professor Jan Hoytink, Professor of Physical Chemistry at the University of Sheffield, died suddenly on 11 April at the age of 53. Born and educated in the Netherlands, he began his academic career in 1953 with his appointment as Lecturer in Physical Chemistry at the Free University and in 1960 moved on to the Chair of Physical Chemistry at the University of Amsterdam in succession to Ketelaar. In 1966 he moved to the Chair at Sheffield. His earliest work was on the thermochemistry of unsaturated systems, but his international reputation lay in his studies of the electrochemistry of aromatic molecules. From electrochemistry he was led to study and interpret the electronic spectra of positive and negative ions of aromatic hydrocarbons, always applying molecular orbital theory and developing its methods and applications. He inspired the publication of the journal, *Chemical Physics Letters*, and was its editor.

Sir Morien Morgan, FRS, a distinguished aeronautical engineer, died 4 April at the age of 65. After a year with private industry, he joined the Royal Aircraft Establishment at Farnborough in 1935, where he was to spend the greater part of his working life. He joined the Flight Section of the Aerodynamics Department and became particularly concerned with the handling characteristics of aircraft. He became Head of the Flight Section in 1946, but in two years he was made Head of the newly formed Guided Weapons Department. Under his leadership, this Department played a notable part in the development of the first-generation guided weapons. In 1954 he became one of the two Deputy Directors of RAE, a post he held for nearly five years. Early in this period he began to consider the possibility of developing a supersonic civil transport aircraft, and he initiated studies in the appropriate Departments of RAE. As a result of these, the Supersonic Transport Aircraft Committee was set up with Morgan as Chairman. This Committee eventually made proposals that led to the development of Concorde. Morgan remained associated with this program for many years. He held a number of posts with the Ministry of Aviation and the Ministry of Technology and in 1969 returned to RAE as Director. Upon his retirement in 1972, he was elected Master of Downing College, Cambridge where he remained until his death.

ONRL REPORTS

R-14-77

PHOTOEMISSION ELECTRON MICROSCOPY: ANOTHER POWERFUL TOOL FOR THE MICROSCOPIST by A. Sosin

Photoemission Electron Microscopy, largely unknown in the United States, is an actively employed technique in several European laboratories. This report describes microscope design, image formation and contrast considerations, resolution and depth of information, and application. Photographs illustrate varying applications in metals, ceramics, and semiconductors.

C-4-78

OPTICAL COMPUTING—A NATIONAL CONFERENCE AT VISEGRAD, HUNGARY by V.N. Smiley

The International Conference on Optical Computing in Research and Development was held in Visegrad, Hungary 4-9 October 1977. The fact that this field is in an early state of evolution was brought out by the speculative and preliminary nature of many papers. Hybrid systems combining digital or analog electronics and optical devices were emphasized in several papers and in a roundtable discussion. A factor slowing the development of such systems is that people from different disciplines are required to integrate their ideas. The main subjects discussed in the report are: *laser graphic devices, holograms,* hybrid image processing, and biological applications. In addition, some critical discussion of the general field of optical computing as well as some specific areas is included.

C-5-78

THE SECOND INTERNATIONAL CONFERENCE ON THE ELECTRONIC PROPERTIES OF 2-DIMENSIONAL SYSTEMS by B.D. McCombe

The Second International Conference on the Electronic Properties of Two Dimensional Systems, 19-22 September 1977, is reviewed critically. Topics discussed include: Space charge layers in Si MOS structures; carrier localization, electric field subband spectroscopy and many-body effects, dc and high frequency magneto-conductivity, cyclotron resonance, charge density waves, surface "superlattices"; electrons on liquid helium, bound state spectra and lifetimes, electron motion parallel to the surface, two-dimensional plasmons, and Wigner crystallization; semiconductor superlattices; and other semiconductor MOS structures.

C-6-78 THE 13TH INTERNATIONAL SYMPOSIUM ON APPLIED MILITARY PSYCHOLOGY by M.J. Farr and C.R.J. Lafleur

The 13th International Symposium on Applied Military Psychology was hosted by Canada at the Canadian Forces Base, Lahr, Federal Republic of Germany, on 25-29 April 1977. There were 22 participants from 10 countries. The conference theme was the military in society. Four major topics were discussed: (1) military management and organization, (2) military personnel practices and problems, (3) attitudes toward the military, and change in those attitudes, and (4) the organization and programs of military psychology research units.

C-7-78 FIRST INTERNATIONAL CONFERENCE ON MATRIX ISOLATION SPECTROSCOPY by R.R. Smardzewski

This report discusses the content of several papers presented at the First International Conference on Matrix Isolation Spectroscopy held on 21-24 June 1977 in West Berlin, FRG. A brief discussion of the technique of matrix isolation spectroscopy is included.

INDEX OF ONRL TECHNICAL AND CONFERENCE REPORTS, 1976

Now that all ONRL Technical and Conference Reports published during 1976 have been accessioned by the Defense Documentation Center, we are pleased to provide this index. Copies of these reports may be obtained from either the Defense Documentation Center, Cameron Station, Alexandria, VA 22314 or the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, by using the listed AD number.

BIOLOGICAL SCIENCES

ONRL C-10-76	M. BLANK, J.W. TWIDELL, R.J. WERRLEIN and J.B. BATEMAN	The Fifth International Biophysics Congress: Four Views (AD-A025151)
ONRL C-15-76	J.B. BATEMAN	The World of Sub-Sensory Receptors: A Symposium on Drug Action at the Molecular Level (AD-A029009)
ONRL R-3-76	"	Aqueous Artefacts: The Riddle of Bound Water (AD-A024643)

COMPUTERS

ONRL C-21-76	D.C. RUMMLER.	1976 International Zurich Seminar on Digital Communications, 9-11 March 1976 (AD-A029185)

EARTH SCIENCES

ONRL R-9-76	A.I. BARCILON	Highlights of Dynamical Climatology in Europe (AD-A033335)

EDUCATION

ONRL R-1-76	H. FREEMAN	USSR Engineering Education in Electronics and Computer Science—Some Recent Observations (AD-A022131)
ONRL R-11-76	A.I. BARCILON	France's Grandes Ecoles (AD-A035447)

ELECTRONICS

ONRL R-6-76	D.K. CHENG	Ptarmigan: A UK Secure Area-Communication System for Armed Forces (AD-A031043)
ONRL R-12-76	"	Electronic and Telecommunication Activities in Egypt (AD-A035445)
ONRL C-34-76	N.M. BLACHMAN	IEE International Conference on Millimetric Waveguide Systems

ENERGY

ONRL C-31-76	R.H. NUNN	International Symposium on Wind Energy Systems (AD-A034871)

ONRL C-14-76	R.F. POTTER	Energy and Physics—Third General Conference of the European Physical Society (AD-A026962)
ONRL C-30-76	W.G. SOPER	The 10th International Power Sources Symposium (AD-A033323)
ONRL C-40-76	"	International Conference on Hydrogen and its Prospects (AD-A036936)

ENGINEERING

ONRL R-7-76	R.H. NUNN and H. HERMAN	An Industrial Technology Called Tribology—The UK Experience (AD-A030898)
ONRL C-17-76	R.H. NUNN	Fifth International Symposium on Fresh Water from the Sea (AD-A027625)

GENERAL

ONRL R-2-76	V.S. HEWITSON and K. CLAPSADDLE	Index of ONR Technical and Conference Reports 1967 through 1974 (AD-A022130)

MATERIALS SCIENCE

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ONRL C-25-76	H. HERMAN	The Israeli-American International Conference on Applied Metallurgy (AD-A030908)
ONRL C-38-76	A. SOSIN	Positron Annihilation: From QED to NDT—A Report on the Fourth International Conference on Positron Annihilation, Helsingor, Denmark, 23-26 August 1976 (AD-A037907)
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ONRL C-2-76	D.E. DODDS	International Symposium on Flames as Reactions in Flow: Padua, Italy: 15-16 December 1976 (AD-A021854)
ONRL C-3-76	E.A. WOLICKI, J.W. BUTLER, K.L. DUNNING and J.K. HIRVONEN	Applications of Ion Beams to Modify the Properties of Materials (AD-A021653)

ONRL C-8-76	A.L. POWELL	Faraday Symposium on Proton Transfer, University of Stirling, Scotland 8-11 September 1975
ONRL C-9-76	"	The International Conference on Colloid and Surface Science (IUPAC), Budapest, Hungary, 15-20 September 1975 (AD-A024159)
ONRL C-12-76	F.L. CARTER and C. FELDMAN	Fifth International Symposium on Boron and Borides (AD-A026961)
ONRL C-27-76	P.J. HERLEY	Eighth International Symposium on the Reactivity of Solids (AD-A033334)
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MECHANICAL ENGINEERING

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ONRL C-4-76	"	Seventh Cranfield Fluidics Conference—Stuttgart, 12-14 November 1975 (AD-A021917)
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ONRL C-32-76	E.A. KARSLEY	From Soup to Nuts—The VIIth International Congress on Rheology (AD-A041227)

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ONRL C-36-76	M. STEK	XIII International Congress of Internal Medicine, Helsinki, Finland, 15-18 August 1976 (AD-A041228)
ONRL C-41-76	J. VOROSMARTI	VIIth International Symposium on Marine Medicine, 23-30 September 1976, Aboard the M/V Bellorussiya (AD-A037949)

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ONRL C-7-76	T.A. KITCHENS, A.K. NEDOLUHA, and D. PAPACONSTANTOPOULIS	Annual Solid State Physics Conference of the Institute of Physics, UK, Manchester, 5-7 March 1976 (AD-A023611)
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ONRL C-19-76	R.F. LOPINA	2nd International Heat Pipe Conference, Bologna, Italy, 31 March-2 April 1976 (AD-A029174)
ONRL C-39-76	N.D. WILSEY and J.H. SCHULMAN	International Conference on Radiation Effects in Semiconductors (AD-A036994)

PSYCHOLOGICAL SCIENCES

ONRL R-14-76	J.W. MILLER	Observations on Psychological Research in Nine British Universities (AD-A003952)
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30-9	AD-A048283
30-10	AD-A048237
30-11	AD-A048233
30-12	AD-A048234