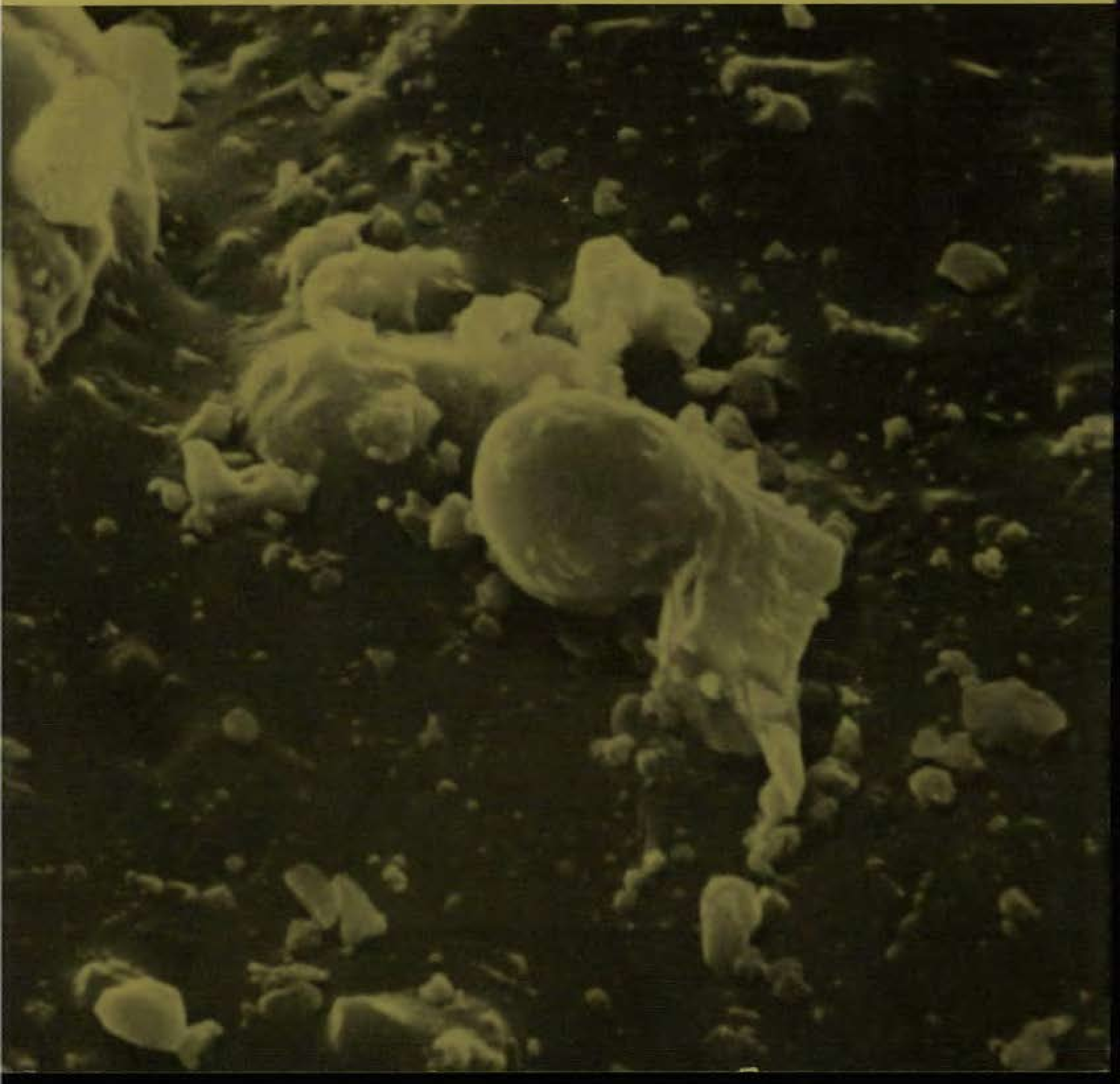
Review

FALL 1970

OAK RIDGE NATIONAL LABORATORY



THE COVER: Absence of water and oxygen, combined with intense bombardment from cosmic radiation, solar wind, and meteorites, result in unusual surface features of lunar minerals. Extremely thin surface layers of lunar fines, as seen here at high magnification in a scanning electron microscope, are currently the subject of studies in the Health Physics Division, using the new technique of thermally stimulated exoelectron emission, which, in other materials, is also being used to measure very low doses of radiation.

The *Review* is published quarterly and distributed to employees and others associated with the Oak Ridge National Laboratory. The editorial office is in Room 291, Building 4500-North, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tennessee 37830. Telephone: 483-8611, Extension 3-6265 (FTS 615-483-6265).

Review

OAK RIDGE NATIONAL LABORATORY

VOLUME 3, NUMBER 5 FALL 1970

FEATURES

OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION • FOR THE U.S. ATOMIC ENERGY COMMISSION

Klaus Becker, an internationally acknowledged leader in the field of solid state dosimetry, received his doctoral degree in physical chemistry in Munich. He was in charge of the personnel dosimetry section and a dosimetry research group at the Jülich Nuclear Research Establishment for more than eight years, barring a sabbatical of one year at the Naval Radiological Defense Laboratory in San Francisco in 1965. From Jülich he joined ORNL in 1967 to head the Applied Dosimetry Research Group of the Health Division's Dosimetry Research Section. He describes here some of the most recent developments in his field.

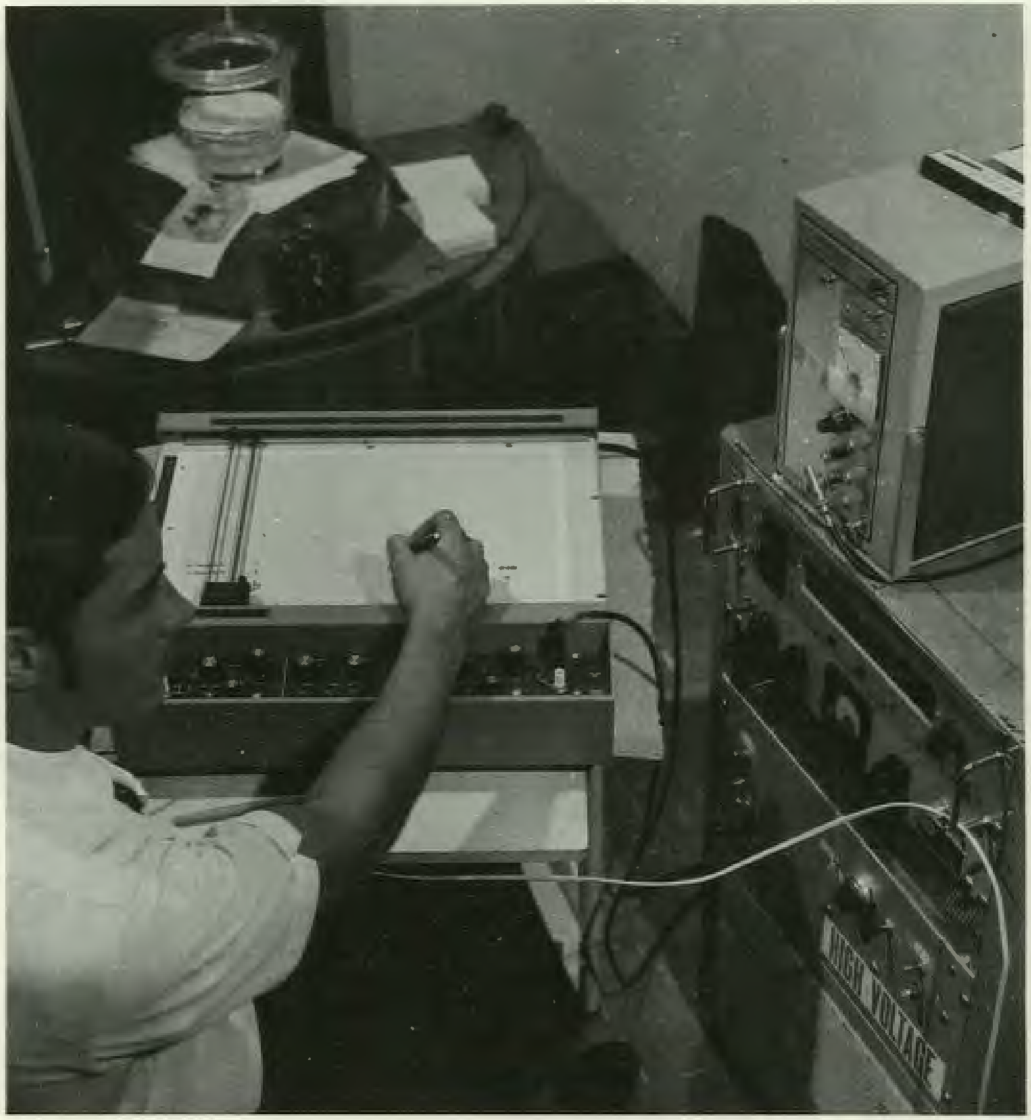
New Trends in Personnel Dosimetry

BY KLAUS BECKER

EVER SINCE THE DISCOVERY of ionizing radiation, the development of radiation detectors has played a key role in promoting our understanding of the nature of radiation and its interactions with matter. It has enhanced our awareness of the myriad benefits as well as the hazards implicit in the use of radiation in our modern world.

Uranium miners, astronauts, and passengers in the new high-flying supersonic transports are among those people who may be exposed to higher natural radiation levels. In addition, an increasingly large fraction of the population is exposed to artificial sources of radiation in medical diagnostics and therapy, or wherever radiation occurs as a regular or potential by-product of technological processes. In all these cases, reliable, simple measurements of accumulated radiation exposures are essential for medical, administrative, and legal reasons. Personnel dosimetry is only one of the

Graduate student K. W. Crase measures the thermally stimulated exoelectron emission from new, extremely sensitive dosimeters containing heat-sensitized ceramic beryllium oxide.



many important applications of "passive" (integrating) dosimeters. They are widely used in biomedical research, for space radiation studies, and in radiation technology, to name only a few other areas.

For several decades in the past, radiation dosimetry has been almost synonymous with the types of detectors that are based on the ionization of gases or photographic effects of ionizing radiation. With the increasing awareness of both the benefits and the risks of radiation and, therefore, the increasing need for more sensitive, more accurate, and less expensive dosimeters, this situation is changing now. Modern integrating solid-state dosimeters, based on the measurement of subtle changes occurring in some solids as a result of irradiation, are, in many cases, rapidly replacing "classical" detector systems like ionization chambers and photographic films.

Solid-state dosimetry is as old as or even older than our knowledge of radiation. The medieval alchemist in his dark laboratory who first observed a strange, transient glow while heating a mineral was probably unaware that he had released stored, radiation-induced luminescence and had, therefore, just discovered thermoluminescence, which is nowadays one of the most widely used techniques of solid-state dosimetery.

As an avalanche of published information indicates, however (there have been close to 10^4 publications on new dosimetric techniques in recent years, making a new information center on the subject highly desirable), it is still a rapidly developing field. Moreover, solid-state dosimetry research, compared to other areas of scientific inquiry comparable in fundamental and practical importance, is still relatively inexpensive, and impressive progress has been made with simple standard laboratory equipment such as microscopes, fluorimeters, and scalers.

All this makes solid-state dosimetry an unusually attractive field of research. Work frequently leads to exciting new applications in unexpected areas. When our research in exoelectron dosimetry began about two years ago, for example, we never expected that it would lead to a research project in lunar science; and when studies on track registration in polymers were initiated, it could not be predicted that the results would contribute to an understanding of the role of oxygen in radiation therapy. A few examples may illustrate how research in solid-state dosimetry can lead to new techniques with a number of interesting applications.

Safety of Uranium Miners

There has long been the problem of individual monitoring of uranium miners. For centuries, these miners have been exposed to dangerous radiation doses due to the inhalation of aerosol particles bearing radioactive materials, resulting in early death for thousands of them (the "Schneeberg lung cancer," as recorded in medieval chronicles in Saxony, is probably the earliest known lethal radiation damage to man). With the recent concern about the safety of miners in this country, it was felt that something should be done about the still high death rate of uranium miners. There was, however, no reliable method available to measure the actual individual exposure of miners to these dangerous agents.

Based on some earlier studies by our group, a new personnel dosimeter for uranium miners was developed last year. After successfully passing all laboratory tests with simulated mine atmospheres under varying conditions, the dosimeters have just been tested by the USAEC Health and Safety Laboratory in an actual uranium mine. The detector is attached to the helmet of the miner. It has the shape and weight of a pocket ionization chamber like those widely used by radiation workers. A small electric motor, operated at constant speed for at least 12 hours by a rechargeable battery, moves air continuously through a filter on which the aerosol particles with their attached radioactive material are collected. Alpha particles emitted in the decay of the material strike a thin plastic foil opposite this filter. The total number of alpha particle impacts over an extended period of, say, one week or one month obviously is proportional to the dangerous radioactivity inhaled by the miner.

When the thin plastic foil is exposed to a caustic solution, a tiny hole is etched in the foil at the location of each alpha particle impact. The total number of the holes in the foil can be counted automatically with a very elegant method which was originally developed in Chalk River for neutron dosimetry via fission fragment registration, and adapted by D. R. Johnson and me for the more difficult alpha particle track registration. The foil is placed on an electrode and covered with an aluminized Mylar foil. A voltage is then applied between the electrode and the thin aluminum layer. At about 500 volts, an electrical discharge will occur through the perforation, which is counted with a scaler. The heat of the spark evaporates a hole in the aluminum that is much larger than the original etched hole, thus removing the counterelectrode so no second sparking occurs through the same perforation. The result is twofold: First, sparks jump from one hole to the next until all holes are sparked, with the scaler recording the number of jumps. Secondly, a replica of the track distribution is created in the aluminized foil that is a directly visible image, and when new aluminized foil is placed on the perforated track detector, copies of this image can be produced that can be kept with the file.

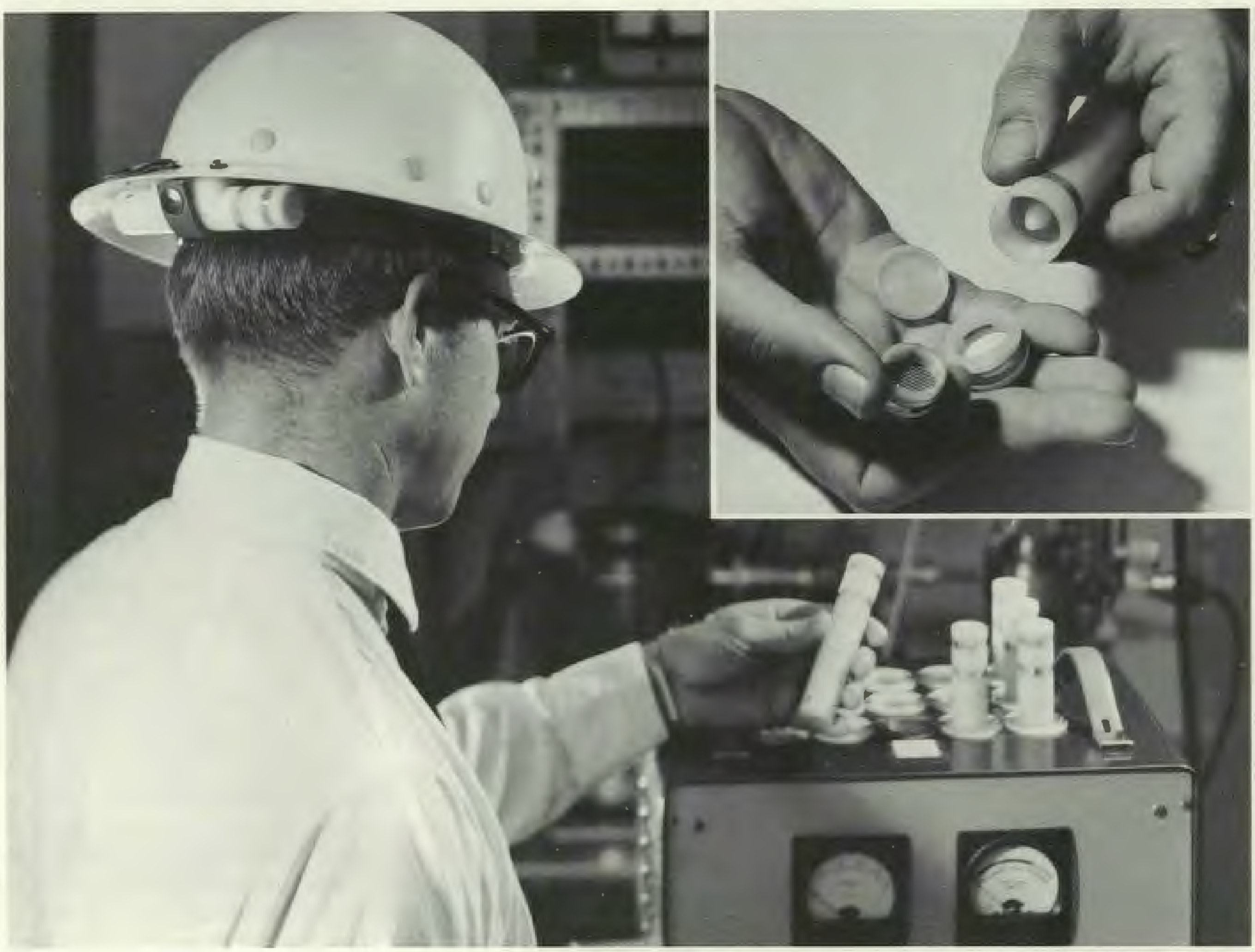
Radiography and Autoradiography

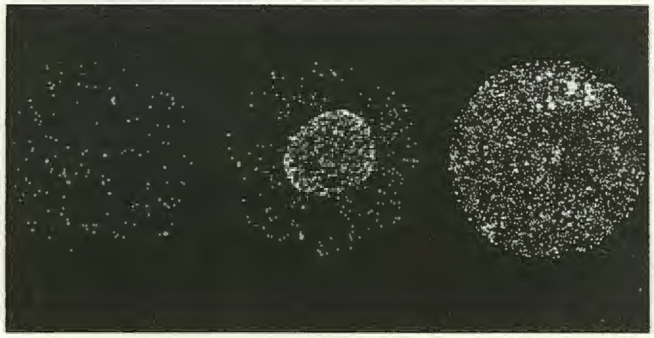
This sparking principle can be used in many other areas. Last year we were, for example, approached by Dr. W. S. S. Jee from the University of Utah. His field of interest is the deposition of radium and plutonium in bone, and using the conventional method of exposing special photographic film to the radiation emitted from a thin cut of the bone, he has had to wait sometimes a matter of years before getting his results. The alpha-sensitive foils that we had developed and that could easily be counted automatically by the sparking technique served to streamline his work so that he was able to obtain the same results in days instead of months of exposure time, with no need for complicated darkroom processing and time-consuming microscopic counting.

An even higher sensitivity in determining the quantity and distribution of fissile elements like uranium, and of elements in which neutrons induce the emission of alpha particles by nuclear reactions (boron and lithium are typical examples) in a multitude of materials can be obtained by a modification of this technique. Samples of a mineral, metal alloy, or a biological specimen are covered with a foil sensitive to fission fragments or alpha particles and the combination exposed to a known neutron flux in a reactor. After etching and sparking of the detector foil, the number of tracks can be related to the amount of the material, and the location of the evaporated spots in the aluminum will indicate, of course, the location of the elements.

It is easy to demonstrate the impressive sensitivity of this simple method. A drop of distilled water contains almost no fissile elements, but in a drop of tap water, approximately 10^{-14} gram of uranium shows up as several hundred spots, each one representing a fission fragment from a uranium atom. A filter through which eight cubic meters of air has passed shows an even higher track density, indicating that it contains fissile elements, too. Obviously, this technique can be used for tracer studies in ecology, hydrology, meteorology, and in

C. H. Abner models a type of hard hat worn by uranium miners carrying the new radon progeny dosimeter as it is designed to be attached. Abner, who participated in developing the new system, is facing the recharging unit where the meters are kept between shifts. In the inset are shown some constituents of the new dosimeter: the rapidly moving propeller is exposed to view when the detector is opened for replacement of the filter and used alpha particle detection foil.





Spark-amplified fission fragment tracks in a foil that has been exposed to thermal neutrons after evaporation of a drop of distilled water on its surface (left), after evaporation of a drop of tap water (middle), and in contact with a filter through which some air has passed, indicating amount and distribution of trace quantities of fissile elements.

many other areas of research. There are also other applications. One is the ultrasensitive detection of thermal and fast neutrons, using (n,α) or fission reactions. A combination of a foil of a fissile material (or one containing boron or lithium) with a track detector can also be used as a "photographic" plate in neutron radiography. The extreme sensitivity for neutrons and complete insensitivity for other types of radiation make new applications of neutron radiographic techniques possible.

Exoelectron Dosimetry

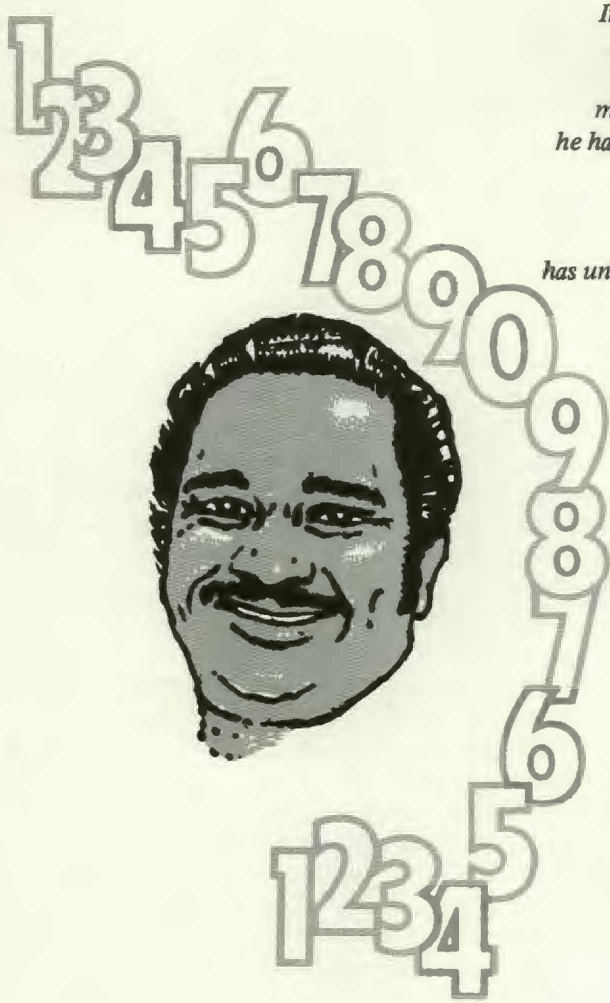
Only heavy charged particles can be detected by etching in polymer foils. Extreme sensitivity for x, gamma, and beta radiation was one of the goals in experiments that we carried out using a little known principle which was discovered by Kramer in Germany a few years ago, namely the thermally stimulated release of very low energy electrons (exoelectrons) from the surface of certain crystals. The number of release electrons can be made proportional to the radiation dose. The reading principle is simple: the irradiated material is heated slowly inside a gas-flow G-M counter and the electrons that are released at certain temperatures, which are characteristic for a given material, are counted. The physical principles of exoelectron emission and dosimetric characteristics (such as sensitivity to different types of radiation, linearity of response, and fading stability) in a multitude of simple inorganic compounds have been studied by J. S. Cheka, R. B. Gammage, J. A. Auxier, J. F. Wilson, N. Chantanakom, K. W. Crase, E. M. Robinson, M. Oberhofer, and myself.

Recently, we found that with a high-temperature treatment, or by diffusing small amounts of metals into the surface of the detector material, the high inherent sensitivity and the reproducibility of a ceramic, sintered beryllium oxide, can be further increased. Optimized treatment of such detectors, resulting perhaps in a reduction of the work function, permits the measurement of radiation doses as low as a few microroentgens, corresponding to less than an hour of normal background radiation exposure. The sensitive and accurate measurement of such low integrated doses with an extremely simple, small, and inexpensive detector opens up new possibilities for studies of population exposures, environmental monitoring around nuclear installations, studies in radiation research demanding an extreme sensitivity, etc. A new personnel dosimeter based on this principle is now under development.

High temperatures, up to 700°C, are required to release the electrons in some detector materials. These materials can obviously be used for radiation dosimetry at temperatures much higher than those accessible by any other integrating system of comparable sensitivity. Exoelectron emission is known to occur from many irradiated nonconductors, including such unlikely substances as hemoglobin, egg shells, and granite. Some studies on exoelectron emission in different rock samples have led us to the conclusion that lunar rocks and soil should also exhibit this effect. Indeed, various lunar surface fines, rocks, and core tube samples from the Apollo 12 mission which R. B. Gammage and I are now examining exhibit complex exoelectron emission characteristics reflecting certain surface properties and changes occurring at the surface.

Another attractive feature of this newest addition to the field of solid-state dosimetry is the fact that the sensitive detector layer is probably not thicker than the diameter of a single DNA molecule. This opens for the first time the possibility of solid-state microdosimetry, that is, dosimetric studies at the molecular level in a condensed detector medium. Perhaps "exoelectron photography" could also replace conventional photography in some areas. These and many other possible applications are, at present, under investigation.

In response to a number of suggestions from readers that the Review *could be made more readable by the addition of shorter and lighter features, it seems appropriate that the hobby of a Laboratory mathematician be exploited in a series of items describing discoveries he has made or learned of concerning numerical oddities. Ram Uppuluri, a research statistician in the Mathematics Division, has long had an interest in numbers and their relationships to each other. In the forthcoming disclosures, he will describe some of the curiosities he has unearthed in the process of pursuing his hobby of rummaging through the integers.*



Take A Number.....

BY V. R. R. UPPULURI

Something Special About 153

Many of us know that one way to test whether an integer is divisible by 3 or not is to add the digits in the integer and see whether this total is divisible by 3 or not.

Take an integer divisible by 3. Cube each digit in this number and add them. If we repeat this process we will eventually end up with 153. For example, let the given integer be 12. $1^3 + 2^3 = 9 \rightarrow 9^3 = 729 \rightarrow 7^3 + 2^3 + 9^3 = 1080 \rightarrow 1^3 + 0^3 + 8^3 + 0^3 = 513 \rightarrow 5^3 + 1^3 + 3^3 = 153$. A mathematical proof of this curio may be fascinating and instructive.

153 has the property that $1^3 + 5^3 + 3^3 = 153$. It is also clear that $1^3 = 1$. A computer might show for us that there are only five positive integers with this property; namely 370, 371, and 407. How about a mathematical proof?

Does 6174 Know?

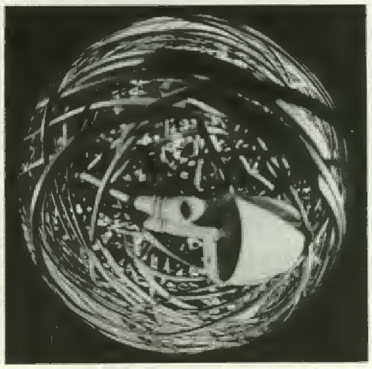
Take a four digit number. Rearrange the digits to form the largest number and the smallest number. Subtract the smallest from the largest. Now we come up with another four digit number. Repeat what we did before. Does 6174 know, that eventually we will end up with it? But in many mathematical circles this is making rounds. Obviously, it is not true if all the four digits are the same, like 2222.

Suppose we start with 0206. Then we subtract 0026 from 6200 and right away end with 6174. Let us say that it took us one step. One might be able to prove this result mathematically. If one is resourceful, he might write a computer program and be pleasantly surprised to find that it never takes more than 7 steps to end in 6174. In fact one can observe the following frequency distribution for numbers between 1 and 9998, excluding 1111, 2222, etc.:

# Steps	0	1	2	3	4	5	6	7	Total
Frequency	1	383	576	2400	1272	1518	1656	2184	9990

Can we show mathematically that it never takes more than 7 steps?

Bob Stone, who shares the credit for the new hybrid system he describes here with O. W. Burke and F. H. Clark, has been with the Laboratory since the fall of 1948, when he joined the Chemistry Division fresh from Cal Tech, where he had just received a bachelor's in physics. For Chemistry he worked in electronic detection systems until 1953, when that part of the Division formed, with part of the General Engineering Division, the new Instrumentation and Controls Division. Here he worked primarily on analog computer simulation of complete reactor systems, and in the early sixties served as Reactor Controls Design Representative to the Operations and Neutron Physics Divisions. Since 1965 he has been head of the Reactor Controls Analysis Group in I & C. The group is concerned with the safety and control of reactors and reactor systems. Further information about the hybrid computer in this article can be obtained from him, or Burke, or Clark.



The HYBRID at I and C

BY R. S. STONE

A MODERN HYBRID COMPUTER, comprising a PDP-10 digital machine and an AD-4 analog, was recently added to the computer facility of the ORNL Controls Department. Although the advantages of combining analog and digital computers have been anticipated for the last ten years, the combination is especially attractive today. Among other reasons, the last five years have produced enormous reductions in both analog switching times and digital computer prices. During this same five-year period, reactor dynamics problems have increased in complexity, and at present virtually demand the speed and capacity of a hybrid computer. Let me cite the advantages of the hybrid concept in general and the ORNL installation in particular.

History

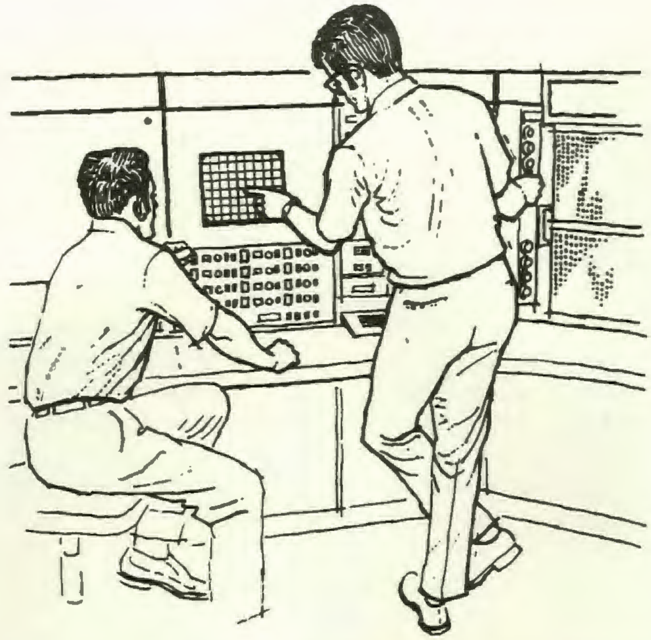
Almost from the inception of chain reacting piles, the ORNL Controls Department has actively advanced the state of the art in reactor control.

Frank Clark, who played a large role in developing the mechanics and software of the new hybrid system, watches while computer operator Charles Murphy runs a check on the digital half.

Created as an offshoot of the Physics Division at a time when a systematic approach to neutron kinetics was just beginning, the Controls Department later became a part of the Instrumentation and Controls Division, utilizing a mixture of reactor physics and modern control theory. Electronic simulators were created and used both as design tools and as a means for assessing the capabilities of control and protection systems. Starting with this early equipment, and adding commercial gear through the next two decades, the department successfully designed control systems to meet the kinetic requirements of a long line of reactors. This systematic treatment began in the late '40's with the Materials Testing Reactor and the nuclear aircraft project, and followed with work on many subsequently built reactors, including all in operation at the Laboratory today. Much additional simulation went into kinetic analyses of other reactors built for military and space applications. The most recent work involves the MSBR, with safety studies on the HTGR and certain aspects of the LMFBR.

In all, the work done represents some 400 man-years of experience in the analysis and design of reactor control systems. These systems have been successfully designed and optimized for the reactors in question, with ultimate performance well tailored to design objectives. Desalination plant control, containment evaluations, fission product distributions, noise analysis, radioactive decay schemes, and biological and ecological models have also been developed. Most of this work has been based on computer simulation of the system under study, wherein the model is exercised, insulted, examined, modified, optimized, and finally understood and controlled.

Ray Booth and Syd Ball at the cathode ray tube of the analog half of the hybrid. Booth is using the hybrid to make a model of the flow of fission product isotopes through the food chain. Ball has used it in his continuing study of multistage flash evaporator plants.



Analog vs Digital

Until now most of our modeling has been done on the analog computer. The characteristics which make the analog desirable for such work are immediate availability of results, speed, economy, and ease of use. The relative inexpensiveness of analog equipment means that the model of a system under study can be left on the computer for as long as a week while the design people prod it, investigate its dynamic behavior, refine it, determine what constants make it match experimental data, and design a control system to make it behave. In other words, the investigator has at his disposal a facsimile of the system under development, instantly available for exploring his ideas and insights. The speed of the analog permits it to run in real time (or at many times real time, in the case of slowly moving phenomena), and this is a further advantage. Each element of the prototype has its counterpart in a component of the simulation, and this one-to-one correspondence makes it easy to alter the model during operation, to investigate the sensitivity to various parameter changes, and to read out whatever variable is currently of interest.

Occasionally a simulation is required which is too big for the available analog, or which requires higher precision than the analog can deliver, and in such cases we have gone to a digital model. A digital program breaks the most complex problem into a chain of simple sequential operations, using the same computer registers over and over. One can therefore increase the size or complexity of a digital program by simply extending the running time on the machine. This has advantages over the analog situation, where increasing the size of the program requires more equipment, so that the size of the largest problem that can be run is determined by the size of the machine. So far as precision goes, single words in a 32-bit digital machine represent approximately nine decimal places. Variables in an analog computer are good to about four places. For some computations, the greater accuracy of the digital machine, and the greater dynamic range that it permits, can be important. Moreover, a digital computer can be preprogrammed to run by itself, and can remember a large number of interim values for later use in a computation. In these respects the digital computer has an edge over the analog.

In order to gain the on-line availability and the speed of the analog, while at the same time taking advantage of the accuracy, memory, and program expandability of the digital, the Controls Department has recently installed its powerful, modern hybrid computer.

Evolution of the Hybrid Computer

Over the past 20 years, analog and digital computers have simultaneously evolved from mere beginnings to vigorous technology. As the two fields have matured, there has tended to be less of the "anything you can do, I can do better" attitude. Instead, each group has looked with covetous eyes at some of the unique capability of the other. Analog machines are severely handicapped because they must live for the moment — they have no memory. Their accuracy is also limited. Digital machines lose tremendous flexibility through lack of on-line interaction with the investigator, and their constraint that all operations be done serially frequently leads to unrealistically long computation times. Each technology has tried within its own format to imitate the other, but with only limited success. An analog system can now remember a few numbers, or at most a few hundred; a digital system, with peripherals, can store millions of numbers. A suitably programmed digital computer can imitate the analog by running "simulations," but the computations are still run incrementally, element after element. Only the simplified coding makes the operation look like an analog; the computation time is determined by digital considerations.

The result is that more and more computer centers are realizing that even a small peripheral digital computer adds enormously to the potentialities of an analog facility, and that however large a digital facility may be, engineering computations can be greatly facilitated by tying in an analog computer. In each case some things can be done that could not be attempted before.

Hybrid Computer Applications

Obviously, a great many problems now being run on the digital computer are perfectly adapted to that medium and would be helped not at all by analog capabilities. A parallel situation holds for many all-analog simulations. Even in problems suited to the hybrid approach, there are varying degrees of intercomputer involvement.

At one extreme, a small digital computer might have no function except to set up the servo potentiometers on the analog computer, or to serve as a complex function-generator. In the other direction, a small analog computer might be used to filter, select, and digitize data for processing on a digital computer. In these applications, the problem is virtually all-analog or all-digital, with the other type of computer used as a peripheral computation aid. One stretches the definition of hybrid to say that these are hybrid computations.

A step toward greater complication occurs when one goes to complete digital control of an analog optimization study or parameter search. Parameter searches are common in biology and chemistry, and represent the situation where a model is assumed, including a set of transport or reaction equations, with some of the constants to be determined. In most cases, the equations themselves are of the type particularly well adapted to the analog computer, i.e., lots of coupled ordinary differential equations, linear or nonlinear. The coupling coefficients and rate constants are to be determined by cut-and-try, comparing computer results with experimental values. Doing this one run at a time on the analog computer could take forever in a large, tightly coupled system. A great advance on this approach is to use a repetitive operation analog, wherein the computer itself runs the computation over and over, in compressed time, displaying any variable(s) desired plotted against time on the oscilloscope. One can vary the coefficients one by one, by hand, during operation, and instantly see the effect of each one as the curve on the scope changes shape. This is a method yielding great insight to the experimenter as to which variables are important, which have little effect, which are coupled, etc. In most cases a good fit to experimental data can be achieved in a reasonable length of time, provided the model is valid to begin with. If not, the faulty area can frequently be inferred, and the model changed. In the hybrid approach, the digital computer is given the responsibility for finding the reaction constants. Criteria for fitting experimental data are given to the machine, and it makes run after run, changing analog coefficients in a programmed way, seeking the experimentally determined correct behavior. This can be done very rapidly, in some cases making a run every few milliseconds.

A third type of hybrid operation arises when the given problem involves some calculations that require a digital computer, and other operations that are much better done on the analog. If these two portions are separable, one simply puts each part on the proper machine, and provides channels whereby the two machines can exchange information and keep up to date on the latest results from the other side of the interface. The requirements of a calculation that tend to put it on the digital machine are high accuracy, wide dynamic range, or the need to store data or make large numbers of logic decisions. The analog is called for when calculations require high speed, or on-line interaction with the operator. For example, in a free piston engine problem done by the Canadian National Research Council, the analog runs the engine dynamics, and pauses at the end of each piston stroke while the digital computer runs thermodynamic calculations for in-cylinder gas conditions. In a variation of this technique, the digital computer keeps track of space vehicle position, while the analog calculates perturbations about the programmed course.

Still another type of hybrid application arises in the case of some very large analog models, where finite difference techniques are used for the solution of large sets of partial differential equations. Simulations of this type can of course be run using all-digital programs, but as the number of nodes goes up, computer time becomes prohibitive. The analog, with its capability for large numbers of simultaneous, infinite resolution integrations, is the ideal machine for these applications. However, as the number of node points goes up, the analog reveals its own frailty: the machine runs out of hardware. Since each node point in a homogeneous matrix requires the same set of analog equations, implemented by the same complement of analog circuitry, the thought naturally occurs, "Why can't we patch up a small number of nodes on the analog, and use digital control to time-share this typical fragment over the whole matrix?" Such an operation turns out to be quite practical. Suppose that a complete run on an analog big enough to handle the whole system were to take five seconds, running in real time. If we patch only 2% of the whole matrix, and time-share this fragment over the whole system, running time is increased to about four minutes. Since the analog no longer enjoys parallel operation of all sections, boundary conditions are no longer automatically satisfied, and a number of iterations will be required. Such a thinly spread analog could take 15 minutes to yield the five-second run, using the analog-multiplex system of hybrid operation. However, in most cases the hybrid can be run at least 10 times real time, which in this example would finish a run in 1.5 minutes. For a problem requiring 10 kHz bandwidth, which would just about permit a 10:1 speedup on the analog, a digital simulation would take about 100 hours to do the same run. Simulations requiring less than 10 kHz bandwidth will run in proportionally less time on either machine, with constant switching time decreasing the advantage of the hybrid computer where bandwidth requirements are low. Running the problem using a more efficient nonsimulation language could cut the digital running time by a small factor. The hybrid's advantage is that it puts the user in a position to trade hardware for computing time, and so to find the optimum balance between the two. In doing the big, fast, space-dependent simulation in the example cited earlier, one could do the same job with a $300,000 digital computer in 100 hours; a $600,000 hybrid in a minute and a half; or a $15,000,000 analog (if there were one that big) in half a second. One could say that the digital is obviously more economical than the hybrid because it does the job with half as expensive a computer. Or the analog is

Arnold Kenerly, instrument technician who performs most of the maintenance on the system, holds one of the operational amplifiers in back of the analog console.

more economical than the hybrid, because for only a 25× increase in price it cuts the computation time by a factor of about 200. If one demands reasonable computing times for reasonable costs, the hybrid approach has obvious merit.

Recognizing a Hybrid Problem

The applications described above give a general picture of the classes of problems best brought to the hybrid. For those presently operating on all-digital or all-analog facilities, there are symptoms which can indicate when a change of machine may be in order.

If a digital program involving families of differential equations is inadequately productive because of unacceptably long running or coding times, it may prove more tractable on a hybrid machine. Or, if turnaround time is a serious problem — i.e., if the investigator really needs to interact with the problem while it is running on the machine — the analog-hybrid approach yields the maximum of "hands-on" control.

The analog user can suspect that a hybrid machine might better fit his needs if large amounts of time are spent in repetitive searches for data-fitting parameters; or if the analog machine is of insufficient accuracy for certain calculations; or the programmer is running out of machine because he is trying to duplicate the same equations at node after node of a spatial mesh.

There are a number of guidelines for properly assigning a problem not yet committed to any machine.

THE ANALOG COMPUTER can provide a great deal of on-line interaction between man and machine. In model building or optimization, where the method of solution is not explicitly defined in every detail, and where the insight of the investigator can be of great importance as calculations proceed, an analog simulation should at least be considered. The analog computer's basic function is dealing with large sets of ordinary differential equations, linear or nonlinear, particularly where fast transients are involved. This type of problem should incline one toward the analog to begin with. If considerations of these types are present, but the calculations have aspects which require better than four-place accuracy, or if there are large numbers of logic decisions to be made, or complex functions of more than one variable to be generated, there is reason to suppose that a digital computer could help a great deal, and that we are dealing with a hybrid computer problem.

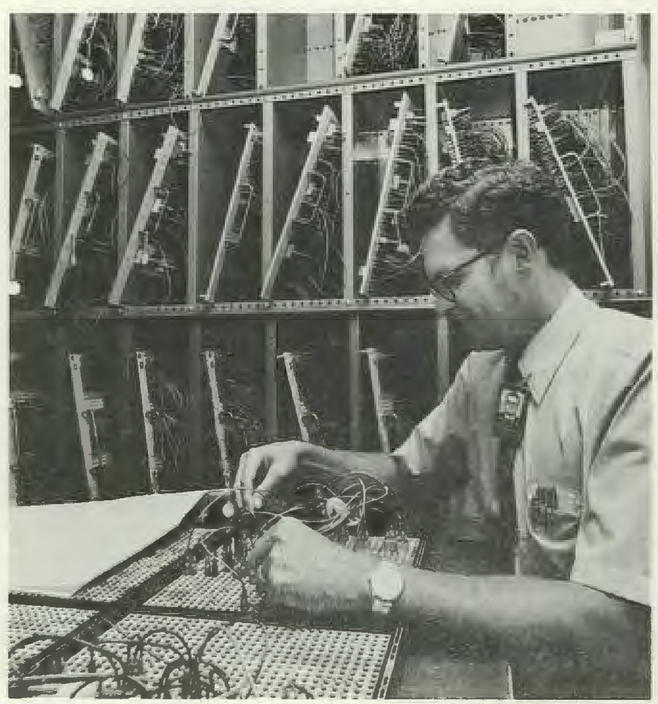
THE DIGITAL COMPUTER is in its element when dealing with large numbers of logic decisions, large arrays of algebraic equations, or calculations requiring many places of accuracy. The requirement that large masses of data be stored for later use is frequently a sign of a digital application. If, in addition, the problem involves large numbers of differential equations, a wide range of time constants, or a need to tie real world hardware or personnel into the computation, then we should suspect we have a job for the hybrid.

THE HYBRID COMPUTER is frequently the best machine for problems involving the dynamics of large, multidimensional distributions of materials or fields. This is the type of problem described by sets of partial differential equations, and might involve neutron diffusion, heat transfer, or particle transport. We would be likely to think of the hybrid in problems wherein some operations require high accuracy and other operations must go at high speed. We might well use the hybrid when dealing with large families of differential equations of which coupling coefficients must be determined. One should think in terms of applications, and not choose the digital because it is familiar, the analog because it is cheap, or the hybrid because it is new.

Incentives for Going Hybrid

The preceding material outlines some of the benefits of a hybrid computer. In choosing it over the analog, one recognizes that there are some problems that simply cannot be run on the analog machine alone. The system to be simulated may be too big for the available machine, or may require accuracy or storage capabilities that the analog does not have. The reason may also involve the economics of running time. An analog optimization program controlled by a digital computer may do in 10 minutes a job a human analog operator would take two days to finish.

When a large digital facility is available, the decision to go to a hybrid computer is usually based on economics, convenience, or both. In principle, almost anything that can be done on a hybrid or analog computer can be done digitally.



Ned Clapp uses the hybrid in his work on nuclear desalting technology.

"The all-analog approach is analogous to providing 12 holes in a house — one for each of 12 cats to run out. This is fast, but wasteful. The hybrid supplies only one hole, and requires the cats to queue up. They don't run quite as fast as before, and their passage is serial rather than parallel, but the process is fairly fast, and minimizes the damage to the wall. The digital approach grinds the cats into hamburger, and pushes them out through the keyhole. No new holes at all need be cut, but an interminable time is required, and familiarity with the dynamics of the system is lost." — R. S. S.

O. W. Burke composes a program on one of the removable patch boards.

Comparing the power of an all-digital machine with that of a hybrid is extremely difficult, but so far as machines that deal with the same class of problems are concerned, the digital will cost five to 10 times as much as the hybrid installation. As an additional incentive, certain classes of problems will run from two to 1000 times faster on the hybrid than on the digital machine.

In a few cases, the same development study has been made using both digital and hybrid methods. In an optimization on a nuclear power plant done for the British, the initial approach was to use a large digital computer and a simulation language. In this situation, it took three hours and 20 minutes to simulate 10 minutes of actual plant operating time. It was estimated that 3000 such runs were required, or complete dedication of a major digital facility for 10,000 hours. Since there are less than 9000 hours in a year, it is clear that a more efficient method was needed. The design was not completed on the digital computer; instead, it was done in 100 hours on a rented hybrid computer at a total cost of about $110,000.

Pacific Northwest Laboratories has made an extensive investigation of the economic advantages of the hybrid vs the central digital facility for systems analysis work. For those problems which were well suited to the hybrid approach, the savings were substantial. One example was a reactor core design study involving the sensitivity of reactor power density to certain parameters. This work was started on a Univac 1108 and an IBM 7090 as an all-digital program. With a deadline two weeks away, four weeks and $1500 had been spent, and it was estimated that it would take $5400 and a month more to finish the job. The effort was moved to the hybrid, where the work was finished in two weeks, including initial programming, at a cost of $2140. A steam particle deposition study was done on the hybrid in five minutes per run. The same problem took 15 minutes per run on an IBM 360/75. A groundwater systems analysis problem took five minutes on the hybrid, two hours on the 1108. It should be emphasized that there is a large capital cost differential between the $400,000 hybrid and the digital computers involved in these studies. There are simply some problems that it makes sense to do on the hybrid facility.

The primary incentive for the use of hybrid computers, then, is economic. But another incentive is the ability it offers for on-line interaction with the problem, and the fast turnaround time. To achieve the latter on a digital computer there exists a family of input-output devices, light pens and the like, that offer the ability to change the program and call for readouts while calculations are in progress. For small, fast-running programs, such things can give the presence and feel of an analog simulation. On the other hand, as I have already mentioned, for a large problem the all-digital approach can be much too slow. The interaction hardware is expensive, and it would seem that in many cases the money would be better spent in providing a small analog computer tie-in to the central facility.

AMW COMMENTS

CONFRONTATION WITH THE YOUNG, PART II

Augsburg College, where I gave the 1970 Commencement Address, is a small liberal arts school in Minneapolis whose president, Oscar Anderson, is the brother of Norman Anderson, director of the ORNL MAN Program. Unfortunately, I had chosen my topic, "Technology, Youth, and the Environment," a few weeks before Cambodia and Kent State. It was obvious to me, as I sat on the podium awaiting my turn to speak, that the students were going to be turned off by something as out-of-date as the environment: that was no longer making it as a now topic.

Then a quite remarkable thing happened. As President Anderson was about to introduce me, a student (whose name I later learned was Doug) jumped onto the stage, grabbed the microphone, and proceeded to make an impassioned statement about what he described as a "wretched, technology-crazy society that had led us into Vietnam." President Anderson, despite a few boos, allowed Doug to finish, and his remarks were applauded enthusiastically by most of the graduates.

What was I to do? I could not, on the spur of the moment, junk my speech and respond to Doug; but neither could I act as though nothing had happened. In fact, I was somewhat grateful for the distraction! Most commencement speeches are greeted with polite yawns by the graduates who want their diplomas and regard the commencement speaker as just the last in a series of obstacles one must hurdle before receiving his academic union card. But Doug's speech had put the audience on edge; there was an obvious electricity in the atmosphere, the kind of electricity that crackles whenever a traditional ceremony is jarred by the unexpected, and no one is quite sure what will happen next.

Luckily, though I had nothing to say about Vietnam, in a sense my talk was relevant to Doug. His unruly manner and rude disregard for the usual amenities placed him, in my mind at least, with the young people who had disrupted the Boston AAAS meeting: with the so-called counterculture, to use an au courant word. And what I had planned to say, fortunately, was directed at the counterculture.

I rejected, as I had at Boston, the counterculture approach to improving the environment, which is to destroy technology. This approach is elitist. Rich people can afford expensive electricity (which would be the consequence of this nihilistic approach to the environment). It is the poor who suffer most from the consequences of less technology. What we need, as Oak Ridgers have been saying for years, is more benign, more humane technology — not less technology.

Achieving this better technology will challenge both the new generation and the old generation. To the new generation the challenge is obvious: it will have to roll up its sleeves, learn hard things, and get to work — as scientists, engineers, technicians, social scientists.

But I believe that there is an even greater challenge to the establishment, by which I mean, the older generation. Surely there will be many young people who are eager to use science and technology to clean up. But their intentions and commitment will lead only to frustration unless the establishment provides the institutions in which the new, concerned generation can focus its latent energies and talents. What we shall need are new institutions — laboratories, industries, universities — at which the scientific attack on the environment can be pursued. We do not have them today, at least in sufficient number. My generation, having contributed to defiling the environment, must provide the places, the institutions, where the newly concerned generation can put its energies to work to set things right.

We now see glimmerings of such action. The Atomic Energy Act was amended in 1967 to allow the AEC National Laboratories to put their large talents to work on the environment. The National Science Foundation is sponsoring, under its IRRPOS program, Interdisciplinary Research on Relevant Problems of the Society, including the environment; and ORNL has been assigned $1,500,000 by NSF to carry out an integrated study of environmental problems. These are only some of the actions that are now being taken.

Thus, in its ponderous way, the establishment is moving to create some of the additional opportunities and mechanisms through which committed young people can work constructively, and in the scientific mode, to improve the environment.

In thinking about ORNL's venture with NSF, it is this aspect which I find most hopeful — that we may, in a small way to be sure, be creating an opportunity for concerned younger people to apply their energies constructively to a job they believe to be important and meaningful. I hope that we and the rest of the establishment are moving fast enough to give the untapped energies of our young people sufficient focused scope, and thus give them enough feeling of accomplishment to forestall this underlying frustration. I trust that enough will be done: that, as we reorder our national priorities (largely under the prodding of youth), we shall create the opportunities, and the resources, for interested youth to work effectively and meaningfully on cleaning up the mess we have helped to create. This is the very least that the establishment owes to the coming concerned generation.

Alvin M. Weinberg

1. When I'm out of the office for more than a few minutes, my secretary knows where I am and when I expect to be back. A B C
2. My secretary takes care of the paper in the office — she files what we need and throws away what we don't need. A B C
3. I consider the telephone my secretary's responsibility. A B C
4. I leave my travel arrangements to my secretary. A B C
5. I expect my secretary to compose letters and memoranda for my signature whenever she can. A B C
6. I expect my secretary to make necessary changes in my dictation to make the transcription grammatically correct. A B C
7. I leave it to my secretary to determine the order of priority in which her tasks are to be completed. A B C
8. I discuss my work with my secretary and I delegate as much responsibility to her as she is willing to accept. A B C

Are you getting the most out of that girl in your office? She may be more valuable to you than you realize. Read:

(For Bosses Only)

BY YVONNE LOVELY, CPS

MEN AND WOMEN at the top of the ladder in industry, in government, or in the professions know that a top-flight secretary is worth every dime of her salary. They know that her value to the office is determined by how well the boss and secretary understand each other and work together. There are other bosses who have little or no knowledge of what a secretary is, or knows, or can do.

The test above contains statements that have been made by bosses about their secretaries. To find your "secretarial I.Q.," mark each of the statements that reflects your attitude toward your secretary with the appropriate initial: "A" for always, "B" for sometimes, and "C" for never.

If you're a "straight A" boss, you have a secretary who hopes to work for you until she retires. If you're a "B" boss, you have a secretary who's keeping an eye out for a transfer. If you're a "C" boss, you don't need a secretary. For those who marked some combination of A-B-C, let's review the statements.

Yvonne Lovely, probably more than anyone else at the Laboratory, typifies the career secretary. She is one of the select few who have been designated officially as a "Professional Secretary" by the Institute for Certifying Secretaries, a distinction that qualifies her to use the coveted CPS after her name. She was, during her membership, prominent in the National Secretaries' Association, holding a number of offices and frequently contributing to its magazine, *The Secretary.* For the Adult Education Program in Oak Ridge she has designed and conducted several cram courses for candidates for the Institute's certifying exams, many of whom are now CPSs. She graduated magna cum laude from the University of Tennessee in Business Administration, and is a member of two national honor societies. Yvonne was on the spot in Oak Ridge in the spring of 1943, and has been with ORNL since 1950. She can be found today in 4500N, maintaining order and efficiency in the Education and University Relations Office for her current boss, Lewis Nelson. The accompanying article was requested of her as a response to the commonly heard generalization that scientists-turned-administrators often do not know how to derive full benefit from the secretarial competence available to them.

1. An executive knows how important it is to keep his secretary informed of his schedule so she will know if he can be reached, where, when, and by whom. A boss who should know better may resent the secretary's interest in where he is going and how long he will be gone; his attitude is "Let her guess." The patient secretary may call a dozen different offices and laboratories before she finally locates him — and her message may be that *his* boss wanted him in a meeting 30 minutes ago.

2. A secretary is trained to organize a system of filing the papers and reports necessary to the operation of her office and to retrieve them promptly upon request; she is also able to decide which of those can be discarded and when. A magpie boss keeps everything on his own desk or in his briefcase; he is noted especially for blaming his secretary for losing something that is right where he put it, and that may be at home on the refrigerator.

3. The executive, as a part of management, wants the most for the labor dollar. He is paid for expertise in his field, not hers, and he knows that a telephone call costs the company about three times as much per minute if he makes it as it does if the secretary takes care of it, assuming that her salary is about one-third of his. The secretary expects to make telephone calls for her boss (it's in her job description) and is prepared to spend five minutes on the FTS, perhaps only to come up with a busy signal or a recorded response. What's more, she doesn't mind trying again. The boss who insists on answering the office telephone will discover that a number of the calls to his office concern matters that his secretary can handle — or should — and that he is, in effect, screening her calls.

4. A secretary learns in a very short time her executive's preference with regard to travel arrangements and needs only a general idea of where he is going, when, and why, to plan the best possible itinerary for him. She knows whether he prefers a tight or a loose schedule, if he is averse to night flying or late hours, and which hotel he prefers. She takes care of the pre-departure paper work and fills out his expense report when he returns. All he has to do is travel.

5. An executive knows that the best way to handle paper is as little as possible; if his secretary composes and types a communication for his signature, he sees the correspondence only once and is through with it. A good secretary composes and types, on her own initiative, at least some of

the nontechnical correspondence for the boss's signature.

6. The most intelligent scientist has been known to struggle with the proper placement of a comma — and guess wrong; he may know all about splitting an atom, but his secretary knows more about splitting an infinitive. Grammar is her field of expertise. An executive expects his secretary to edit and correct any material she prepares in final form, including the dictation. The boss who painstakingly writes out everything he wants typed and wants it typed just as it is (even a memorandum to order Kleenex) does not need a secretary: a good typist will serve him just as well.

7. The secretary knows, often better than her boss, which tasks should have priority. She keeps a record of deadlines, meetings, appointments, mail pickup and delivery service, and other data to help her schedule her work. Bad cess to the boss who tries to hasten a rush job by breathing down the secretary's neck as she sits at the typewriter! Some of our scientific and technical personnel have apparently failed to note some typing statistics. A good rate of speed for a typist is 65 words a minute, or about six double-spaced pages of typed copy in an hour. This, of course, assumes that the original material can be read without difficulty and contains no technical typography; nor does the rate of production include normal interruptions encountered in every office.

8. An executive wants his secretary to know as much as possible about his work so she can relieve him of as much administrative and clerical detail as possible. He knows that she can be trusted with confidential information. The boss must delegate to the secretary the responsibility he wishes her to assume; a good secretary will accept, but not usurp, responsibility. As the boss and the secretary become accustomed to working as a team, she becomes an assistant to her executive, always remembering that he is the chief and she is the Indian. The secretary will discharge her responsi-

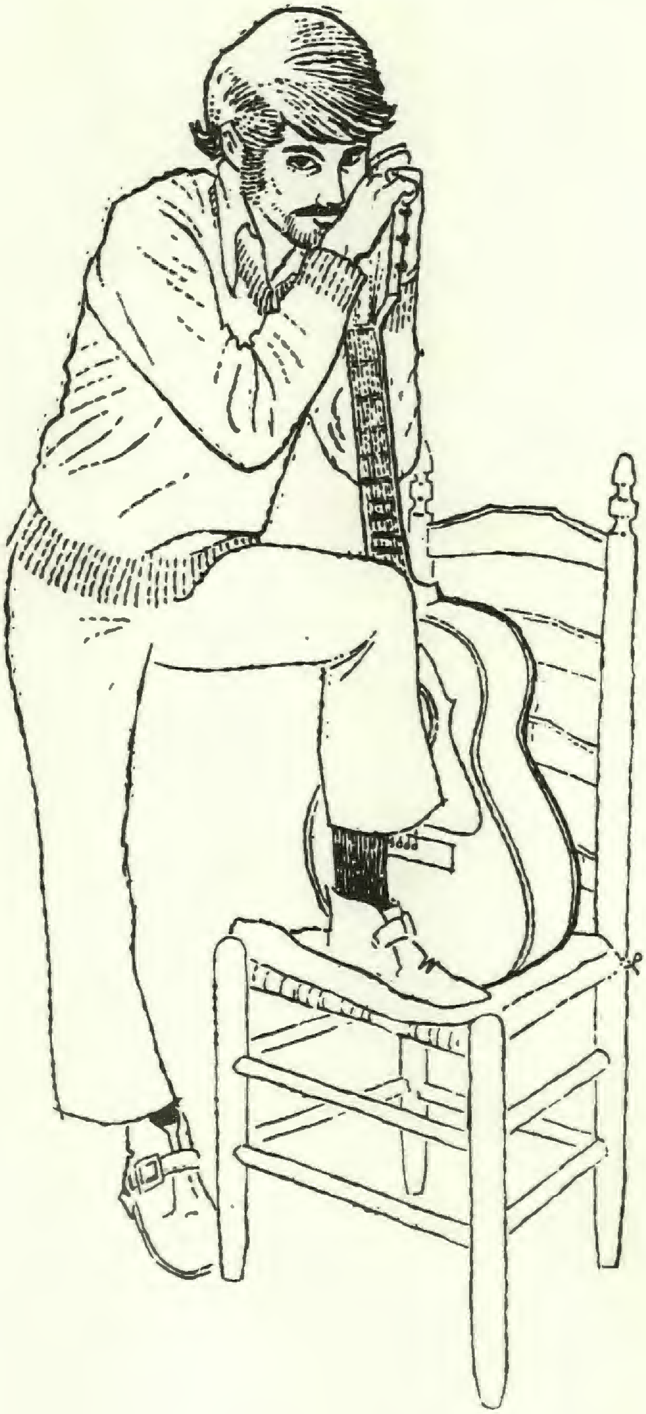
bilities promptly and efficiently, according to company policies and procedures, and always within the scope of her delegated authority. An unhappy secretary is not the one with too much responsibility, but the one with none.

The Shared Secretary

The foregoing statements have assumed that the executive in question has his own personal secretary. But for the junior executive who shares a secretary, two of the eight statements are particularly important: the whereabouts of the bosses, and the priority of the work. A secretary who must keep up with the work for a number of men has no time to telephone around the Laboratory or run up and down the hall to find a missing person. If a boss doesn't answer his buzzer and has left no forwarding address, he should be content with a message in his pigeonhole. Each man who shares the services of a secretary is prone to consider his work more important than that of the others and expects the secretary to agree with him; he is frequently annoyed when any of his work is delayed while another's is completed. If the secretary is not permitted to determine the order in which her tasks are to be completed, a logical solution to this problem would be for the men to agree among themselves on the priority of the work and to so inform the secretary — but few, if any, have ever done so. The result is that the secretary in such a position must have the tact of a diplomat, the endurance of a horse, the hide of an armadillo, the patience of Job, and a drawer full of tranquilizers.

Scientists talk about the optimum efficiency of a machine. The secretary is a fantastic office machine with one capability unmatched by the most advanced computer developed — the ability to think. A boss can contribute to the optimum efficiency or to the malfunction of the human secretarial machine.

What is your secretarial I. Q.?



BOOKS

By Alex Zucker

THE YOUTHFUL OPPOSITION

The Making of a Counter Culture, by Theodore Roszak. Anchor Books (1969). 303 pages, $1.95.

LONG BEFORE C. P. SNOW, Pascal saw the dichotomy of his civilization. He too found two guiding principles: *l'ésprit géométrique* — "that excels in all subjects that are capable of perfect analysis — that may be divided into their first elements" — and *l'ésprit de finesse* — to take into account "things which because of their subtlety and their infinite variety defy every attempt at logical analysis." Confrontations between these two points of view, in various guises, can be seen throughout history. To take two examples widely separated in time, recall the early Mediterranean competition of the gods: Astarte vs the Sun God;

and more recently the mind-wrenching revolution of the romantic era as it succeeded the rationalism of the 18th century. The conflict of cultures is not new, and should not surprise us. Nevertheless, our own travail is so puzzling and so violent that an analysis of our current cultural confrontation is highly desirable. It is with this in mind that I recommend Theodore Roszak's book "The Making of a Counter Culture."

Roszak is no friend to science. He holds little brief for the establishment. He is no longer the dispassionate chronicler, the historian he was trained to be. In this book he is committed to the counter culture, that unlikely mixture of the politicized new left, the hippie cult, the mysticism of the gurus, MacLuhan, Leary, Dylan, sexual freedom, pot, and peace. With fact and fancy, with subtlety and bluntness he attacks the bastions of technocracy to extirpate the *ésprit géométrique* that has, according to Roszak, dehumanized man, and threatens to destroy him in spirit certainly, but probably in body as well.

The book divides into three parts. In the first Roszak describes the villain and introduces the hero, in the second he describes the origins and character of the counter culture, and in the third part he returns to shred the technocrat again. I will describe them briefly.

The culture we live in is a technocracy. The more advanced the nation, the more pervasive its technocracy. It matters not what the form of government, nor is the underlying philosophy of any consequence. American, European, Asian, capitalist, communist, socialist; all nations, all establishments are technocratic. They are run consonant with the *ésprit géométrique*, by experts, by computers, by ever more powerful technological-scientific cliques. The establishment includes social as well as natural sciences, the communication media, the government — everything but a handful of rebels. The key word is "expert." Everything is run by experts, we turn to their authority for advice, for reassurance, for rules, and for amusement. An attempt is made to create a perfectly rational society, without problems, or if problems arise we study them, solve them, and return to the state of rational bliss. Roszak says that "the great secret of the technocracy lies, then, in its capacity to convince us of three interlocking premises. They are:

"1. That the vital needs of man are (contrary to everything the great souls of history have told us) purely technical in character. Meaning: the requirements of our humanity yield wholly to some manner of formal analysis which can be carried out by specialists possessing certain impenetrable skills and which can then be translated by them directly into a congeries of social and economic programs, personnel management procedures, merchandise, and mechanical gadgetry. If a problem does not have such a technical solution, it must not be a real problem. It is but an illusion . . . a figment born of some regressive cultural tendency.

"2. . . . Thus we need only sit down and reason together and all will be well.

"3. That the experts who have fathomed our heart's desires and who alone can continue providing for our needs, the experts who *really* know what they're talking about, all happen to be on the official payroll of the state and/or corporate structure. . . . "

Against this establishment Goliath, a new David has arisen. The young, and only the young are taking arms against a society gone insanely wrong. They are contending with a powerful establishment, not the least of whose weapons is, according to Marcuse, "its absorbent power," . . . its capacity to "provide satisfaction in a way which generates submission and weakens . . . protest." The principal sin of the establishment is that it has suppressed the kind of intellectual activity that commonly goes by the name of mysticism, mythology, etc.; a visionary world epitomized as the *ésprit de finesse.* Who are we to decide, questions Roszak, that certain kinds of experience are meaningless, particularly since the technocratic society has not only failed in its promise, but is dragging us ever deeper into its own quicksand.

There is a measure of truth in this analysis. We have lost something of our humanity as we reap the fruits of technocracy. But, I believe Roszak suffers, as so many others do, from a case of gilded hindsight and tunnel vision. Ask a mother of a child with a flaming throat what she thinks of a society that has invented antibiotics, or ask a farmer in Tennessee what he thinks of electrification. Candlelight remains romantic only so long as it is not a necessary source of light.

The second part of the book is the most interesting. Here Roszak traces the intellectual roots of the counter culture, from the work of Herbert Marcuse and Norman Brown. The intellectual source of the new synthesis is the marriage of two of the most unlikely partners: Marx and Freud. In common they both question the validity of the old concepts: one the exploitive nature of the social system, the other the supremacy of the conscious mind *vis à vis* the underlying subconscious material. The attempt at a synthesis is an interesting idea, but often murky with social criticism derived from psychological insights. Both Marcuse and Brown eschew Marx's pathological preoccupation with industrial statistics, both insist "that we have more to learn of man from the fabulous images of Narcissus, Orpheus, Dionysius, Apollo, than from the hard data of getting and spending . . . . Industrial statistics are the language of the present; myth is the language of the ages." It is true that both Freud and Marx are revolutionaries, that they both preach the overthrow of the old conditions of human servitude, in one case libidinal servitude that leads to alienation, in the other economic servitude that leads to exploitation. The wide-sounding conclusion is that the "revolution which will free us . . . must be primarily therapeutic . . . not merely institutional." Liberation is non-Marxian, in Marcuse it is the achievement of "libidinal rationality." From this it is but a short step to conclude that the poets rather than the sociologists have the truth — that "visions mean more than research."

I admit that one of the most attractive features of the counter culture is the fact that it is led by poets. Allan Ginsberg is the Homer of the counter culture. "Howl" is the founding document of the movement, and the considerable revival that poetry now enjoys in the United States is probably due in large measure to the fact that poets are once again speaking to the people instead of to each other. They once again carry the word that affects and influences; their voice is heard. No longer do poets revel in esoteric obscurantism. They now declaim their message to the youth, and a most receptive audience it is. Much of the poetry is sung, frequently by the poets themselves, and its influence is pervasive within the culture. Roszak, however, is annoyed that the acknowledged thinkers, like Marcuse and Brown, are not more influential; the posters and the records actually carry the message of the counter culture, and these are not as dear to a historian as books with references, footnotes, etc. The counter culture is unusual in another way, compared with historical precedents for confronting cultures. It does not have its roots solidly in the past, it does not require historical terms of reference; unlike many of its antecedents it does not march in new directions under the banner of "reviving the old virtues." For this reason it is less accessible to the older generation, and because it is so strange it suffers from the peril of being exploited as an "amusing side show of the swinging society."

Roszak is adamant in condemning violence and the use of drugs, as these are frequently attributed to the counter culture. He says there is no place in the movement either for the Black Panthers or for the Weathermen, and that violence is completely alien to its ethos. But he does concede that one of the weaknesses of the counter culture is its lack of rapport with the disadvantaged; the heart is in the right place, but the young are too concerned with themselves to be the focus of a reformist movement. Nor does he have any patience with the drug scene. He condemns it as soundly as the best Rotarian. Nevertheless, the fact is that drugs are an integral part of the lives of his constituents, and I doubt that exhortations will be more successful in this book than they had been elsewhere. It is hard to put a limit on permissiveness now that the old economic brakes are no longer operative. The moral precept, "everything is all right, so long as it does not hurt anyone," assigns a very secondary value to the qualifying clause, and hurting oneself is rarely taken as a serious interdiction. I prefer, "Thou shalt not kill."

Roszak puts forward a strong case: take away drugs and violence, and the counter culture is in many ways an attractive movement. It certainly reemphasizes our feelings and our visions, it enriches our lives by introducing Eastern ideas, it stands for a kind of joy and peace that was symbolized by the flower children. Who among us is so hardened that he cannot see the beauty of young people decorated with flowers? But where Roszak fails is in his assessment of science. That, in fact, constitutes the last and least successful part of the book. He describes the scientist as by nature "beset by timidity and fearfulness . . . by plain insensitivity and whose habitual mode of contact with the world is a cool curiosity untouched by love, tenderness, or passionate wonder." Well, once you describe a fellow this way, it follows that nothing good can ever come of him. Roszak simply builds his own straw scientist and then pummels him righteously for 50 pages. An exercise totally without value, and a regrettable anticlimax to what is basically an interesting book.

Stan Auerbach, director of the newly formed Division of Ecological Sciences at ORNL, enjoys international renown in the offices and honors he holds in his field. As a program director in charge of the Eastern Deciduous Biome for the International Biological Program, he is responsible for the ecosystems analysis of the entire eastern U.S. His activities include chairing the Committee on Radioecology of the Ecological Society of America and the Division of Ecology of the American Society of Zoologists; he has been an associate editor of *Ecology* and on the editorial board of *Radiation Botany*; currently he is Secretary of ESA. He delivered the invited paper from which this article was taken on August 14 before a meeting held during the International Atomic Energy Agency Symposium on the Environmental Aspects of Nuclear Power Stations at the United Nations. Coauthors of the work described here are ORNL ecologists D. J. Nelson, S. V. Kaye, D. E. Reichle, and C. C. Coutant.

What's going to happen to

The Ecology around a Reactor

BY S. I. AUERBACH

THE GROWING INTEREST in using nuclear energy as a power source has resulted in the focus of public attention on the benefits and risks associated with peaceful uses of the atom. Today's concern differs markedly from the last period of major public interest in atomic matters, which occurred during the period of weapon testing with its associated worldwide radioactive fallout. The current phase is more oriented toward environmental quality, being an outcome, very likely, of the impact of new technologies on the environment.

As a result of this, conservationists and other environmentally concerned individuals across the country are voicing their objections to proposed installation of nuclear power stations. These objections have consistent themes: impact of radioactivity on the environment, movement of radionuclides through food chains with possible hazard to humans, and effects of thermal effluents on the ecology of the region.

Low Level Releases

In the concern over nuclear power stations the question has been raised whether the doses that would result from release of radionuclides in accordance with current guidelines would cause

The top pictures show two stages of the life cycle of Chironomus riparius, *commonly called the midge. The adult male, about 1/4 in. long, being nonfeeding, only lives a few days. The species is a good indicator species for stream pollution and is often found in abundance below the outfall from sewage plants. In the middle is a fourth-instar larva emerging from a tubule it has constructed from sand and bottom debris. The larval stage, commonly known as bloodworms, lasts for several weeks. In the bottom picture is one of the polytene chromosomes found in the salivary glands of the larvae. They are unusually large, offering excellent material for cytogenetic studies. This one shows a type of chromosome rearrangement known as an inversion.*

ecological problems. Would they, in short, result in demonstrable effects that might bear on the location of particular reactor sites?

These guidelines, expressed in MPC's (maximum permissible concentrations), are derived for internal exposure to man. This, then, gives rise to the obvious question: what is the dose to organisms of natural populations that are submerged in water that is maintained at or below prescribed MPC? Would the dose rate acceptable to man result in detectable biological effects on aquatic organisms over a period of time?

Because in actual practice the limit currently set for effluents from nuclear power reactor stations is so low (one picocurie, or a millionth of a microcurie, per cubic centimeter), extremely sophisticated means of detection is needed and sensitive biological endpoints must be used as criteria for ascertaining radiation damage. In experimental practice when dose rates are lowered to one rad per day or less, the number of factors otherwise affecting the organism are enough to mask any effects that might be present. Such commonly used end points as survivorship, fecundity, growth, development, and susceptibility to infection have not as yet been shown to be unequivocally affected by such low dose rates. Evaluating the impact of doses of less than one rad per day on organisms and populations under field conditions, therefore, is a challenge of considerable magnitude.

Very few studies have been made on natural populations exposed to chronic radiation higher than background. The salivary chromosomes of midge larvae inhabiting the radioactively contaminated bottom sediments of the White Oak Creek and White Oak Lake at ORNL were analyzed for five years for chromosomal aberrations. Calculations and measurements of the dose they thus absorbed revealed values of around 240 rads/year, about 1000 times background for the organisms dwelling in the bottom sediments of non-contaminated lakes. Over the previous 22 years some 130 generations had been exposed to this dose or greater. In the irradiated population 17 different aberrations were observed, whereas only six different aberrations were observed in the nonirradiated population. All six of the latter inversions were found in each population more than once and three occurred at relatively high frequency.

If all new mutations and chromosomal aberrations are considered to be deleterious, these findings could be construed as harmful; on the other hand, the populations in this irradiated area show no sign of detrimental effects, using population numbers and reproductive capability as criteria, under dose rates much higher than those that would be obtained under present guidelines of release.

Another series of investigations was launched in this radioactive habitat. In this case the natural population studied was the hardy, highly adaptable mosquito fish, *Gambusia affinis affinis*. Approximately 100 generations of this fish have lived in this area since the first release of radioactive waste effluents. In this investigation another parameter of population fitness, fecundity, or the number of offspring per female, was measured, since laboratory studies have shown that it can be influenced by ionizing radiation. These fish lived in a shallow part of the lake where the sediment contained appreciable quantities of the radioisotopes cesium-137, ruthenium-106, cobalt-60, strontium-90, and zinc-65. Exposures were calculated to approximate 11 rads/day external gamma radiation and 1.75 rads/year internal beta radiation.

The most striking finding of this study was the fact that the irradiated populations had a highly significant greater fecundity than the control population. In the description of the study, evidence was marshaled that supports the idea that irradiation can possibly increase the fitness of organisms. The data support the hypothesis that radiation-induced mutations, most of which would be deleterious in the homozygous condition, produce enough cumulative effects in the heterozygous condition to more than counterbalance induced dominant deleterious mutations. Apparently, under certain conditions, genetic variability resulting from radiation-induced mutations can improve the fitness of organisms. Natural selection operating on a population with increased genetic variability results in an increased rate of evolution of the population and in its adaptation to environmental factors.

An increased mortality of embryos that could be attributed to ionizing radiation was also found in this population, leading to the speculation that the increased fecundity of the female may be an adjustment to what is essentially a changed environmental factor. Another effect of radiation would be the increased genetic variability resulting from radiation-induced mutations. This would increase the rate of evolution and speed up the adjustment of the population to the increased mortality. However, this would not occur without some expense to the population. Many genetic combinations would be selected against and the individuals eliminated. In populations with a relatively short life cycle, such as fish and insects, where overproduction of young is the rule and selection is severe, the population level could be maintained in spite of the elimination of many individuals.

Similar findings were recently reported in a study of the snail populations that inhabit radioactive waste seeps in the disposal area of ORNL. These populations are exposed to a calculated dose rate of 0.65 rad/day. They had not developed resistance to ionizing radiation, according to laboratory experiments using acute gamma radiation. A comparison of reproduction of snails from the irradiated populations and snails from a control population showed that the irradiated snails had a significantly decreased production of egg capsules and a significantly increased number of eggs per capsule. The inference is that the latter change was in compensation for the former, thus maintaining the level of fecundity. Selection pressure in these circumstances would be for those individuals that would contribute the most to the overall fitness of the populations. Under these conditions the compensations of increased eggs per capsule would be advantageous to the entire population.

At the University of Washington, Prof. Loren Donaldson has had under way a long-term study of the effect of chronic, low-level gamma radiation on the Chinook salmon. In his experiments, eggs and newly hatched fish were exposed to rates of 0.5, 1.0, 2.5, or 5.0 rads/day beginning immediately after fertilization and extending daily until the yolk is absorbed and the young fish are completely formed, a period of about 100 days. After another period of 90 days in which the fish were fed, along with an equal number of a control group, both groups were released to migrate to the sea. In the ocean the young fish must compete in a natural

B. G. Blaylock and Neil Griffith seining for Gambusia *in White Oak Lake. On the right, some of their harvest.*

environment that presents many hazards. Upon their return from the sea, the fish were subjected to detailed study for all possible effects.

The results of this series of long-term experiments, with numbers of fish ranging from 96,000 to 256,000 per experiment, have given no indication that these high exposure rates are injurious to the fish. Irradiations at the early life stages have not caused significant mortality or retardation of growth in either smolts or returning spawners, or in fecundity. Donaldson and his colleagues report that at the lowest exposure rate of 0.5 rad/day — a rate about 1800 times that of background — the irradiated stock returned in greater numbers and produced a greater total of viable eggs than the controls.

Another Pacific Coast researcher examined the effects of zinc-65, chromium-51, and strontium/yttrium-90 on oyster larvae, setting the biological end point as abnormal development of shells 48 hours after fertilization. On the basis of these experiments, the conclusion was that the concentration of strontium/yttrium-90 necessary to produce abnormal oyster larvae is 10^7 times as much as the maximum concentration of strontium-90 in natural marine environments. The concentration of carrier-free zinc-65 necessary to affect oyster larvae is 10^7 times as much as the concentration found in Willapa Bay. Concentrations of chromium-51 causing demonstrable effects were found to be 800,000 times as much as those reported in water collected between the mouth of the Columbia River and Wallapa Bay in 1961, when all eight Hanford production reactors were still in operation. Since then six have been shut down.

Battelle technicians prepare Columbia River salmon for studies of effects of low-level radiation exposures. (Photo courtesy of Battelle-Northwest)

No review of this nature can omit mention of Russian work in this field, especially since Russians report effects at much lower concentrations of radionuclides than other workers. Russian emphasis has been placed on fish eggs. They have reported on extensive studies with eggs of a large number of marine and freshwater species over the concentration range of 10^{-2} picocuries/liter to 10^{8} pCi/liter (maximum concentration of strontium-90 in natural marine environments in Washington State yields 10 pCi/liter). The Russians reported reduced hatching of the larvae and early mortality at concentrations of 10^{5} pCi/liter and above, and the number of abnormalities increased significantly at concentrations of 10^{2} pCi/liter and above with remarkable consistency.

British scientists performed similar experiments with eggs of two fish species maintained, from right after fertilization to hatching, in water contaminated with strontium/yttrium-90 over a concentration range of 10^{2} to 10^{8} pCi/liter. They did not observe any significant increase in mortality or in the production of abnormal larvae.

In addition to the above, preliminary experiments have been performed both at ORNL and at the University of Washington to determine the effect of tritium on fish eggs. Concentrations up to eight orders of magnitude greater than the maximum concentrations permitted showed no significant effects on the hatchability of the eggs.

Much more data of this kind could be cited. All would tend, with the possible exception of the Russian work, to show that the dose necessary to evoke an unequivocally detectable biological response is considerably greater than the dose present in currently permissible concentrations in the environment. There is no doubt that the picture is clouded by the fact that other factors are changing in the environment, other substances being added that are certain to have an effect on the resident organisms. These substances (chemicals, nutrients, etc.) may modify the habitat and affect the constituent organisms present to the extent that results of low-level radioactivity become increasingly difficult to isolate.

One could invoke special effects, or select organisms with undefined or special roles in the ecosystem that make them (and consequently the ecosystem as well) uniquely sensitive to the low dose rates that might occur in the vicinity of nuclear power stations. It is possible that organisms' radiosensitivity may be increased significantly as a result of environmental interactions. Ecologists are always seeking some unusual effect, or a species with high sensitivity to ionizing radiation. So far they have not found any that have a radiosensitivity at the levels of currently permitted concentrations. They continue to try, however, including as many different kinds of organisms as possible from a variety of habitats, in order to differentiate the effects of radiation within an environmental context.

Tracing the Radionuclides

Predicting the hazard to humans in a nuclear-powered economy is going to require a coherent theory, leading to a mathematical model, of radionuclide cycling through the environment. Limited data are available for many aspects of the biological uptake and movement of radioactive isotopes in certain segments of environmental cycles, especially in the food chains that lead to man. It is one matter to know that food chains are important, and quite a different matter to quantify these complex chains for natural and agricultural ecosystems. Although the mathematical techniques are available, in the form, for instance, of compartment models of systems analysis, the lack lies in sufficient radioecological data with which to work either in acute releases or chronic releases of radionuclides into the environment.

There is at present no overall predictive methodology to ascertain expected total doses to populations from a release of radionuclides that subsequently move in a variety of exposure pathways. Such a methodology, to be useful, would make possible the comparison of actual doses to

"Cold-branding" juvenile rainbow trout to distinguish heat-shocked and not-heat-shocked test fish. The marking technique, which does not injure the fish, makes use of a liquid-nitrogen-chilled brand. (Photo courtesy of Battelle-Northwest)

human populations with radiation standards and guidelines. In future nuclear power economies it may be advisable to know in detail the expected dose commitments to segments of the human population.

One approach that offers considerable promise as a methodology for predicting doses from multiple sources like power reactors, routine or accidental releases, or other sources of radionuclides, which might be moved through a variety of environmental pathways, is called "environmental systems analysis." Systems ecologists usually begin by formulating an *a priori* coupled-compartment flow diagram based on whatever information is available. This is the first of several steps in the hierarchy of modeling techniques that might be employed. As the body of data on each subsystem develops, the initially simple models are updated and modifications are incorporated until predictions are checked to be within the desired accuracy. Eventually, sufficient information may become available to use nonlinear functions and probability distributions. A unique feature of systems modeling is that each step can have a feedback loop, which helps to improve the accuracy of the model, so that as modeling continues, the accuracy of prediction may be expected to improve. Indeed, environmental systems analysis can be thought of as an outgrowth or a logical extension of the long and widely accepted use of systems analysis to study nuclear reactor dynamics.

Although environmental systems analysis is becoming increasingly recognized as a tool of considerable potential for predicting the movement of substances and energy in natural systems, there have been few demonstrations of its practical value for predicting the intake of radionuclides by man. Closest to it was in a feasibility study performed on the proposed construction of a sea-level canal with nuclear explosives, when environmental systems modeling was used in an attempt to predict concentrations of radioactivity in foods and beverages that might be consumed by man after reentry to a contaminated exclusion zone. Doses were estimated as a function of age and population group and compared to radiation standards of recognized authorities.

Thermal Effects

Temperature is one of the most important physical factors affecting ecological processes. Its change by thermal generating stations should therefore be considered seriously. In an established ecosystem, a rise in temperature generally results in increased rates of operating for each process until an upper limit is reached in each case. Thereafter, continued temperature rise invokes precipitous decline. An aquatic ecosystem has a multitude of individual processes operating simultaneously at several levels of organization: molecular, cellular, organism, population, and community. The summation of the individual processes yields specific, and often seasonably variable, upper and lower temperature requirements that must not be exceeded if the ecosystem is to remain biologically productive. In order to design and locate thermal power plants that utilize natural water for cooling without disrupting ecological systems we must know these requirements. Lacking such knowledge, regulatory agencies can operate on assumptions that may restrict optimal use of aquatic environments in some cases, or fail to protect the important species in others.

A thorough understanding of the new processes and the effects on existing processes introduced into aquatic ecosystems by thermal power plants is necessary. We must learn the relationships between these new processes and the diverse ecological communities that reside in potential cooling water supplies. With appropriate plant siting and design, the operation of some of these necessary processes like thermal shock can be engineered to affect few organisms or non-vital portions of the ecosystem; or the intensity of the process can be designed to be below detrimental levels for organisms. Proper selection of alternative plant designs can reduce significantly the operation of other introduced processes, like organic enrichment, once quantitative biological data are available.

B. G. Blaylock gathers Chironomus *with a Needham scraper.*

OAK RIDGE NATIONAL LABORATORY *REVIEW*
P. O. BOX X: OAK RIDGE, TENNESSEE 37830

U.S. Postage
PAID
BULK RATE
Oak Ridge, Tenn.
Permit No. 3

Bird's-eye view of the hybrid computer in I&C. Left to right, facing front more or less, are Ball, Booth, Burke, and Clapp. Stone reads the printout in the background. (See article beginning on page 7)