Review

SUMMER 1972

OAK RIDGE NATIONAL LABORATORY

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VOLUME 5, NUMBER 4 **SUMMER 1972**

THE COVER: Some of the descendents of the original colony of 17,000 germfree mice on which low-level radiation studies were begun in 1967. Not all the data are in, but what has been learned has included some surprises. Read John Storer's account, opposite page, of the Low-Level Experiment.

FEATURES

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Assistance is provided by Graphic Arts, Photography, and Technical Publications Departments of the ORNL Information Division.

The *Review* is published quarterly and distributed to employees and others associated with the Oak Ridge National Laboratory. The editorial office is in Room 147, 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).

OAK RIDGE NATIONAL LABORATORY
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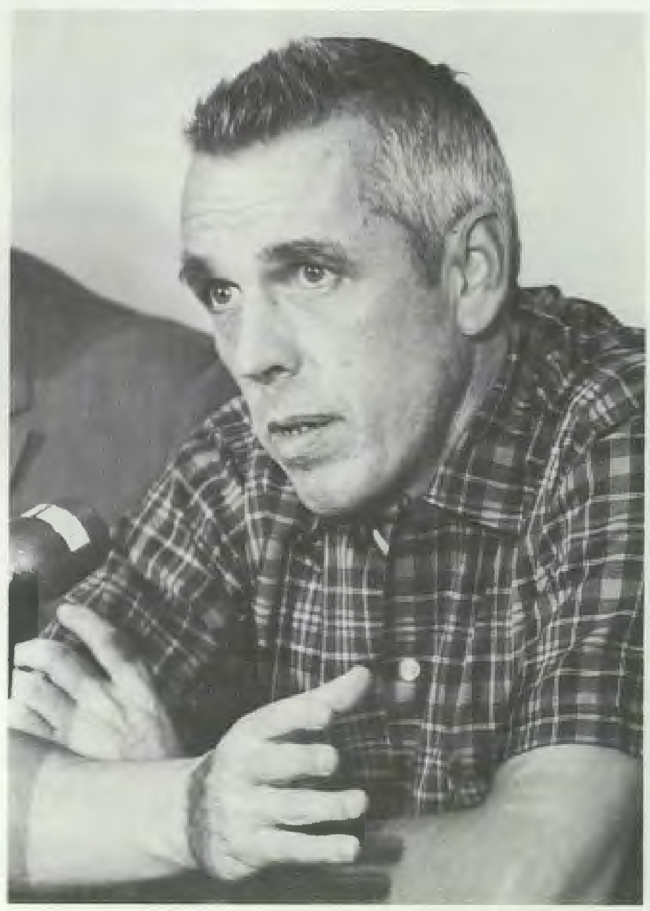
Pathologist John B. Storer received his formal education, from undergraduate through residency, at the University of Chicago, where, when he left in 1950, he held the position of Pathologist to the University's Toxicity Laboratory. From there he joined the Biomedical Research Group at Los Alamos, where he remained, except for a two-year military stint, until 1958, at which time he moved to The Jackson Laboratory at Bar Harbor, in his native state of Maine. In 1967 he was appointed Deputy Director of the AEC's Division of Biology and Medicine, from which office he came to Oak Ridge in 1969 to join the Biology Division as Scientific Director for Pathology and Immunology. As he recounts here, he took up an experiment that had been started several years before his arrival, the significance of which was to change over the years with changes in historical events and political climate. Although the experiment has suffered some curtailment from its original scope, this account makes clear the implications for full-scale inquiry along these lines into the long-term effects of very low levels of radiation exposure.

The Low Level Experiment

By JOHN B. STORER



THEORIES, BANDWAGONS, AND FADS in science come and go, but unsolved problems have a disconcerting habit of hanging around, and the pressures for their solutions are periodically intensified. An example of such a problem is the question of whether small doses of ionizing radiation produce deleterious effects such as an increased likelihood of cancer or leukemia. Interest in this question was intense in the late 1950s because of exposures to radioactive fallout from nuclear weapons testing. At that time the Atomic Energy Commission's Division of Biology and Medicine put increased emphasis on experimental studies to obtain answers to the question. Public interest waned through the early and middle 1960s, only to revive with perhaps greater intensity in the late '60s and early '70s because of the controversies about the siting of nuclear power stations.

Throughout this period, when research budgets were becoming increasingly restrictive, scientists who had undertaken experiments to provide insights into the problem continued their work, and these studies are as timely today as when they were initiated. The Biology Division of ORNL has been deeply involved in this type of research for many years. The unparalleled and classic genetic studies of the Russells are well known. Less well known are the extensive studies on somatic effects (life shortening, and the induction of cancer or leukemia) initiated by Arthur Upton and his colleagues in the early 1960s. This article reviews briefly the history and scope of this work and describes its present status.

The uncertainties about effects of low radiation doses were documented in three volumes of proceedings of the hearing on Fallout from Nuclear Weapons Tests, held in 1959 before the Joint Congressional Committee on Atomic Energy. At about this time Alex Hollaender, then director of the Biology Division, held extensive discussions with DBM Director Charles Dunham and J. L. Liverman, at that time chief of DBM's Biology Branch, on the advisability of undertaking large-scale experiments on somatic effects of radiation. There were three compelling arguments in favor of locating the research in the Biology Division: Drs. Jacob Furth and Upton and their colleagues had previously studied in meticulous detail the incidence of late-occurring disease in mice exposed to nuclear radiation at Operation Greenhouse, a weapons test in the Pacific; the Biology Division was experienced in some of the logistics of large-scale mouse experiments from the Russells' studies; and, thirdly, a solid nucleus of senior scientists besides Upton — Gerald Cosgrove, Bill Gude, Ted Odell, and Ed Darden — were already at work on related problems. After insisting on and receiving assurances of a long-term commitment of interest and support, Hollaender returned to Oak Ridge and turned over the planning of the research to Upton and his colleagues.

There were two obvious major difficulties. Facilities for housing the required large number of mice did not exist, and the staff was too small to accomplish the proposed work. Odell and Upton (later joined by Ed Les from the Jackson Laboratory) undertook the extensive planning of physical facilities, but recruiting of staff had to wait until the experiment was fully defined.

How big is a "large-scale" experiment, and what is a "low" radiation dose? Upton's early notes show that he estimated needing 184,000 male and female mice from four inbred strains. The mice were to be exposed to single high-rate doses, fractionated low-rate doses, or continuous protracted doses in a dose range of 10 to 400 rads (10 rads = "low dose"). The mice would be observed over their entire life-span, with a detailed autopsy at death.

Fortunately there are precise statistical techniques available for estimating the number of mice needed to detect a small effect for any specified level of probability of not reaching an erroneous conclusion because of sampling variability. Such calculations were made, principally by Allyn W. Kimball and Marvin A. Kastenbaum of the Math Panel. Because such calculations determined the final experimental design and because they are important in planning experiments generally, a few words about this approach might be useful.

An experiment was being proposed to try to arrive at the biological truth of whether a small dose of radiation, say 5 rads, does or does not increase the incidence of leukemia in mice. The experiment had three possible outcomes: (1) an increase in leukemia would be observed, (2) a decrease would be observed, or (3) there would be no change in incidence. If either of the last two outcomes was seen, then the conclusion would be reached that 5 rads does not increase the incidence of leukemia. But this conclusion might be wrong because of sampling variability in batches of mice. This type of error, which could have serious consequences, is called a Type II error by the statisticians. Another false conclusion would be reached if the incidence was seen to be increased but the true case is that there is no effect. This is a Type I error, not so serious for obvious reasons. In advance of the experiment, the investigator must decide the chance he is willing to take of making either of these types of error, whether one chance in 10, one in 20, one in 100, and so on. It follows, of course, that as the chances of making an error are decreased, the number of mice required is greatly increased. In addition to the specification of acceptable probability levels, the biometrician also needs to know the magnitude of the effect that may reasonably be expected. In other words, it would be nice to know the results of the experiment in order to plan it. Fortunately, data were available from the previously mentioned experiment from Operation Greenhouse and from some smaller experiments previously conducted in the Biology Division. The radiation doses em-

The mouse workers operate in two shifts. Shown above, listening to Animal Lab Director Louis Serrano, are, left to right, David Rose, Don Bennett, Don Stooksbury, Betty Ellis, Phyllis Rouse, Shelby Teasley, Emily Gains, Bernie Liford, and Supervisor Bill Anthony. The other shift, below, consists of Charles Eubanks, Scotty Joseph, Allen Smith, Mary Jones, Claude Gettner, Louise Singleton, Murrell Dunn, and Supervisor N. L. Ensor. Not present are Jim Cox, Melvin Smith, Charlestine Thrift, and Carl Porter.

ployed were much above 5 and 10 rads, but, by making some assumptions about the likely shape of the dose-response curve, it was possible for Kimball and Kastenbaum to calculate required sample sizes. From their calculations it appeared that a dose as low as 5 rads could be used without making the experiment reach unreasonable population requirements.

As planning for the facilities proceeded, other decisions about the experiment had to be made. Mouse viruses, some of which were implicated in cancer induction, were known to be endemic in many mouse colonies. Could we eliminate them from our mice? A dense population of mice would be susceptible to the rapid spread of disease. Could we protect them, and the experiment, from disease-producing microbes? Unusual fluctuations in the number of nonpathogenic bacteria contacting the mice might also affect the reliability of the experimental data. Could this be controlled? These considerations led to the concept of deriving the breeding stocks in the germfree (and perhaps virus-free) state and conducting the experiment in a rigidly controlled animal facility that would minimize the likelihood of the animals becoming reinfected. This decision led to some serious technological problems that we had to solve but which I won't go into here.

Because of the massive amount of record keeping that would be required, it was apparent that computers would have to be used extensively. Computer application to much of the data, such as breeding records, radiation doses, birth and death dates, was straightforward, but the system had to be programmed. The problem of pathology records was considerably more complex. There have long been numerical coding systems for various diseases, and although these systems are satisfactory, they require coding computer input and decoding output, both of which operations provide a chance for human error. A system of computer feeding and retrieval of diagnosis in English would be preferable. Cosgrove, working in consultation with Chandler Smith at Western Reserve University, wrote a modified dictionary of pathology terminology patterned after the one developed for hospital use by Dr. Smith. The computer group at K-25 translated this into suitable programming instructions to the computer and so solved the problem of keeping pathology records in English.

By 1962, progress on construction made it feasible to begin recruiting staff. At about this time, Ray Popp, Pete Walburg, Dick Tyndall, Gus Cudkowicz, Bob Allen, and Ed Les joined the staff. The first three are still in the Division. Popp's responsibility was principally to ensure genetic uniformity of the experimental animals. Walburg, a D.V.M., was to set up the initial germfree colony and provide breeding stock to the main experiment. Cudkowicz, Upton, and Cosgrove were project pathologists. Allen was responsible for developing bacteriological testing procedures to monitor for possible contamination of the colony. Tyndall, trained in virology, was to determine whether mouse viruses could be eliminated by using germfree mice. As mentioned earlier, Ed Les was to help with planning of the facility and setting up procedures for maintaining the mouse stocks. Lou Satterfield joined the group to work on some other research problems, but she later directed her efforts full time to the main experiment. Carlene Amsbury and Homer Swann, both old hands in the Division, were already maintaining mouse breeding colonies elsewhere in the building in anticipation of the start of operations in the new quarters.

In March 1963 the first RFM-strain mice were introduced into a germfree isolator. Germfree female mice of the ICR strain had previously been obtained from the University of Notre Dame to serve as foster mothers. With the successful expansion of the RFM strain in the isolators, it became possible to test whether the known mouse viruses had been eliminated by the procedure. At that time there were serological tests for eight murine viruses. The stocks remain free of these also. However, so-called "C-type virus," which is implicated in the development of mouse leukemias, was seen in electron micrographs of tissues from these mice.

Louis Serrano, D.V.M., joined the staff in 1963, in time to put the finishing touches on the design of the barrier (or isolation) facility, which could house more than 60,000 mice. Though purposely contaminated with harmless bacteria, these mice would be maintained free of all known disease-producing microbes. Howard Hicks was then the liaison engineer between Biology and Y-12 Engineering and worked closely with Serrano on design problems.

By February 1964, construction was complete, radiation sources had been installed in a special exposure room, and the operation was ready to begin. The only problem was that germfree mice were to be introduced into an area known to be heavily contaminated with an enormous variety of bacteria. To solve this, experts on bacteriological decontamination from Fort Detrick were called in. Bacteriological sampling was done before and after decontamination, and results were very encouraging, indicating that sterilization of the facility was nearly complete. Germfree mice were placed in the facility to see what bacteria they would pick up. Transiently, the mice showed positive cultures for only four harmless types of bacteria. Two of these later disappeared, and the animals stabilized with only a harmless staphylococcus and streptococcus. They were then deliberately contaminated with three additional types of bacteria to maintain the necessary intestinal flora. In May 1964, breeding stock of the RFM strain was introduced into the barrier facility. Bill Anthony, now one of the supervisors for the facility, was the first animal attendant employed to care for these very precious mice.

By now the experimental design had been fixed. RFM-strain mice of both sexes would be exposed to radiation at three different dose rates. At the highest dose rate the lowest total dose would be 5 rads. Other doses were: zero (controls), 25, 50, 100, 150, and 300 rads. While the breeder colony was expanding in the barrier facility, a small pilot study was initiated. Its purpose was to see if these microbially very clean mice responded to radiation in the same way as more conventional mice had responded in earlier experiments. Importantly also, it would provide realistic conditions for training personnel and developing techniques. The doses administered in the pilot study ranged from 50 to 300 rads. It was found that myelogenous leukemia was very much reduced in the clean animals but there was a compensating increase in the incidence of thymic lymphomas. Other cancers were induced to about the same extent as seen earlier.

Just when everything was ready to proceed at full speed, it became painfully apparent that costs were rising faster than budgets and the scope of the experiment would have to be curtailed. The decision was made to use a low dose of 10 rather than 5 rads. This reduced the required sample size from 80,000 mice to about 30,000 mice. In May 1966, mice began to be entered into the main experiment. By spring of 1967, about 2000 males and 2000 females had been irradiated when the budgetary ax fell again. The sample size was accordingly reduced to about 17,000 mice, and the use of male mice, except those already irradiated, was discontinued.

In 1969, I replaced Upton as chief of the Pathology Unit, and John Yuhas replaced pathologist Bob Brown, who had joined the group in 1964.

The last mouse entered the experiment in May of 1970. In the meantime the program had been considerably restructured and streamlined. Consultation with DBM led to revival of some of the earlier plans. The low-dose-rate portion of the experiment using both RFM and BALB/c mice was reinstituted under Serrano. A new gamma irradiation facility, which could provide dose rates ranging from 1 rad/day to 1 rad/sec, was set up. Yuhas, with the help of Mildred Hayes, Anita Walker, and Judith Proctor, began a systematic study of the effects of a wide range of doses and dose rates. A facility was established for exposing mice continuously to neutrons from californium-252 at 1 rad/day. Mice are also being exposed to high dose rates from the Health Physics Research Reactor at DOSAR. These neutron studies are being conducted by Darden and Mark Jernigan.

Because of the difficulty of recruiting pathologists, three pathology technicians are being trained by Cosgrove to perform autopsies and read slides. Progress in diagnostic acumen of the three "parapathologists" has been outstanding. I share, with Yuhas, the principal responsibility for analyzing the data generated by these many large experiments.

What is the current status, and what has been learned from the 17,000-mouse experiment? As of June 1972, only 20 mice remain alive. The backlog of pathology amounts to about 100 cases. It is premature and inefficient to attempt any analysis until all the data are in. However, the data for the 2000 males have been analyzed, and some surprises have turned up among the following tentative conclusions: Briefly, there was no loss of longevity at doses below 50 rads, nor was there an increased incidence of leukemia. Solid tumors such as Harderian gland carcinomas, sarcomas, etc., were increased only at doses in excess of 100 rads. The entire life-shortening effect at 50, 100, and 150 rads was accounted for by the increased incidence of thymic lymphoma and myelogenous leukemia, indicating a lack of nonspecific life shortening or premature aging. Since this sample size was not large, firm conclusions will have to await analysis of the data from the 15,000 females, at the most a year away.

AMW COMMENTS

ON FIXES, TECHNOLOGICAL AND SOCIAL

One of the most attractive aspects of ORNL is the diversity of opinion that prevails here. This makes it hard, even for the Director, to get away with very much. This was brought home to me recently when I was preparing a review of a book on energy written by two environmental activists.

The quarrel between the energy technologists and the environmental activists is a real one. After all, as The Environmental Handbook *says, "All power pollutes." There is no way to repeal the second law of thermodynamics.*

The general tone of the book was rather anti nuclear energy. In my first draft I therefore came out slugging: How dare the environmental activists fault us energy promoters! Wasn't abundant energy a blessing which, though tainted by deleterious environmental side effects, was really not tainted very much? Anyone who was against more energy was a dunce or worse, was socially irresponsible — at least that's what my first draft said.

Fortunately I tried this draft out on some of our NSF environmental people, and as a result I was forced to think through my position more carefully. What came out, I believe, is more sensible and goes like this.

Energy technologists and environmental activists alike concede that energy pollutes; moreover, in the very long run, limits must be placed on the use of energy. In the short run, three rather distinct strategies are available for reducing the environmental impact of energy. The first is to clean up the production of energy with better technology: coal gasification, radiochemical plants with practically zero effluent, underground transmission of electricity, and so on. The second strategy is to use energy more efficiently — by building houses with better insulation or improving the efficiency of air conditioners. The third strategy is to force, or to encourage, people to use less energy — either by regulation or by fiscal policy, or by making licensing of power plants so difficult that energy is simply unavailable.

Technologists and environmental activists differ as to which of these strategies they like, which they dislike. The technologist finds strategies 1 and 2, which are in effect technological fixes, highly acceptable; he tends to be suspicious of strategy 3, which is rather more of a social fix than a technological fix. To the environmental activist, at least judging from the actions of the more extreme of his fellows, the priorities seem to be reversed: the social fix — use less energy — seems to him more appealing than the technological fix — use energy more efficiently and cleanly.

The arguments raised against technological solutions to social problems amount to the assertion that technological fixes carry with them unforeseen and unpredictable side effects. For example, nuclear energy, which ten years ago seemed to the environmental activist to be a great advance over fossil-fueled energy, turns out because of the long half-lives of some of the radioactive wastes to require social commitments of unprecedented longevity that would be difficult to guarantee. In view of such shortcomings of technological fixes, what does social science tell us about the technological approach to social problems?

The social effectiveness of six specific technological fixes was studied recently by Professor Amitai Etzioni and Mr. Richard Remp of the Center for Policy Research. In a paper "Technological 'Shortcuts' to Social Change" (Science **175**, pp. 31–38, January 7, 1972), the authors examined these technological fixes: methadone for heroin addiction; Antabuse for alcohol addiction; the intrauterine device; instructional television; the breath analyzer for reducing traffic fatalities; and gun control laws (internal disarmament) as a means of reducing violent crime. (Such laws are really a cross between a technological and a social fix: they are technological in that they attack crime by removing the implements of crime; they are social in that they remove the weapons by law rather than by, say, reengineering guns so that they can be fired only on some central command.) Etzioni and Remp's main finding was: "To the degree that the data permit us to conclude, each of the six technologies 'works,' in that it allows the handling of a significant part of the social problem faced at a considerable reduction in cost and in pains of adjustment. These conclusions are tentative, since the technologies are still experimental and limitations are inherent in evaluation research." These rather favorable conclusions were the more surprising to me since the authors are sociologists.

Why do technologists look upon social fixes with suspicion? It is really for much the same reason that environmental activists tend to be suspicious of technological fixes. For just as technological fixes have undesirable and unpredictable social side effects that often defy prior assessment, so social fixes also have side effects that are difficult to assess.

Consider the strategy of resolving the energy-environment impasse by regulating the use of energy — i.e., by placing a ceiling on the availability of energy. The obvious social side effect of such action would be economic. Is it possible to predict what the effect on the economy would be of a no-growth energy policy, or a reduction in the rate of expansion of energy? Would such a policy lead to economic distress with its consequences in human suffering?

As far as I know, we do not really know what a lid on energy growth would do to the economy. Obviously it is a matter that deserves very serious study, and perhaps it can be taken up by our own environmental project. It is the belief or, more accurately, the hunch of the technologists that a no-growth energy policy would, in the short run, have serious social consequences that accounts for the technologists' suspicion of this particular social fix.

Evidently neither the purely technological nor the purely social approach is the whole answer. It is good to know that at ORNL we have people who represent both points of view. A melding of the two viewpoints will be needed for a resolution of the energy-environment impasse.

Alvin M. Weinberg

The Energy Dilemma

Remarks at a meeting of The Conference Board, an association of New York business men, in April 1972.

By JAMES R. SCHLESINGER, CHAIRMAN, AEC

I AM DELIGHTED TO BE HERE with you today, as you deliberate on the broad issues of energy and public policy — and I very much appreciate the invitation by the Conference Board to join with you in these deliberations. I believe I would normally be expected to offer some inspirational remarks on "You and the Atom" or the prospective glories of nuclear power. I trust that you will bear with me, however, if I spread my net far more broadly — and touch on the underlying issues of public policy and on the ability of our society to deal coherently with these issues in light of present discontents.

Later, I shall make a few remarks about nuclear power, but it must be remembered that nuclear generating facilities provide only one of several alternative instrumentalities for the production of electric power and that electric production inti-

"This is such an intelligent statement I would suggest we run it in the ORNL Review. *I realize this is unprecedented, but I do think this speech deserves very wide circulation." – memo to editors from Alvin M. Weinberg.*

mately and subtly intersects with the broader issue of energy usage. Moreover, energy not only represents increasingly our basic economic resource; energy usage represents a principal issue with respect to the protection or degradation of the environment. Finally, because of this dualism, our society has shown increasing signs of ambivalence — some might say schizophrenia — regarding energy usage. As a consequence, society has encountered difficulties in developing the shared values and the discipline to provide coherent policies on this subject. For this reason I should like to approach this subject indirectly by addressing some of the difficulties of the society in achieving orderly and intelligible discussion of these fundamental problems.

The American public has the privilege of determining goals and of selecting a mix of measures to achieve those goals. It can proscribe or constrain various means — if it appreciates that there must be a high measure of consistency between means and ends. In the energy area, a variety of proposals have recently been elaborated: among them — no strip mining, a moratorium on nuclear plants, limit offshore drilling, no port facilities for imported LNG, no Alaska pipeline. The rationale for each one is perhaps understandable. The total set would be, to say the least, difficult to achieve. Obviously this is the case, if one presupposes a continued flow of energy to supply industry and commerce, to say nothing of the array of domestic services that delight the American consumer. It becomes even more visionary, if one adds such objectives as limited dependence on foreign sources of energy supply, limited utilization of foreign exchange within the balance of payments constraint, and low-cost energy.

The point is simple: the public has a right to choose, but one may hope that choice would be explicit — after weighing the full consequences of particular decisions. Piecemeal policies inevitably result in the inadvertent shortchanging of higher policy objectives. Haphazard choice, based on immediate emotion, is potentially crippling; it is tolerable only if not carried too far.

While these points should be obvious, I mention them only because they do not seem to be obvious in today's climate. Much public discussion seems to reflect the premise that benefits are available without costs or risks. In energy matters, there seems to be an assumption that the interdiction of various energy sources can be abstracted from the continued flow of power to homes and to industry. These are false premises. Unlike manna from the heavens, public benefits do not descend on us adventitously or miraculously. There has to be better understanding of process — of the relationship between cause and effect. The clear implication is that the utilization of energy must be attacked in its entirety and in light of the true alternatives, not in terms of particular elements or sources.

I dwell on these matters, not because they require particular insight, but because they are true. I fear that much of our present difficulty reflects the failure to appreciate these home truths. There is question today whether our society possesses the internal discipline consciously and calmly to choose a coherent set of policies. A society like our own can function effectively over the long run only if there are shared values — and "consensus" today is a much derided term. There is a widespread and exaggerated skepticism, even hostility, directed toward those in authority, both public and private. There seems to be no dearth of volunteers who wish to "send them a message." Unless we are able to restore a degree of civility, forebearance, and responsibility in our public

". . .the utilization of energy must be attacked in its entirety and in the light of the true alternatives not in terms of particular elements or sources."

discourses and a search for common values, there will be either a breakdown in the implementation of policy or policies instituted by *force majeure* over a fragmented and disheartened public.

Some of our difficulties, but only some, reflect the transitional problems of absorbing environmentalism into the set of shared public values. By and large, the impact of the environmental movement on the perception of policy issues by government agencies has been healthy. I feel it to have been particularly fruitful in the case of the Atomic Energy Commission, where the environmental implications are increasingly better balanced in relation to traditional technical or engineering objectives.

Nonetheless, the movement has been too ready to sacrifice longer run strategic objectives for transitory tactical successes. Any set of militants — not necessarily representative of the entire movement — has been in a position to delay or block individual projects piecemeal. I am persuaded that the high road to environmental improvement does not lie along the route of litigation. The most effective route for environmentalists is to obtain responsiveness on the part of government agencies. Litigation should be a last resort, used only in matters of fundamental importance.

I trust that the environmental movement will not be seduced by the heady atmosphere of recent years. It has achieved some notable objectives, but will it now proceed to consolidate the gains that have been made and become a durable force within our society? I would hope that strategies will be formulated in terms of longer run objectives and systematic treatment of the entirety of a policy issue, rather than the pursuit of immediate tactical objectives in the manner of sea lawyers. All this will be necessary if we are adequately to resolve the difficult problem of reconciling the demand for energy utilization with the goal of protecting the environment — recognizing that energy utilization is a principal source of environmental degradation — and if we are to achieve shared national goals in the quest for coherent policies.

Let me turn now to a brief review of the overall energy balance and to the prospective trends regarding energy supply and demand in the years ahead. Americans have grown accustomed over the years to an abundance of energy resources, to the ability freely to select among competing fuels, and to the utilization of energy resources without stint. Now we are confronted by the declining availability of domestically produced fuels of the desired type — with all that implies regarding dependence on external sources of supply. With the relative reduction of supply, we can no longer enjoy the luxury of regarding fuels as competing. Rather we are faced with the necessity of husbanding our BTU's and of treating the available fuels as complementary resources — in developing conscious policies for achieving maximum returns from what is available. Thus we must shape our energy policies under a set of constraints hitherto unimaginable.

I am sure that the general quantitative picture is familiar to most of you. In 1971 this nation consumed close to 70 quadrillion British thermal units. Included in this total are some 5.5 billion barrels of oil, 511 million tons of coal, and 22 trillion cubic feet of natural gas, supplemented by relatively small quantities of hydropower and uranium.

Looking out to 1980 and beyond, there are a number of projections, such as the recent one by the National Petroleum Council (NPC). Such projections are, of course, useful in providing a general

"...we can no longer enjoy the luxury of regarding fuels as competing. Rather we are faced with the necessity of husbanding our BTU's and of treating the available fuels as complementary resources...."

measure of the magnitude of the energy problem, but it should be noted that they are not constrained by major measures of conservation.

The NPC study projects the growth of energy consumption in the United States by some 50% to a total in 1980 in excess of 100 quadrillion BTU's. It is estimated that by 1980, nuclear energy will have expanded some forty fold over 1970 and will be approaching supplying close to 10% of total energy consumption. Coal consumption will have increased to 800 million tons. Despite the attractiveness of natural gas as a fuel and potential demand on the order of 35 trillion cubic feet, it is estimated that limited availability of natural gas will not permit utilization above the present level. Hydropower will increase only slightly.

The most significant change would be in petroleum consumption, increasing from 14.7 million barrels a day in 1970 to 22.5 million barrels a day in 1980. Since it is anticipated that domestic production will be only on the order of 12 million barrels a day, almost half of our petroleum supply will come from foreign sources. Increasingly the sources of supply would be in the Middle East, where the bulk of reserves are located. On an annual basis, U.S. consumption would increase from 5.4 billion barrels in 1970 to 8.3 billion barrels in 1980. The costs in terms of foreign exchange in 1980 would run between 12 and 15 billion dollars a year.

In a recent talk before the American Petroleum Institute, Joseph Swidler, of the New York State Public Service Commission, suggested that the NPC estimates were in a number of respects too "optimistic." Briefly, he suggested that the projections for both coal and nuclear were much too high. He noted the relatively rapid shift from coal to oil by utilities in the eastern section of the country and the relatively slow progress being made in getting nuclear capacity into operation. As a result, the increased burden would presumably fall even more on oil — imported oil. Consequently, he projected oil demand of 28.3 mmbd, as opposed to the NPC's 22.5 mmbd. This would imply that something approaching 60% of national oil requirements in 1980 would come from foreign sources and almost 40% of total energy needs. It would also imply imports of 6 billion barrels of oil a year (with a tanker arriving in a U.S. port every hour) and foreign exchange costs approaching $20 billion a year.

Such projections are illuminating, if not conclusive. They have the usual deficiencies of projections in that they do not reveal sensitivities to possible changes in policy and changes in economic conditions. Nonetheless, they do indicate very roughly the size of the problem that we face.

I do not know how much attention many of you have lavished of late on our ailing friend, the U.S. balance of payments. I think it proper to suggest that the BOP is not in sufficiently robust condition, now or prospectively, to bear an additional $15 billion or so of outpayments for oil imports. In raw financial terms, this nation can probably not afford so great a degree of dependence on imported energy resources.

If the raw financial considerations are not sufficiently persuasive, there are other disquieting questions. The national security implications of dependence of the American economy on resources subject to interdiction have been widely discussed over many years. Those considerations become increasingly pertinent in the years ahead. The closely allied international political implications of high dependence upon sources of supply geographically restricted and politically volatile is a

"I think it proper to suggest that the balance of payments is not in sufficiently robust condition, now or prospectively, to bear an additional $15 billion or so of outpayments for oil imports."

matter on which you may care to reflect. Moreover, the environmental impact of this particular pattern of meeting energy demand has a number of highly unattractive features.

The general pattern for meeting the nation's fuel needs that I have outlined is one toward which we could readily drift. This alternative strikes me as neither financially feasible nor substantively attractive. We would do well, therefore, to take major policy steps to avoid the dependence, penalties, and risks implicit in this pattern of energy usage.

I take it for granted that the American public will demand increasing numbers of BTU's. It also seems apparent that the altered availabilities of the several categories of fuels constrain our national choice and preclude that free selection among fuels we have known in the past. In particular, given the distribution of the world's petroleum reserves, 6% of the world's population cannot indefinitely consume 35% of the world's energy output, including this resource category, without becoming highly dependent on overseas sources of supply. That is not a matter of judgment; it is a matter of arithmetic.

Nuclear and coal are the energy sources in which our own resources permit far more extended usage in the foreseeable future without undue dependence on overseas supplies. They afford major possibilities for substitution. In its recent National Power Survey, the FPC estimates that by 1990, 53% of thermoelectric generating capacity in this country will be nuclear. The AEC's breeder development is intended to increase by a factor of 60 or 70 the exploitation of the energy content in uranium. Assuming breeder technology develops as anticipated, and is exploited, the very tails left over from the AEC's gaseous diffusion operations would be sufficient to fuel reactors for upwards of a century. Whatever concerns have developed in some quarters regarding reactor safety, I think it fair to say that there is widespread agreement regarding the net environmental advantages from properly operated nuclear generating facilities in relation to fossil fuel facilities.

By contrast, in recent years, coal has received diminished emphasis due to the environmental problems associated with some of our better located coal fields. Nonetheless, coal represents the predominant domestic source of hydrocarbons. Estimated reserves amount to 84 quintillion BTU's, of which approximately half is considered recoverable — a source that could last for a century or more. I believe it obvious, therefore, that we should devote the effort to develop coal gasification and other technologies which would allow us better to exploit these resources without increasing the untoward environmental effects.

These fuels are best utilized at present in generating electricity. Broadly speaking, electricity is a superior energy form which can be readily and flexibly employed. The exception at present is in mobile energy burners, and the AEC's efforts in battery development could bring a change in that respect within a decade. Over the years, electricity has increasingly been substituted for other types of energy usage, and we should take care that debates over power plant siting do not forestall what is basically a desirable development.

I have spent little time on the current difficulties in putting electrical generating capacity on the line. Just as we need improved structures at the Federal level to grapple with our energy problems, so we need improved structures at the regional and state levels to provide advance planning and acceptable recommendations with respect to such issues as power plant siting. As you know, it takes 6—8 years from inception to operation for a modern power plant — a cycle far longer than the comparable swings in public opinion. The inability to get large plants licensed and operating has contributed to some of the anomalies we observe. For example, 20% of our natural gas is being used to generate electric power, when its highest use in all probability is in the home.

I do not know whether the problems I have discussed warrant in your judgment the term "energy crisis." To some observers the phrase is too melodramatic. A crisis, after all, comes only if it is unanticipated and if appropriate policy adjustments are not made.

I think the phrase "energy dilemma" may be more descriptive. More precisely, there are a number of energy dilemmas. We face a congeries of problems far transcending the dramatic issue of fuel supply. There is, of course, the matter of power plant siting. Everyone wants the power; nobody wants the plants, and even less is there a desire for transmission lines. There is the matter of the efficiency of energy production and utilization, particularly as it impacts upon environmental quality. There is the matter of the appropriate combination of technologies to obtain higher efficiencies, and of government structures which will better contribute toward those ends. Each of these areas poses its own dilemmas. And in each of these areas the American society stands some risk of being impaled on the horns of those dilemmas.

In addition, I am inhibited in referring to an energy "crisis," because our national behavior clearly does not conform to such professions. On the one hand, some number of environmentalists seem to feel that the problem of demand expansion in relation to supply will yield to a combination of good will, abstention from the use of electric toothbrushes, sumptuary laws, and continuous litigation leading to load shedding. These views do not seem to me to correspond closely to the inherent difficulties of the situation. Nonetheless, an essential element in the envisaged energy crisis is the presupposition that irrespective of policy objectives and constraints, demand for energy grows more or less automatically. Challenging that presupposition is — or should be — the heart of the environmentalists' case — and in that respect they are right.

On the other hand, those who perceive a crisis or the possibility of a crisis are obligated to do more than to accept the growth of demand in the traditional manner. If we describe the increasing dependence on foreign fuels as a threat to the national security, to the balance of payments, or the steadfastness of our foreign policy, then we would seem obliged to consider measures more drastic for conserving on energy use. After all, if these are matters of fundamental importance to the national security, to international politics, and to foreign economic policy, then we can do somewhat better than automobiles that move at 10 miles to the gallon and badly insulated buildings that are simultaneously heated and cooled. We need to do better not only for these reasons, but for the time-honored motives of conservation in the Roosevelt-Pinchot tradition — as well as for the more recent concern regarding environmental protection.

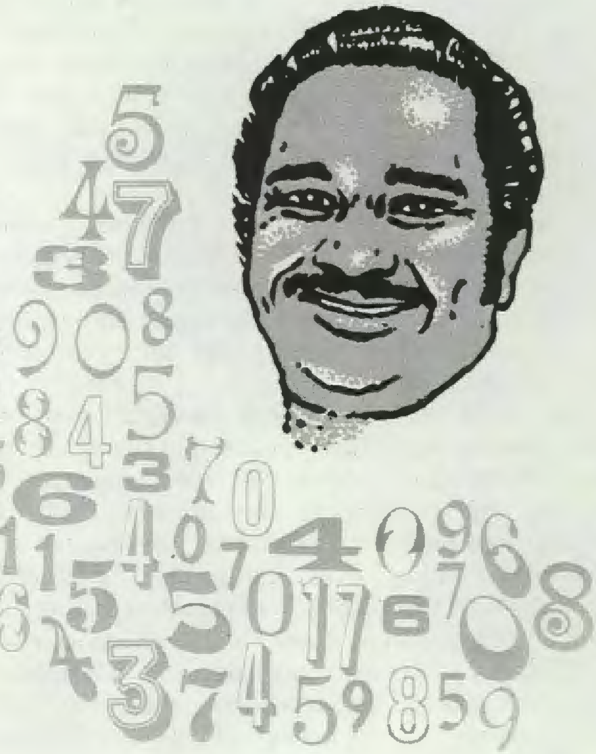
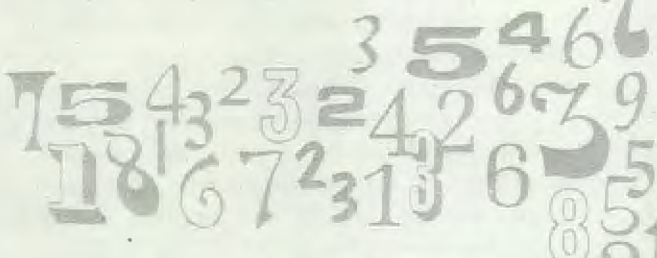
BUZZ WORDS

Robin Wallace, in the Fall 71 issue, gave us a general buzzword construct for the research proposal. Herm Postma reminds us that each new scientific field creates new words to describe its phenomena, plasma physics being particularly susceptible. He offers herewith a buzzword table for CTR in the interests of more coherent discussion on such topics as metalinear stability (421).

A	B	C
NEO	CLASSICAL	STABILITY
PARA	LINEAR	DIFFUSION
DIA	ANOMALOUS	RESISTIVITY
META	TURBULENT	CONFINEMENT
PSEUDO	HYDROMAGNETIC	RELAXATION
ORTHO	PRUDENT	THERMALIZATION
CRYPTO	RELEVANT	VISCOSITY
NON	CONGRESSIONAL	PROMISES

Take A Number.....

BY V. R. R. UPPULURI

Letter to Take a Number:

You write:

$10S_o + S_e$ is divisible by 11 if the sum of its digits is divisible by 11. My formula is:

$$S_o - S_e \quad \text{(ditto)}$$

Then,

$$(10S_o + S_e) + (S_o - S_e) = 11S_o.$$

Thus, if your formula is correct, so is mine.

(signed) Herb Pomerance

Where Is the Fallacy?

Some logical derivations contain the same fallacy as the following "proof" that the sum of the angles of a triangle is π (or 180°). Let x denote the sum of the angles of any triangle. Divide the triangle *ABC* into three triangles by joining its vertices to an interior point *D*. The sum of the nine angles of these three triangles, namely $3x$, minus the sum of the three angles at *D*, namely 2π, gives the sum of the angles of the triangle *ABC*, namely x. Thus we have $3x - 2\pi = x$, or $x = \pi$. This "proof," which works just as well for spherical triangles, leads to a conclusion that is false.

A Way to Reach 1

Take any positive integer. Multiply by 3 and add 1 to it. Remove all the factors of 2 in the result; either you are left with 1 or another odd integer. Repeat the same process and you will eventually reach 1. For example, take $7 \rightarrow 7 \times 3 + 1 = 22$: $11 \rightarrow 11 \times 3 + 1 = 34$: $17 \rightarrow 17 \times 3 + 1 = 52$: 26: $13 \rightarrow 13 \times 3 + 1 = 40$: 20: 10: $5 \rightarrow 5 \times 3 + 1 = 16$: 8: 4: 2: 1. This problem is making rounds in mathematical circles, and a rigorous proof that you will always reach 1 seems to be unavailable.

John Gerin, shown here against a micrograph of pure hepatitis Australia antigen magnified 250,000 times, is the resident director of the MAN Program's "satellite laboratory," situated in Rockville, Md. Recently *Review* Editor Barbara Lyon went up to take a look at this unique interagency product: a laboratory owned by the U.S., assigned to the AEC, operated by Union Carbide Corporation, reporting to National Institutes of Health, served and supervised by ORNL, and housed by General Services Administration. Although this would appear to add up to a monstrous witch hobble of red tape, actually a great deal has been accomplished by the Rockville Laboratory in its short life. The following is Lyon's account of what she found.

MAN in Orbit...

By BARBARA LYON

The gold letters on the window of the front door read:

MOLECULAR ANATOMY PROGRAM
Rockville Laboratory
OAK RIDGE NATIONAL LABORATORY
Operated By
UNION CARBIDE CORPORATION
Nuclear Division
For The
U.S. Atomic Energy Commission
And The
National Institute of Allergy and Infectious Diseases

HOUSED IN A ONE-STORY building no older than the laboratory itself, and surrounded by the heavy traffic of the intersection of Fishers Lane and Twinbrook Parkway in Rockville, Maryland, the MAN Program's "satellite laboratory" is a small island of ORNL in the swift current of this D.C. periphery.

Lab Technician Charlotte Langer, l., accepts a tissue culture from Dr. Meera A. Gharpure, visiting virologist, who plans to return to Bombay after two years with the Laboratory.

Its staff of nine, led by physiologist John Gerin, operates in all of its 4000 square feet of occupancy, and in fact plans are afoot to expand to half again this area by taking over much of the rest of the building.

Gerin, a long-time resident of the Washington area, having taken his undergraduate schooling at Georgetown University, received his doctorate from the University of Tennessee in 1964, performing research at the Oak Ridge MAN laboratory. He was employed by Abbott Laboratories in Chicago for the next three years, evaluating zonal systems for the concentration and purification of viral and bacterial antigens. In early 1968 he joined the MAN Program staff and was accordingly assigned to the National Institute of Allergy and Infectious Diseases (NIAID), where he prepared for eventual occupation of the building then under construction.

Originally conceived to bridge the gap between the ORNL MAN Program technology and NIAID research, the Rockville laboratory from the first was an exercise in coordination. First came the agreement with ORNL. Following this, a massive coordinating effort was launched, probably unprecedented in its complexity, involving the interaction of NIH, AEC, Union Carbide Corporation, General Services Administration, and Danac, a Rockville investment corporation and construction firm engaged by GSA. That this network of disparate forces was ultimately productive is credited by everyone involved to the patience, industry, and dogged perseverance of biologist Robert E. Canning, executive assistant and chief trouble shooter on the Oak Ridge MAN Program. From the completion of the plans in early 1968 to the laboratory's final occupation of its custom-built quarters in the fall of 1969, Canning made countless trips between Tennessee and Maryland in the course of getting everyone moving in the same direction.

Recently a visitor from Oak Ridge toured the facility, and in a conversation with Peggy Jensen, Gerin's secretary and factotum to the whole staff,

Paul C. Skinner catches up on his homework from his courses at Montgomery Junior College between jobs as laboratory aide in the "kitchen" of the satellite laboratory.

commented on the prevailing air of pride in the lab and general good cheer that seems to abound.

"Oh yes," Peggy said, beaming. "This is a wonderful place to work. Back when Dr. Gerin was setting up the lab, I worked as a secretary in an office across the street. Some of the heavy equipment was expected in by truck when no one could be around to receive it, so they gave me a key to the place and asked me to let the movers in and sign for the goods. By the time they were ready for operation, I had become so involved with the whole operation that I offered myself as secretary. Dr. Gerin hired me on the spot, and I haven't had a moment's regret.

"But," she added, "we do feel the lack of support services the rest of you at ORNL take for granted."

As Laboratory employees, Gerin's staff must go through ORNL medical clearance like everyone else. That is to say, each one has made the trip to Tennessee to get checked out, an inconvenience at best, and one that lacks the compensation of the free medical attention to minor ills that the Oak Ridge employees enjoy. Or the research shop services offered by Plant and Equipment Division, or the immediate availability of many kinds of office supplies.

Gerin added that more than once, when equipping his highly sophisticated research facility, he has come a cropper with Carbide's Oak Ridge purchasing office, some of the members of which had never heard of his laboratory.

"*Rockville*?" he has heard on the phone from Tennessee, "Rockville, *Maryland*!? Why are you ordering through *us*?"

"Tell them down there," said the sometimes beleaguered physiologist, "—tell them we're up here, and we're a part of ORNL just like you." It was an earnest plea.

The Rockville laboratory's research mission has so far been threefold: Besides the isolation and analysis of the Australia antigen of serum hepatitis, the lab is also engaged in the preparation of a special influenza vaccine and the study of a virus known as the Respiratory Syncytial virus.

In all three of these pursuits, Gerin and his staff have made gratifying progress. Making use of a large variety of highly refined versions of the Oak Ridge-developed zonal centrifuge, the scientists have succeeded in producing gram quantities of the hepatitis-associated antigen (HAA) and in developing sensitive methods of detecting its antibody.

The concern with HAA has been spurred by the rising incidence of serum hepatitis associated

Ralph M. Faust examines one of the many zonal centrifuges kept in an entire wall of cabinets in the main laboratory of the installation. Engineer Faust keeps everything spinning.

Eugenie Ford, electron microscopist, prepares a virus for photography.

with drug addiction. Although it was this near-crisis condition that moved NIAID to launch its attack on the virus with centrifugation techniques, the newborn laboratory is already exploiting its versatility in the use of its machinery to produce a new flu vaccine and to isolate for analysis a respiratory pathogen.

Besides Gerin and Peggy, the staff currently consists of James Shih, a biochemist from Taiwan whose Ph.D. is from Vanderbilt; Meera Gharpure, a virologist holding both medical and scientific doctorates, in the U.S. for two years before returning to her native India; Edwin J. Hoffman, chemist; Eugenie Ford, electron microscopist; Ralph Faust, field engineer originally from Beckman, the company that makes the laboratory's centrifuges; Charlotte Langer, technician; and a student aide, Paul Skinner. Shih is in the process of becoming a U.S. citizen.

Because of the extreme virulence of some of the materials dealt with, the laboratory has a

Chemist Edwin J. Hoffman, l., confers with biochemist Dr. James W. Shih in the main lab.

Peggy Jensen keeps it all together.

biohazardous area, a containment room under negative pressure, with a glove-boxed centrifuge and complete decontamination facilities. In addition, a compact three-room unit is devoted to Genie Ford's electron microscope operations: slide preparation, film development, viewing room. Tissue culture goes on in another section, and the main lab, containing the bulk of the spinning equipment, has one wall of cabinets devoted to the laboratory's collection of rotors, all designed for different purposes.

On a visit with Canning earlier this year were two design engineers from Y-12, L. P. Wynns, who participated in the laboratory's original design, and Howard Hicks; Dick Willis, an instrument designer with the Oak Ridge MAN Program; and Lloyd Kahler of UCC Purchasing. Their purpose in making the trip was to confer with Gerin about plans to expand the laboratory to about 6100 square feet.

The Rockville laboratory's arrangement of collaborative research with nearby NIAID is unique to NIH. The Institutes' multipronged attack on serum, or post-transfusion, hepatitis (Type B, as opposed to infectious hepatitis, which is Type A) includes research performed under both intramural and extramural program grants, but the interagency relationship in the ORNL satellite laboratory is unlike any other operation. Gerin reports directly to Bob Byrne, head of collaborative research for NIAID, and it is from this office that the program grants come to the laboratory through NIAID. The laboratory serves NIAID directly also by offering a training ground where Institute scientists may become familiar with the zonal centrifuge and its uses in biomedical research.

Staff morale at this vital little satellite is sky-high, all right, but they do wish all of us down here knew they were up there!

Barry Nichols, a candidate for the doctorate in ecology at UT, served his apprenticeship in environmental assessment of nuclear technology in 1969, when, while attached to ORAU, he was engaged by DTI to help plan for the now historical Burlington (Vt.) Conference on Nuclear Power and the Environment. The following spring he joined ORNL as a consultant in environmental matters, and besides his assistance with the Commission's compliance with the National Environmental Policy Act of 1969, he has been involved in studies of waste heat use and offshore siting, among other related subjects. His bachelor's degree, from the University of Wisconsin, represents a broad base in the natural sciences, with particular emphasis in biology. Before coming to Tennessee, Nichols taught high school biology for four years in Wisconsin, serving as head of the science department for the latter half of that time. Although ORNL had been engaged in some impact statement activity previously, intensive work did not start in earnest until mid-October last year.

ORNL and the Calvert Cliffs Decision

By BARRY NICHOLS

ON JANUARY 1, 1970, Public Act 91-190, known as the National Environmental Policy Act of 1969, became law. The purpose of the Act was to declare a national policy "to encourage productive and enjoyable harmony between man and his environment, to promote efforts that will prevent or eliminate damage to the environment and biosphere, to stimulate the health and welfare of man, to enrich the understanding of ecological systems and natural resources important to the nation, and to establish a Council on Environmental Quality." To carry out these purposes, several important steps were required of Federal agencies. These steps have come to be identified as Section 102 of the National Environmental Policy Act.

The requirements are fairly simple. All agencies of the Federal government are to use a systematic, interdisciplinary approach which will insure that an integration of the natural and social sciences is employed in any Federal decision making that may have a significant impact on the natural environment. They must identify and develop methods and procedures that will insure that the environmental amenities are given full consideration along with the economic and technical factors.

With every recommendation or report on proposals for legislation or other Federal actions significantly affecting the quality of the human environment, a detailed statement must be prepared by the responsible Federal official, covering the following aspects:

(1) The environmental impact of the proposed action;

(2) Any adverse environmental effects which cannot be avoided should the proposal be implemented;

(3) Alternatives to the proposed action;

(4) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and

(5) Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Before preparing the final detailed statement, Federal officials must consult with others having jurisdiction or special expertise with regard to the environmental impact, copies of the detailed statement along with the comments and views of appropriate Federal, state, and local agencies must be made available to the President and the Council on Environmental Quality; and this statement should follow the proposal through the Federal decision-making process. Federal agencies must examine alternatives to the recommended courses of action in any proposal, and make this information available to the states for establishing, restoring, or maintaining the quality of the environment.

The AEC, deciding that all actions related to the licensing and regulation of nuclear power plants represented major actions having a potential for affecting the environment, undertook to prepare environmental impact statements for each nuclear power plant, fuel fabrication facility, fuel reprocessing plant, or other activities; and, by mid-1970, the Commission had drafted a few such detailed statements.

By the end of the year, it was evident that so many statements were required that the AEC would need help, and in March of 1971, ORNL was asked to draft environmental impact statements for two nuclear power stations: the Hatch Nuclear Plant of Georgia Power Corporation at Baxley, and the Arkansas Nuclear One Plant at Russellville, owned by the Arkansas Power and Light Company. These turned out to be the mere beginning of a long list of environmental impact statements since drafted by ORNL for the Directorate of Licensing in the AEC's Division of Regulations.

Calvert Cliffs Decision

By early spring, seven members of the Laboratory staff from the Health Physics, Ecology, Chemical Technology, Reactor, and Reactor Chemistry Divisions were actively involved in the drafting of environmental impact statements. Then, late in July 1971, the U.S. District Court for the District of Columbia concluded in a case brought against the AEC by the Calvert Cliffs Coordinating Committee (a coalition of environmental groups) that the AEC was not fulfilling the mandates of the National Environmental Policy Act. The now famous Calvert Cliffs court decision set forth five important points which can be summarized as follows:

(1) It struck down the "grandfather clause" which exempted from the ASLR (Atomic Safety and Licensing Board) hearings those NEPA issues which were pending at the time the AEC published its regulations related to NEPA on December 3, 1970.

(2) It required that the National Environmental Policy Act be implemented for all licensing proceedings after January 1, 1970, and that this implementation include independent AEC assessment of water quality and other environmental factors. The AEC could not simply determine that water quality certification on Federal or state standards was adequate, but had to be prepared to set forth more stringent requirements of its own and to make an overall balancing of project benefits and environmental costs if this was deemed necessary.

(3) The licensing boards (ASLB) were to give independent substantive review to all NEPA matters in uncontested as well as contested cases. The court stated that this independent review of the NEPA environmental statement and the independent balancing of factors in an uncontested hearing would take some time if it was done properly.

(4) The AEC was required to give prompt NEPA consideration to facilities for which permits and licenses had been issued after January 1, 1970, the date when NEPA became law, if such matters had not been substantially considered in the original licensing action.

(5) With respect to construction permits issued before January 1, 1970, the AEC was required to consider on its own, or to entertain a show-cause request from a third party, any significant nonradiological environmental impact; and, finally, the AEC was required to direct that design and/or operating alternatives be carried out as indicated by the review. (NEPA review of cases in which a construction permit had been issued was not to be delayed for the operating licensing review. This was

to ensure that the impact be as small as practical and to minimize irretrievable commitments of resources.)

In the 45-page decision, the court set forth interpretations of the Act which caused the AEC — and ORNL — to reconsider all previous environmental impact statement writing and to begin a new and expanded effort to assist the AEC in carrying out its responsibility under NEPA.

Environmental Impact Reports Project

By mid-August 1971, ORNL was in the process of forming the Environmental Impact Reports Project. This project, headed by E. G. Struxness as director and Tom Row as deputy director, is organized into four groups. It took the following form: Task groups made up of individuals assigned to write specific sections of each statement; problem groups made up of specialists in areas of particular importance to impact statements; review groups to review the draft statements prepared by the task groups; and an editorial group to coordinate publication of the preliminary drafts and final submissions.

The task group leaders, each with the responsibility for drafting the statements for particular reactors, are Roy Thoma, Jack McWherter, Bill Yee, Bill Browning, John Witherspoon, Walt Stockdale, Arvin Quist, and Oscar Sisman. Each six-man task group has one member for each problem area. These areas are thermal effects and heat dissipation systems, gaseous effluents, liquid effluents, site and environs, radiological impacts, biological and environmental impacts, and cost-benefit analyses. Each problem group leader is responsible for seeing that considerations and evaluations in his specialty area are treated consistently and correctly: Bob Wichner heads the heat dissipation group, Frank Binford coordinates the gaseous effluent group, Bob Rickard leads the liquid effluents group, Bob Bryan coordinates the site and environs group, DeVaughn Nelson coordinates the radiological impact group, Dan Nelson the biological and environmental group, and the cost-benefit analysis is headed by Bob Hill.

After a statement is prepared, it is reviewed by the problem leaders, the task group, and then by special ORNL review groups, composed of staff members not involved with writing the statements, but who are competent in the various specialty areas and interested in conservation and environmental matters. After the review group's evaluation, the draft statement is revised accordingly and sent to the AEC in Washington.

Efforts and Results

As of late May 1972, the Environmental Impact Reports Project had undertaken NEPA reviews of 20 plants. Although reactor components are much the same in these power plants, each plant and each site carries with it those unique characteristics that create its own problems. To date, the greatest weakness has been the lack of information and techniques needed to understand or predict the extent of thermal plumes and to assess this thermal impact on aquatic organisms for once-through cooling systems. Many analytical thermal and ecological models have been developed (and the theory for analytical modeling of thermal plumes is reasonably well developed), but the models have not been tested extensively, since interest in thermal modeling is relatively new. Although the AEC has been involved in some thermal modeling for several years, recent efforts in conjunction with the preparation of environmental impact statements have greatly expanded such activity in the Commission's laboratories. As a result of the development of more sophisticated thermal modeling techniques we have been able to identify problems that the utilities had not been able to discover.

For example, in one case, problems related to the thermal plume modeling were identified because the applicant had considered only two flow conditions (but had not considered modeling for higher flows or for minimum flows, either of which can be sustained for significant periods of time).

In another case, the applicant's report was based on data which was interpreted differently by the AEC than by the applicant. Whereas the thermal problem was not deemed serious by the staff, the problem of entrainment of organisms (i.e., the drawing of organisms into the cooling system of the plant) was considered to be so. In short, as a result of the development of more sophisticated thermal modeling techniques, we have been able to identify problems that the utilities had not been able to discover.

These problems are similar to the kinds that have arisen. As the ORNL project continues to assess the impact of nuclear plants, problems are being identified, both for the Commission and for the applicant, which, if uncorrected, could present serious impacts at some later date, particularly with the installation of additional plants. By their early identification during the preparation of impact statements, it is possible that considerable amounts of money may be saved for the applicant by allowing him to consider modification of his system at an early stage, and at the same time to protect the environment.

The cooperative work of ecologists, physical scientists, and engineers has brought together significant amounts of new information on the impacts resulting from the construction and operation of nuclear plants. One interesting and consistent outcome is the fact that radiation from normal operations (one principal cause of the public's concern) is rarely the major impact of nuclear plants. Instead, the thermal discharge or chemical impacts dominate the concern of ecologists.

Spinoff Benefits

In the course of these environmental reviews, the national laboratories have disclosed several prime research areas needing further study for improved impact assessments. Some of them are: Problems related to cooling towers, such as measurement of drift from towers, and determination of increase in fogging, icing, and drift residues from tower operation; the impact of chemicals from tower blowdown on aquatic organisms; and the impact of transmission line right-of-ways on land use.

Modeling to determine the impact on aquatic organisms in estuary situations has also been identified as necessary for impact assessment, and some model development has been completed by the Laboratory.

The AEC has not in the past examined impact of transmission lines. However, following the Calvert Cliffs decision, impact evaluation is being made of *all* effects resulting from the generation of electric power, including the routing of transmission lines. A study of the environmental factors associated with transmission lines is now being made by members of ORNL's Environmental Sciences Division.

Further study of radiation effects on aquatic and terrestrial populations is also under way. (Much is already known about the impact on select species of wildlife, and on domestic organisms; also, much study has gone into identifying the impact on man.) Further research now under way will examine the impact of radiation on entire populations of aquatic and terrestrial wildlife.

Finally, a projection of power demand and reserve requirements needed to provide a supply of uninterrupted power is being carried out by the Laboratory as part of the impact assessment. Such a projection is difficult at best, yet the lead times, i.e., from planning to operation, which range from six to ten years for power plants, require more sophisticated calculations than have been necessary in the past. For the electric power industry, today's decisions are being made to provide for power in 1985. Therefore, the efforts of the industry and the work of the Commission and its laboratories must be aimed toward anticipating power needs for the 1980's.

Impact of the Impact Statements

The effort which began with early concern of ecologists throughout the country has resulted in legislation to minimize impact on man's environment. This legislation, known as the National Environmental Policy Act, has had a profound effect on the industry, on the U.S. Government,

PROCEDURE FOLLOWED IN IMPACT STATEMENT PREPARATION

Plant assigned to ORNL by AEC Division of Reactor Licensing.

ORNL receives assignment copies of the applicant's Environmental Report.

ORNL makes a site visit; interviews, questions.

Preliminary draft statement prepared for review by Task Group and Problem Group leaders and team members.

First draft prepared for review by the ORNL Review Committee and AEC Division of Reactor Licensing (initial review).

First draft statement redrafted to incorporate suggestions of Review Committee and AEC's DRL.

Second draft statement prepared for issuance to the AEC.

AEC draft statement issued for Agency comments.

Federal and state agencies' comments incorporated in statement, preparatory to issuance of a final detailed statement.

Final statement issued by AEC.

and on the Oak Ridge National Laboratory and our society as a whole.

The assessment of impacts from power plants has shed new light on the way in which man modifies his environment, and as we proceed to understand this impact more fully, we are developing ways in which man in the future may minimize his impact on the environment.

The efforts of staff members at ORNL are oriented toward providing a better understanding of how man affects his environment through power generation and to determining ways in which this impact on the environment can be held to a minimum. The assessment of environmental impacts from power production may well be some of the most important work now being carried out at the Laboratory. Perhaps these efforts will assist man to provide the maximum protection of his environment consistent with the provision of electric power demanded by him in this 20th Century.

ORGANIZATION OF ENVIRONMENTAL IMPACT REPORTS PROJECT

Task Groups:	Problem Groups: Reactor Cooling Systems	Gaseous Effluents	Liquid Effluents	Site and Resources	Radiological Impact	Biological & Environmental Impact	Benefit-Cost Analysis
	R. Wichner	F. Binford	R. Rickard	R. Bryan	D. R. Nelson	T. Kitchings	R. Hill
R. E. Thoma							
Palisades*							
Surry*							
North Anna	M. Mitchell	G. Parker	R. Rush	W. Ross	D. R. Nelson	J. Elwood	N. Hinkle
Mendocino	M. Mitchell	C. Baumann	R. Rush	W. Ross	C. Easterly	C. Gehrs	N. Hinkle
J. R. McWherter							
Oconee*							
McGuire			R. Bevan	B. Sturm	G. Kerr	B. Nichols	Huffstetler
Diablo Canyon	J. Hafford	G. Parker	H. Zittel	B. Sturm	C. Easterly	Nichols/Kitchings	H. Arnold
W. C. Yee							
Indian Pt. 1 & 2	M. Siman-Tov	W. Davis	R. Rickard	Ross/Bryan	D. R. Nelson	P. Goodyear	C. Carter
Shoreham	R. Robertson	W. Davis	R. Rickard	Farrar/Bryan	T. Clark	C. Coutant	C. Carter
Indian Point 3	M. Siman-Tov			W. Vaughn		P. Goodyear	C. Carter
Newbold Island	Tunnell Picklesimer	G. Parker	H. Zittel	W. Ross	T. Clark	J. Mattice	C. Carter
W. E. Browning							
Vermont Yankee*							
Ft. St. Vrain*							
San Onofre	M. Crowley		H. Kohn	L. Farrar	T. Burnett	G. Blaylock	W. Stanley
A. S. Quist							
Hatch 1 & 2*							
Arkansas 2 Arkansas 1 & 2	T. Shapiro	G. Parker	W. Waggener	R. Gilbert W. Vaughn	M. Kelly	J. Witherspoon	R. Browning
Farley*							
O. Sisman							
Limerick	M. Crowley		T. Berg	Berg/Sturm	T. Clark	J. Trabalka	H. Walker
Peach Bottom		C. Baumann	T. Berg	Sturm/Good	T. Clark	J. Trabalka	H. Walker
Consultants:	E. Picklesimer V. Cain M. Ozisik A. Eraslan W. Snyder	T. Hamrick G. Parker	R. Blanco	W. deLaguna J. Reed	G. Killough G. Kerr P. Rohwer S. Kaye	G. Blaylock C. Coutant P. Goodyear	M. Bender B. Ahmed

*Completed.

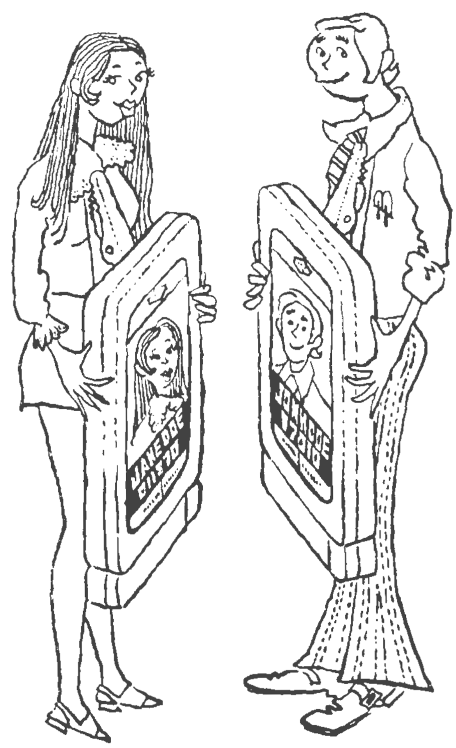
HISTORY THRU NUMBERS

LAB ANECDOTE

In its early days the Clinton Laboratories tried to put life and meaning into the badge numbers. Nowadays in its successor, Oak Ridge National Laboratory, only the library has the gumption to play with numbers.

The construction branch of Du Pont came and went in 1943 and 1944 without any remembered badge numbers. The branch of Du Pont that operated the Clinton Laboratories, Box 1991, Knoxville, Tennessee, set up four number groups for payroll purposes. Badge No. 1 went to Stu Pratt, the Supervisor, the next numbers to Du Ponters on the Wilmington payroll. Badge No. 1000 went to M. D. Whitaker, the Laboratory Director, and succeeding numbers to those who were on the Oak Ridge payroll. Badge No. 5000 went to Mr. Arthur Holly, better known as Prof. Arthur Holly Compton of the University of Chicago. Other numbers in the 5000 series went to persons not on the Oak Ridge rolls but who nontheless worked here. The 7000 series was used for the nearly 200 Du Ponters who trained in Oak Ridge for operation of the Hanford reactors. The badge numbers were grouped by payroll, and Larry Riordan had no trouble assigning four-digit numbers in an installation intended for two years of service. The dozens of soldiers who worked in the labs were not considered to be persons, and their dog tag numbers sufficed. After the war, the soldiers who mustered out of the Army but elected to remain here got badge numbers from about 3900 into the 4000s and no credit for their Army service.

In 1946 the Training School under Eugene Wigner and Fred Seitz began its year of operation (sometimes called the Klinch Kollege of Knuclear Knowledge). Its students were sponsored by various industrial firms, and they first received badges from No. 9000; those who later stayed at Oak Ridge got new numbers in the orderly sequence. In order to avoid five-digit badge numbers, the orderly sequence which had jumped from 4999 to 6000 and from 6999 to 8000 later went backwards to pick up the missing groups. The sequence in thousands is 1, 2, 3, 4, 6, 8, 9, 7, 5, 10, and onwards. The numbers in the 5, 7, and 9 groups were reassigned; the old handwritten books in the



payroll department do not show who the first holders were, and the old books in the personnel department are not complete.

When Monsanto succeeded Du Pont in July 1945 as the plant operator, the Du Ponters who transferred and the direct Monsanto employees got badges in the 500 series. Larry Riordan, who had No. 22 under Du Pont, became No. 522 under Monsanto. Eleven badges are still in use in that series.

Several years ago the Central Research Library computerized. It is convenient to record all book loans by badge number because there are only 10 digits in 5 columns in place of 26 letters in 10 or 15 columns. What does one do with users who have no badge numbers: consultants, foreign visitors, sponsored workers, other libraries, local industries? Why, one issues fictive numbers in the 99 000 series, then in the 98 000 series, and doesn't worry about what will happen when the downward-moving library numbers meet the upward-moving badge and payroll numbers.

— Herbert Pomerance

OAK RIDGE NATIONAL LABORATORY *REVIEW*

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