Review

WINTER 1968

OAK RIDGE NATIONAL LABORATORY

THE COVER: Norman G. Anderson, director of the Molecular Anatomy (MAN) Program, in which the zonal centrifuge was developed, with associates C. T. Rankin, Jr. (l.) and L. Hunter Elrod (r.). The centrifuge has made possible a vaccine free of the impurities that cause side effects (see article on page 1).

Review

OAK RIDGE NATIONAL LABORATORY

VOLUME 1, NUMBER 2 **WINTER 1968**

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OAK RIDGE NATIONAL LABORATORY

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UNION CARBIDE

London, 1661

"... And what is all this, but the Hellish and dismal cloud of Sea-Coal, which is not only perpetually imminent . . . but so universally mixed with the otherwise wholesome and excellent air, that [*London's*] *Inhabitants breathe nothing but impure and thick Mist, accompanied with a . . . filthy vapour, which renders them obnoxious to a thousand inconveniences, corrupting the Lungs, and disordering the entire habit of their Bodies; so that Catharrs . . . Coughs and Consumptions, rage more in this one City, than in the whole Earth besides."*

—the diarist John Evelyn

The Oak Ridge Life Sciences Program as a Challenge to the Pollution Problem

By James L. Liverman

NOXIOUS wastes that plagued 17th century London were but a mild forerunner of the vast pollution crisis which, three hundred years later, is posing a heavy threat to humanity throughout the civilized world.

What can be done about it? What role does the Oak Ridge scientific complex have in assessing or in alleviating the hazards of pollution? This seems a particularly opportune time to review our capabilities in this regard, because the Atomic Energy Commission has been asked by Congressman Holifield, Vice Chairman of the Joint Committee on Atomic Energy, to explore ways in which the National Laboratories could mobilize around the pressing problems of pollution.

For more than a year, personnel in the Oak Ridge National Laboratory and other AEC-Union Carbide plants in Oak Ridge have been examining what the biomedical programs here can contribute to an evaluation or an abatement of some of the hazards of environmental pollution. We in Oak Ridge are well qualified to investigate environmental pollution in general because of our more than twenty years of experience in studying one of them—radiation. The same or similar biological techniques required to elucidate the hazards of low levels of radiation may be applied directly to evaluate the effects of other physical insults to our environment. This experience in biology, coupled with the enormous physical science, engineering, and technical back-up available in Oak Ridge, provides a powerful scientific complex—a unique combination!

This article explores those areas in which the Life Science Programs of the Oak Ridge National Laboratory are already doing research concerned with physical insults to our environment brought about

J. L. Liverman, Assistant Director of ORNL, came to the Laboratory three years ago from the U.S. Atomic Energy Commission, where he was Chief of the Biology Branch and Assistant to the Associate Director for Research, in the Division of Biology and Medicine. He has recently been named Professor of Biomedical Sciences in the University of Tennessee-Oak Ridge Graduate School of Biomedical Sciences. For the past year he has headed a study of the role which ORNL is equipped to play in the nation's battle on environmental pollution in response to an inquiry by AEC. The proposals embodied in this article are the result of penetrating examination of the problem and Liverman's familiarity with the resources of the Laboratory. Liverman has presented speeches on this subject twice in the past few months at special seminars by Oak Ridge Associated Universities.

by man's own hand—air pollutants, soil contaminants, solid wastes, etc. It will also present additional areas to which we can contribute in the future.

As a background for this discussion, let me first outline some of the more pressing pollution problems.

Principal Pollutants

Atmospheric pollutants

The accompanying table shows the principal atmospheric pollutants in the United States and their sources.

Most of us have witnessed the extremely polluted air in Los Angeles, St. Louis, New York City, Chicago, Detroit, Pittsburgh and other crowded cities. Polluted air is found even in the deserts of Texas and Arizona. There, air pollutants which are released from refineries, smelters, and other mineral processing plants located in remote places

PRINCIPAL ATMOSPHERIC POLLUTANTS IN THE UNITED STATES

	MT/YEAR*	Percent
By Type		
Carbon Monoxide	65	52
Oxides of Sulfur	23	18
Hydrocarbons	15	12
Particulate Matter	12	10
Oxides of Nitrogen	8	6
Other Gases and Vapors	2	2
Total	125	100
By Source		
Transportation	74.8	59.9
Manufacturing	23.4	18.7
Generation of Electricity	15.7	12.5
Space Heating	7.8	6.3
Refuse Disposal	3.3	2.6
Total	125.0	100.0

Source: Committee on Pollution, *Waste Management and Control* (Washington, National Academy of Sciences, Publication 1400, 1966).

*MT = million tons

get boxed in by inversion layers and finally reach congested city areas 80 and 100 miles away.

Transportation both public and private, together with power-producing industries are responsible for almost 75% of the atmospheric pollution. "Transportation," incidentally, includes you and me in our worn-out cars which send out smoke and half-burned fuel instead of carbon dioxide and water vapor from the exhaust.

Only those of us who do not smoke would consider cigar, cigarette, and pipe smoke as an air pollutant. Nevertheless, it seems that the combination of smoking with inhalation of other environmental pollutants leads to an increased incidence of lung cancer.

High concentrations of a number of these atmospheric pollutants are lethal, but little meaningful data exist to show where the threshold level, if such exists, really lies. Are the 40,000–50,000 deaths from lung cancer every year due, in part, to these pollutants? Do these pollutants bear part of the blame for increased heart disease and kidney disease? Technological means exist to control most of these pollutants at the source; economic cost is generally the penalty. However, in some industries it is possible for cleanup at the source to result in economic gain to the industry from sale or use of the recovered products—sulfuric acid, chlorine, etc. We can and must control atmospheric pollutants but we need to establish the levels to which they must be reduced in order to evaluate these costs.

Many of the atmospheric pollutants mentioned above fall on the ground and as a result of being scrubbed out by the rain they end up contaminating our water supplies and soil.

Municipal and Industrial Sewage

More than 125 million people in the United States are served by domestic sewers. About one-tenth of this sewage is discharged raw and more than one-fourth of the rest receives only very primary treatment. This means that the total sewage discharge, even when taking into account existing treatment plants, is equivalent to the raw sewage of almost 50 million people. Further treatment could reduce the disease-causing organisms and cause more complete oxidation of the raw sewage. However, methods have not been developed to remove phosphorus, nitrogen, and other plant nutrients from the effluent. These nutrients result in over-fertilization of the rivers, lakes, and estuaries, with a subsequent overgrowth of algae.

In communities where storm and sanitary sewers are combined, the problem of pollution from domestic sewage is even greater. When there are large runoffs from rainfall the sanitary sewer cannot process the material at the rate required to handle the excess, resulting in a greater degree of pollution. A partial solution is to separate the storm and sanitary sewers, but there would be considerable psychological resistance to tearing up every street in town and the cost would be almost prohibitive.

Something must be done. The precise answer will come from more research—research, in fact, to which the Oak Ridge complex can contribute.

Animal Wastes

We are all fully aware of the odor and fly problems associated with animal stockyards, feed lots, slaughterhouses, chicken farms, and related areas. We are much less aware of the tremendous amount of waste which accumulates around such sites. In fact, farm animals in the United States are responsible for roughly ten times as much bodily waste as the human population. For instance, one cow produces as much waste as sixteen humans; one hog as much as two people; seven chickens as much as one person. In the early days of this country our ancestors were able to settle in a fair and unspoiled land which was capable of absorbing the wastes of its animal and human population. The wastes could be plowed back into the field as fertilizer with little net waste accumulation. Industrialization of agriculture has caused a severely localized accumulation. The costs of packaging, processing, and shipping the waste materials to the point where it could be utilized is not at all competitive with other commercial fertilizers—and so the wastes accumulate.

These wastes, rich in nitrogen and phosphorus, when washed by rain into streams have often resulted in high kills of fish and in damage to oyster and other commercial shell fisheries. If infants drink well water contaminated with high concentrations of nitrate from the decaying manure, they may develop a serious disease called methemoglobinemia. It is clear that the cost of proper disposal of these materials will soon cease to be adequate consideration for ignoring the problem—the problem must and will be solved.

Urban Solid Wastes and Consumer Goods Wastes

Another major source of pollution comes from paper, grass and brush cuttings, garbage, ashes, metal and glass, etc., that man generates during his daily activities. It is estimated that each of us is responsible for generating about five pounds of such solid waste per day.

The cost of removing this accumulation of trash from our homes is more than $2.5 billion annually and the amount is increasing. In fact, it costs more to collect and dispose of one ton of garbage in New York City than it does to buy and deliver a ton of West Virginia coal to a New York home.

The matter of disposal of materials from wrecked buildings, worn-out roadbeds, etc., constitutes another area of great magnitude. At present, the placing of such materials in swamps to reclaim land seems an adequate but certainly only a temporary solution. For the future, evaluations are being made of such schemes as building off-shore airports in the New York area or using wastes to fill the holes left by strip and open pit mining of coal.

One of the gravest eyesores arising from our industrial metabolism is the appearance over our landscape of junk cars, worn-out tires, old refrigerators, old farm machinery, worn-out air conditioners, beer cans, drink bottles, paper cups, etc. It is interesting to note, however, that salvage of these wastes has turned out to be one of the major industries in this country. For example, in a recent year one-sixth of the iron, 40% of the copper, and 25% of the aluminum used in this country came from salvage. Twice as much lead came from salvage as from mining. These materials can be directly recycled back into the basic materials pool. In addition, some garbage is used to feed animals, or to generate heat by incineration to produce steam for power, or used for sanitary fills to upgrade land values. At least, in the cases cited above there is considerable monetary incentive for the industry to dispose of many of the wastes—the $5–7 billion netted annually from the sale of these materials "ain't hay."

Mining Wastes

One has but to look across the valley to the north of Oak Ridge into the Cumberlands to see a blight of our beautiful country in the form of surface mines. The coal and land cover has been removed, leaving in their place only ugly scars, sterile soil, and polluted waters. In all, there are over three billion tons of waste rock and mill tailings created every year in this country and, in addition, mountains of slag, ash, and other wastes are left from the refining of ores, the combustion of coal, the production of metals and non-metallic materials. Surface soil changes from strip mining, along with acid mine-drainage containing acid sulfates or other minerals in the coal regions of the U.S., are problems of significant proportion. As much as one million acres of land may be involved in the eastern half of the nation. These acid liquors sorely contaminate our rivers with poisons which kill the fish and make the waters unfit for human and animal consumption. To some states, such as West Virginia and Pennsylvania, this source of potential water pollution presents one of their most serious problems. There does not appear to be an economic incentive to lead to spontaneous elimination of these worn-out mines full of polluted waters. One possible use of them is for disposal of solid wastes from large cities such as New York or Pittsburgh.

Other Pollutants

Those pollutants which insult our sense of smell or taste, which cause us pain or overtly affect our health, which cost us money or disturb our esthetic senses are recognized with little difficulty. Rachel Carson focused dramatically on another kind of pollutant in *Silent Spring*, published in 1961. In retrospect, this book was an inflammatory call to straight-thinking people throughout the world to evaluate the hazards of agricultural chemical pollutants. Man, in his constant rush to have the good life, has made wide use of pesticides, herbicides, fertilizers, growth promoters, detergents, etc. We nearly all seem imbued with the feeling that if a little bit is good, a lot should be ever so much better. So we overdo our use of these conveniences with a resultant pollution of our environment. These are the things which are hardest to control and, at the same time, are the things which in the long run, i.e., over a lifetime, or a generation, may cause man his most serious health hazard.

While the use of drugs in animals can hardly be classed as a pollutant of the usual type, there are some obvious warning signs to their indiscriminate use in agriculture. For instance, the wide use of antibiotics in animals to increase their rate of growth and to prevent disease has led to the development of drug resistant strains of pathogens which also infect man. Man is thus placed at a considerable disadvantage when he in turn becomes infected with these drug resistant pathogens.

There do not seem at this point to be any clearly demonstrable cases of toxicity to man from eating flesh of animals fed drugs and hormones but it is not at all clear that such effects will not arise with longer exposures. We must, therefore, be on a constant lookout for danger signs. We have not really examined in detail many of these pollutants for an increased allergic sensitivity to them or for more subtle effects. Even those materials which we might at first discount as being of no consequence—the fertilizers—have created serious problems when they have found their way into our lakes, fresh water streams, or estuaries. There they have caused a great overgrowth of algae which clogs the waterways or decays and pollutes the water to the point where it becomes virtually useless.

Possible Oak Ridge Contributions

What can the Life Science Programs in Oak Ridge do to evaluate these hazards? What are they now doing?

Air Pollution

In the air pollution area we are already engaged in a joint program with the National Cancer Institute. Researchers in the Biology Division are studying the interaction of chemicals (which in this particular case are petroleum vapors or smog) with viruses and with radiation in the initiation of lung cancer. While these experiments are in their infancy, there are already suggestions that the factors, when combined, may be more carcinogenic than any one alone. Additionally, through a combination of the talents of the Analytical Chemistry Division, the Health Physics Division, and the Isotopes Division, we have just initiated programs with the Division of Environmental Health Sciences of the National Institutes of Health on the methodology for assessing the hazards of tobacco smoking in causing lung cancer in humans. It is likely that these programs will expand as time goes on because of the unique competences of the Laboratory to look at some of the questions related to smoking and health.

We are currently exploring ways we can help with the problem of uranium miners who, when they smoke, contract lung cancer at a rate ten times that of non-smoking uranium miners, a ratio far greater than occurs in other occupations.

Environmental Effects

Many of the problems which I have outlined have a great bearing on the general health of the environment. Do the ecology and the waste disposal sections of the Health Physics Division, with their environmental science programs, have a contribution to make beyond studying the effect of radioactivity on the environment?

The waste disposal section has pointed clearly to ways in which this country will be able to dispose of its radioactive wastes as the nuclear power industry becomes full-blown. It has also, in conjunction with other groups, established guidelines for the safe release of low-level radioactive wastes. The conceptual framework that has shown the way to nuclear waste handling and disposal appears in many respects to be applicable to finding ways to dispose of other kinds of wastes and of determining the effect upon man of various levels of water and environmental pollutants. The personnel from the Oak Ridge Gaseous Diffusion Plant have contributed to the work of this group and that of the ecology section in their use of centrifuges to separate the many viral and bacterial species found in our fresh waters.

The ecology section has, over the years, become one of the largest as well as one of the most outstanding environmental science groups in the world. Its program has assessed the hazards of radiation in the environment to animals, fish, insects, and plants. The techniques and approaches used to study cycling of radionuclides among organisms in terrestrial and aquatic habitats relate to many pollution problems affecting the balance of nature. These experimental approaches, combined with the considerable strengths in theoretical and systems ecology, coupled with the backup in chemistry, chemical engineering, and instrumentation available in ORNL's Divisions of Analytical Chemistry, Chemical Technology, and Instrumentation and Controls, and K-25's Development Division can bring a powerful scientific team to bear on the problems of pollution.

Besides these scientific strengths in environmental science, ORNL has a valuable resource in a large land reservation which has been under observation for a number of years in order to establish

Pontoon boat designed by Ecology Department for use in studies of natural recycling of elements in fish and plant life in White Oak Creek.

baseline values for the qualitative and quantitative nature of the flora and fauna. There are five controlled watersheds on this site which among them represent reasonably typical kinds of forestation and soil found throughout much of the Southern Appalachian region.

In addition, in the Oak Ridge area, there exists a wide spectrum of sources of pollution of different types which are subject to control and modification. For instance, there are (a) five separate sewage disposal plants with primary and/or secondary processing, (b) runoffs from several parking lots and effluents from various research and development activities resembling industrial wastes, (c) animal wastes arising from the large experimental animal colonies of the laboratory and from the animal research activities at the University of Tennessee Agricultural Research Laboratory, and (d) fertilizers and pesticides applied at various intervals on various portions of the site.

Thus, not only is there the scientific competence to investigate the effects of pollutants on the environment but there are examples of many of the worst kinds of pollutants and the controlled or controllable land masses, watersheds and waterways upon which to run controlled studies. It seems very clear that an understanding of the impact of pollution on the environment will only come from a broad, in depth study such as we seem to be uniquely in a position to launch right here in Oak Ridge.

Effects on the Individual

In the first part of this section I have dealt with the broader environmental problems affecting large populations. For the remainder of this article I will turn to that area of the Laboratory's endeavors which have to do with understanding the effects of environmental hazards on the individual organism. These programs are being carried out principally in the Biology Division of the Laboratory.

It has been mentioned earlier that when pollutants affect our sense of smell or touch, or insult our esthetic senses, the public mobilizes to do something about it. Until recently, however, we have chosen to ignore or have been unaware of those more subtle forms of physical insults arising from use of industrial and agricultural chemicals, drugs, etc.—things which may affect us profoundly over a lifetime or over several generations but which are not so evident on a day-to-day basis. In these areas, too, our competence is excellent for evaluating, and perhaps for suggesting ways of alleviating, these hazards.

The biomedical programs of the Oak Ridge National Laboratory were started because the AEC needed to know the effects of radiation at the level of the total environment, as well as what somatic (present generation) and genetic (subsequent generations) changes might be produced. It also needed to know ways in which these effects could be modified or completely alleviated. The Biology Division of the Oak Ridge National Laboratory, which was created in 1946, has concentrated its efforts into these three areas, particularly with regard to the effects of radiation from a fixed source external to the organism (as opposed to radiation from radioisotopes which might be ingested or inhaled).

Possible Genetic Effects

It is the Division's policy to have only a few (three to five) mission-oriented programs, intermeshed with and supported by the most fundamental kind of research on a wide variety of organisms. Out of this kind of philosophy of operation has grown one of the world's outstanding programs in radiation genetics of mammals. This program, under the leadership of William L. Russell, has yielded some of the most important information in existence on the effects of radiation on animals and how these effects relate to those in man. The findings have been landmarks for the establishment of radiation standards.

These studies on the hereditary effects of radiation have resulted in the buildup of large genetically defined colonies of mice which are particularly useful for analysing the genetic effects of various kinds of insults. The techniques which have proven so extremely useful in assessing the genetic hazard of low and high doses of radiation have been shown recently to be directly applicable to assessing the hazards of chemical pollutants. Triethylenemelamine, a chemical used in the manufacturing of plastics, when given at below lethal concentrations to mice, seems to be as effective as 600 r of X-rays in causing mutations in spermatozoa and as effective as 200 r of X-rays in causing mutations in spermatids. This very modest program on chemical mutagenesis in mammals was recently expanded by a joint program between the AEC's Division of Biology and Medicine and the National Institute of General Medical Sciences to assess the genetic hazards of a number of chemical pollutants suspected to be hazardous. Closely related to this mammalian program is one on microorganisms, jointly sponsored by the AEC and the National Cancer Institute, studying the relationship between the carcinogenicity and mutagenicity of several compounds.

Even less is known about the mutagenic effects of the many other pollutants dumped into our environment by our industrial processes—pollutants over which man at present has little regulatory control. It is not possible to estimate at this time

A colony of specific pathogen free mice has been developed in ORNL's Biology Division for the purpose of studying the effects of low-level radiation. They are bred under controlled conditions in order to prevent unwanted infection.

the degree of hazard to which a sizable segment of the population is being exposed. Our concern about these possible hazards led recently to a proposal for a much larger national program to assess the hazards not only of industrial chemicals but of drugs in common use including oral contraceptives. This proposal was urged before the Drug Research Board of the National Academy of Sciences. We consider the proposed program to be urgently in the national interest, because evaluation of the possible genetic hazards is not now one of the safety criteria for the approval of drugs for human use nor for the general use of pesticides.

We are all aware of the somatic effects of viruses. They cause many of our most infectious diseases, such as influenza, colds, and measles. Polio took a devastating toll of mankind before we were able to develop an effective vaccine. No one then can really question that we will continue to use vaccines whether or not they are of live or attenuated viruses, at least until something better is developed. However, on the basis of recent evidence obtained here in Oak Ridge by Stanfield Rogers using mammalian systems, we feel that a serious effort should be devoted to assessing the possible genetic engineering we may already be achieving inadvertently and unexpectedly by using whole virus vaccines. Rogers' results strongly suggest, and perhaps prove, that a virus which causes skin cancer in rabbits also appears to be picked up by people who work with it, though it apparently causes no ill effects. The evidence suggests that the genetic information carried on the nucleic acid of the virus is in some way carried along into man's cells and continues to be reproduced.

The fact that this virus, which does no obvious harm, leaves its information around in our cells, and that we could conceivably pass it on to our offspring, is a cause for considerable concern. The least that we as scientists can do is to evaluate whether there is a danger of using vaccines made from viruses which still contain their nucleic acid, and proceed posthaste to develop vaccines without it. The broad technology to develop a nucleic acid free vaccine already exists. All that is needed is that the goal be firmly established and the necessary funds allocated. It is significant that in Oak Ridge we have the capability and technology to assist in both the evaluation of the hazard and in alleviating it.

Somatic Effects

Also in vaccines, there is another pollution problem: that of their purity. With few exceptions, the aim of vaccines, i.e., to build up immunity, is achieved. Most vaccines, however, contain a considerable amount of impurity that often results in severe side reactions. Recent efforts by Norman G. Anderson, working in collaboration with various drug companies, have succeeded in the development of a greatly purified, yet effective influenza vaccine which causes few side effects. It seems likely that, as a result of these efforts, all vaccines will be pushed to a degree of purity never before attained.

In the earlier days of the atomic energy programs it was necessary to establish the effects of lethal and sublethal amounts of radiation on living organisms. Experiments establishing these levels were done quite adequately with fairly ordinary laboratory animals because radiation provided a clearly overwhelming component of the environment controlling the health of the animals. As we have gone to lower and lower levels of radiation in order to approach more nearly those levels encountered by man in his environment, we have had to develop a colony of germ-free animals with which to measure the most subtle and elusive effects of radiation.

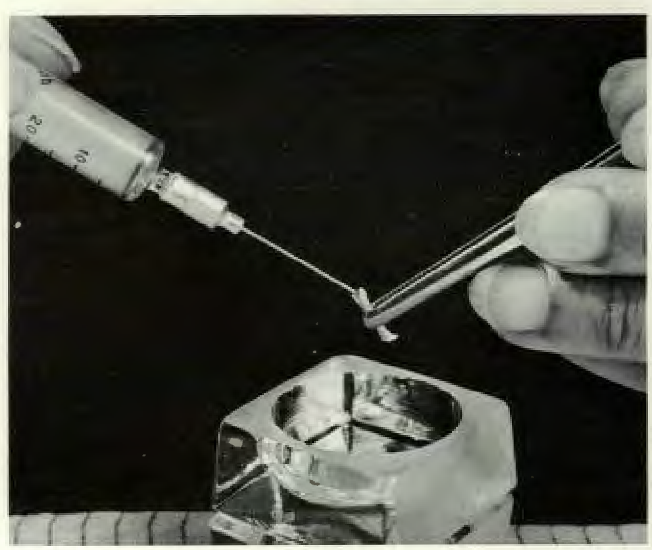
The fundamental aim in such experiments is to determine whether there is a threshold level of radiation below which there is no measurable effect. Already we have suggestions that the use of specific pathogen free mice and standard care mice combined will yield more meaningful information than either alone. For instance, with conventional animals, a particular type of leukemia develops, whereas in the animals in which the bacterial flora has been modified a different type of leukemia develops. While we are still busily engaged in answering the threshold question, it is clear that the kinds of animals developed to answer the radiation question are the same kinds as are needed to evaluate the biological effects of very low levels of environmental pollution.

We have the know-how and the willingness to tackle those critically important national problems which require our facilities and trained manpower so long as they do not directly conflict with current research.

Shortly after we began to understand something of the lethal and sublethal effects of radiation, it became obvious that there was a recovery process. One of the major effects of sublethal doses of radia-

"We Stand Ready to Explore It in Depth . . . "

ORNL biologist performs the delicate process of transplanting bone marrow in a mouse femur for the Laboratory's mammalian recovery studies.



tion was to lower the capacity of the animal to make blood components, a function of bone marrow. This capacity could be restored if unirradiated bone marrow of the individual or of a closely related individual could be transplanted into the irradiated animal. If, however, bone marrow from a nonrelated individual were used, there was only temporary recovery—a consequence of the body's normal reaction to foreign protein, its immune response.

In order to understand these events in detail we launched a major program to study the immune response. One of the most interesting things to come out of these studies is the demonstration that, at least in the mouse, the immune response is related to the age of the individual. When young, a mouse has little resistance to disease; its ability to make antibodies is low. Within about the first ten weeks of its life, however, it has reached its maximum capability. This is followed by a fairly rapid decline so that, by the time a mouse is 70 weeks old, its antibody-forming ability is only about 20% of the maximum.

It is not yet clear whether man's immune capacity follows a similar relationship, i.e., reaches a maximum at about puberty and then falls off so that by age 45 this ability to respond to insult is down to only 20% of what it was earlier. Neither is it clear whether this capability even in the mouse can be maintained at a higher level in the aging mouse by storing antibody-forming cells when taken from the mouse when young and implanting them at intervals during the individual's lifetime.

Experiments with spleen cells transplanted from a younger individual to an older one seem to suggest that the antibody-forming potential can be maintained at a higher level. On the other hand, when cells are transplanted from an older animal the treated animal dies at a much earlier age.

Although this study is still young, it may one day give rise to the question whether our present practice of transfusing blood from a mixed pool from several age groups is a wise one. In a sense, this problem may constitute another new and until now unsuspected pollutant. We stand ready to explore it in depth and will so do so as time and funds permit.

Currently Takashi Makinodan and colleagues, in order to examine the question of whether environmental changes affect antibody-forming potential, are studying individual mice raised in dirty, in standard clean, and in germ-free conditions. If these experiments demonstrate a clear difference, we may quite unexpectedly have come upon one of the most sensitive methods and meaningful parameters for exploring the biological effects of various pollutants; their effects upon the immune potential may be detectable at a lower level than the somatic or genetic effects mentioned earlier.

In Summary

Throughout this article I have posed a number of questions about pollution to which there are no simple answers. Choices must be made between the cost of seeking solutions and the cost of further postponement.

We would like to be rid of all the pollutants from industrial activities but we also want all of the benefits deriving from these efforts. We want all the benefits that accrue to our agriculture through the use of pesticides, fertilizers and hormones, but we do not want the pollution of our environment that is the result: streams loaded with algae and rough fish and filth.

We are not going to stop using vaccines with antigenic impurities or ones with nucleic acids because we are afraid of the possible hazards of the impurities, if by stopping we risk letting the diseases for which the vaccines were developed become rampant again.

We are not likely to stop using drugs because they may be mutagenic or carcinogenic when these very drugs may be the only protection against death and crippling diseases and a tremendously overcrowded world.

To rid ourselves of the pollutants which ruin our water and air, it has been estimated, will cost more than $300 billion over the next 30 years. This figure does not include the additional costs for improved medicine, for cleaned up vaccines, and for assessment of the genetic and carcinogenic hazards that may arise from use of drugs and chemicals.

These are some of the choices which we as individuals, as a community of individuals, and as a nation must make. The problems which I have outlined earlier are with us and pollution is constantly increasing. We can go on as we have for a few more centuries just throwing things over our shoulders hoping they will go away, but if we do, it will be like playing Russian roulette with our future. Shall we continue to take our chances by continuing to dump pollutants into the environment without attempts to assess their hazard and to control them, or shall we act sensibly and begin our chore?

We as a nation have already started to face some of these issues squarely by providing funds to begin the research necessary for assessment of the hazards of these environmental pollutants and to develop the technology to abate them. I do not believe, however, that even yet we fully realize the necessary degree of commitment to this task which must be made. The problems cannot be solved piecemeal; rather, they must be studied in coordinated programs that look for common denominator solutions.

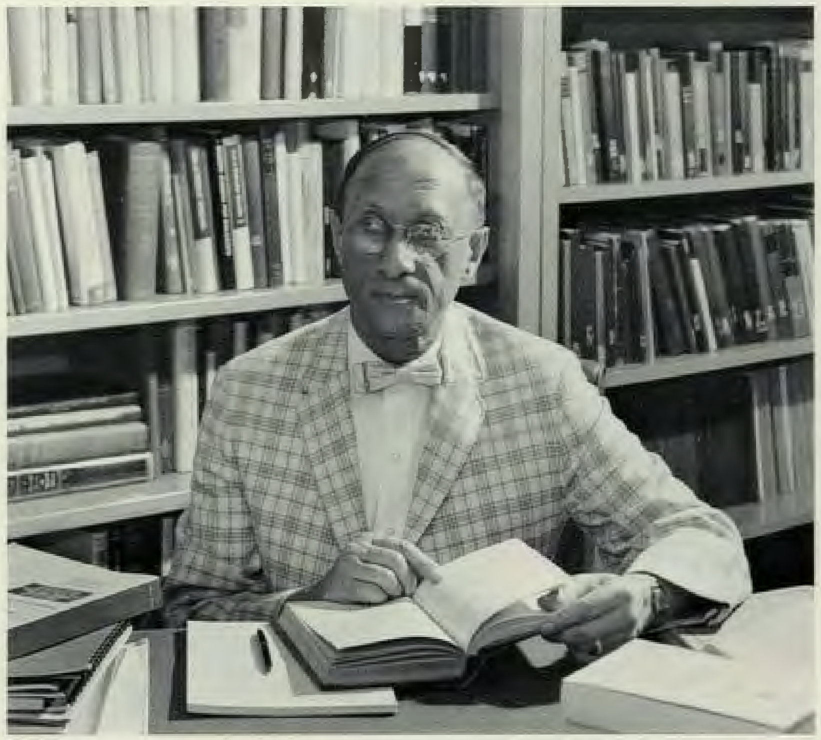
And so, in answer to Congressman Holifield's question: The Oak Ridge National Laboratory and, more broadly, the Oak Ridge scientific complex provides a unique national resource to attack many of the problems of pollution. The mission-oriented nature of the Laboratory, in whose projects some of the world's outstanding basic research scientists are engaged, equips it to investigate these problems, assess their biological hazards, and develop the technology for abatement of some of them.

It is, indeed a mission that needs to be undertaken, and soon.

"The Problems . . . Are With Us . . ."

Overabundance of pondweed chokes the public marina at Warriors Path State Park. It is believed to be caused by excessive nutrients in agricultural and industrial waste effluents. (TVA Photo)

Associated with Oak Ridge as a consultant since 1948, Eugene Guth is currently technical advisor to ORNL Director Alvin Weinberg. A native of Budapest, Guth was educated at the University of Vienna, and was later research associate at Zurich, Leipzig, and Vienna. In 1937 he joined the University of Notre Dame where he became Research Professor of Physics and established the Polymer Physics Laboratory, which he directed. He is one of the founders and chief developers of the fields of both the physics and physical chemistry of polymers. In 1965 he received the Bingham Medal, the highest honor of the Society of Rheology. He initiated the statistical treatment of flexible randomly linked polymer molecules in Brownian motion and applied it to the explanation of rubberlike elasticity. Guth's article reaches back through a thirty-year acquaintance with Oppenheimer and many of his students and associates.



Julius Robert Oppenheimer (1904-1967)

A Fellow Physicist's Tribute to a Pioneer of the Nuclear Age

By Eugene Guth

WITH the death of J. Robert Oppenheimer on February 18, 1967, the scientific world in general and American science in particular suffered a great loss. Though the world may remember him longest for his instrumental role in the development of the atomic bomb, Oppenheimer excelled as a creative scientist, an inspiring teacher, a public servant and a great leader within the scientific community.

He was also a great wartime leader and dedicated post-war public figure. In both of these capacities Oppie (as he was usually called by his friends) had some influence on Oak Ridge.

Born in New York on April 22, 1904, Oppenheimer was a sensitive son of highly cultured parents, members of an "Ethical Community." His father was a textile importer. Already in his early years, his family provided him with an environment where his lively mind was given every opportunity and encouragement to develop. He was surrounded by books and paintings and had a small chemical laboratory built for him when he was still very young. At the age of five he started a rock collection and was admitted to the New York Mineralogical Club when he was only eleven years old—all this in spite of the fact that he suffered from tuberculosis in his youth.

In 1922, he went to Harvard, with the initial intention of becoming a chemist. In addition to chemistry, physics and mathematics, he also learned Latin, Greek, German and Dutch, finally graduating "summa cum laude" in 1925, completing four years of work in three and shifting from chemistry to theoretical physics. He went to Europe, at that time the center for red-hot atomic and nuclear physics. In nuclear physics, Rutherford, at Cambridge, was the leader. In theoretical atomic physics, Born had created a center at Göttingen. Oppenheimer first worked under Rutherford then at Born's invitation went to Göttingen, where he received his Doctorate in 1927. He returned in 1928 to the United States as a research fellow at Harvard and at the California Institute of Technology. In 1929 he took his first teaching positions, concurrent appointments as assistant professor at Caltech and at the University of California at Berkeley, advancing to full professor in 1936. He married Katherine Harrison in 1940 and is survived by her and their two children, Peter and Katherine.

Beginning in the fall of 1941, Oppenheimer, by then the chief theorist at Berkeley, became more and more involved in the United States' effort to manufacture atomic weapons. In 1943 he was chosen director of the Los Alamos Laboratory, established at a site of a fashionable boys' school, near the Oppenheimer family summer ranch in northern New Mexico. He remained at Los Alamos until the fall of 1945 when he returned to Berkeley.

Accelerated Developments at Oak Ridge

Oppenheimer's great wartime leadership as director of the Los Alamos Scientific Laboratory is well known. It is, perhaps, lesser known that, at least on two occasions, he directly accelerated developments at Oak Ridge also.

Oppenheimer's first contact with the uranium project arose when, in 1941, Lawrence asked him to help on the electromagnetic separation process for the production of U^{235}.

Oppenheimer as the wartime director of Los Alamos Scientific Laboratory.

Oppenheimer's suggestions led to a considerable increase in the efficiency of the process. Of course, it was natural that Lawrence ask Oppenheimer to participate in his project, since Oppenheimer was in close touch with the experimental work of Lawrence's group. In the fall of 1941, at Lawrence's recommendation, Oppenheimer was invited to the first comprehensive discussion of the physics of the bomb. Oppenheimer made preliminary estimates of the critical mass needed for a U^{235}-bomb (between 2 and 100 kilograms). In 1942, Oppenheimer organized a group for weapon study. New cross-section data led to a critical mass for a sphere of U^{235} between 2.5 and 5 kg. In the middle of 1942, Oppenheimer was chosen by A. H. Compton to head a fast neutron theoretical research group. This group estimated the U^{235} critical mass to be between 5 and 10 kg. Incidentally, already at this early time, the group envisaged the possibility of an H-bomb! In the beginning of 1943, construction of Alpha and Beta tracks was initiated at Y-12 at Oak Ridge. Somewhat later, the Oak Ridge Gaseous Diffusion Plant, K-25, got started. It was thought that Y-12 and K-25 together could produce enough U^{235} for a bomb.

In the meantime, Los Alamos had been established, with Oppenheimer as director. It is to the great credit of General Groves that he fully approved the selection of Oppenheimer as director in spite of Oppie's lack of previous administrative experience. Moreover, General Groves always emphasized that Oppenheimer was a magnificent director. This was the beginning of a dramatic story. The estimates for the critical mass had their "ups" and "downs" or rather "downs" and "ups". First they were more optimistic. This led to the visualization of smaller production plants, than the later, more pessimistic, estimates necessitated. His theoretical group made new estimates of the critical mass, roughly tripling the previous estimate. This led to plans to enlarge Y-12, inasmuch as some barrier troubles developed at K-25. In March 1944, the Military Policy Committee called an important meeting in Chicago; General Groves, Oppenheimer, and Lawrence all expected the expansion of Y-12 to be the chief issue. However, for some reason, the Y-12 expansion was not discussed. In a roundabout way, through a letter from Oliphant, Lawrence heard rumors that U^{235} would be abandoned in favor of Pu^{239} from Hanford. Receiving a wire from Lawrence about this matter, Oppenheimer reassured him that he still favored the Y-12 expansion. Lawrence went immediately to Oak Ridge to accelerate developments. Still, it looked as though even the combined capabilities of Y-12 and K-25 would not suffice to produce enough U^{235}. Here, again, Oppenheimer came up with the suggestion to push the liquid thermal diffusion method. His suggestion led to the construction of the S-50 plant in Oak Ridge. Combination of S-50, K-25, and Y-12 finally produced U^{235} in sufficient quantity.

Oppenheimer traveled to wartime Oak Ridge several times, first in the fall of 1943, and on at least one occasion visited his brother, Frank Oppenheimer, who worked at the Y-12 plant from 1943 to 1944.

After the war, in February 1946, Oppenheimer revisited Oak Ridge as a member of the Lilienthal Board of Consultants connected with the Acheson-Lilienthal report. As a matter of fact, Oppenheimer was the guiding spirit of this Board. The report asked for an international authority for the control of atomic energy in all its ramifications. The job of the authority would have been dual: development of atomic reactors for peaceful uses and also of atomic weapons, if needed. This remarkable plan was endorsed by a State Department committee chaired by Dean Acheson and was declared official U.S. policy. Baruch presented it to the United Nations but there, unfortunately, the U.S.S.R. rejected it. Oppenheimer as a wartime leader and as a postwar public figure was a "realist" and one of the first to see that the American plan would be rejected by Russia.

After creation of the AEC early in 1947, Oppenheimer was appointed chairman of its General Advisory Committee (GAC). He was also a consultant to DOD on atomic weapons and on the general strategic policy of U.S. The GAC, under Oppenheimer, recommended extensive basic research which gave U. S. its present leadership in nuclear and high energy physics. The national laboratories at Oak Ridge, Brookhaven, and Argonne were either established or strengthened during this period. The AEC and its GAC took care of the need for fissionable materials, both for reactors and for atomic weapons. Sufficient production facilities in Oak Ridge and elsewhere were constructed for this purpose forming the basis for our present pre-eminence in atomic energy.

In 1947 Oppenheimer left Berkeley (and Pasadena) to become director of the Institute for Advanced Study at Princeton, a position which he held until 1966.

Wide Range of Research

As a physicist, Oppenheimer's original work covered a tremendous range corresponding to his extraordinarily wide interests. With Born, he wrote a fundamental paper on the quantum mechanics of molecules (1927); the Born-Oppenheimer method has been applied also in other situations in which particles of widely different masses interact with each other. Oppie was the first (1928) to call attention to the importance of particle exchange in scattering processes. He was also the first (1928) to recognize the possibility of the "leaking" of the electron from a hydrogen atom in an intense electric field. He was also first to understand (1930) that the unfilled, negative-energy states cannot correspond to protons, as originally suggested by Dirac, but must be associated with (anti) particles of the mass of electrons. Jointly with Ehrenfest, he showed how the statistics obeyed by nuclei could be determined from the statistics of their constituents. This work gave strong evidence against the existence of electrons within nuclei a year before the discovery of the neutron. With his students, H. S. Snyder and G. M. Volkoff, and his associate, R. Serber, Oppie was the pioneer (1938) in the general relativistic treatment of the gravitational collapse of highly massive stars. This pioneering work is one of the basic ideas in current attempts to understand the recently discovered quasars.

Oppie also first (1947) suggested the role of the neutral pi meson in the origin of cosmic ray showers. With H. W. Lewis and S. A. Wouthuysen, he developed one of the first (1948) theories of multiple meson production in very high energy proton collisions. Finally, with W. A. Arnold, he published (1950) an influential paper on transfer of energy in biological molecules.

Of almost as great importance as his own papers, only a few of which are mentioned here, was his participation in the work of many students and colleagues and his ever-inspiring leadership in scientific conferences and informal discussions. A great many papers and conference reports of the last 35 years contain comments by and acknowledgments to Oppenheimer.

Although his own work was distinguished by originality and diversity, of at least equal significance was his fabulous grasp of what was going on in science in general, physics in particular. Few scientists had his wide, and still deep, knowledge of physics. His incredibly quick mind absorbed new ideas like blotting paper.

Moreover, he always believed that physics is an experimental science and maintained close contacts with the research groups headed by Lawrence at Berkeley, and Millikan, C. C. Lauritsen and C. D. Anderson at Pasadena.

As a teacher of theoretical physics, Oppenheimer created two great schools at Berkeley and Pasadena in the 1930's and at Princeton in the last twenty years. Following his years in Europe, it is not much exaggeration to say that he almost singlehandedly carried quantum theory to the U.S. His brilliance as a teacher with an extraordinarily vivid personality and extremely wide range of interests helped form many of the great theoretical physicists in the U.S. In Pasadena and Berkeley, all aspects of quantum theory, electrodynamics, nuclear structure and reactions, the then newly discovered positrons and mesons, cosmic rays, general relativity, and statistical mechanics were intensely discussed in Oppenheimer's group.

At Princeton, Oppenheimer was the guiding spirit for dozens of the best and most active young postdoctoral theoretical physicists. He created the world's center for theoretical high-energy physics and field theory. In the 1950's Princeton became the "Mecca of Theoretical Physics." Among young post-doctorals spending some time in Princeton and receiving, so to say, final training and taste were Gell-Mann, Goldberger, Thirring, Chew, Low, Nambu and many others from this country and from abroad. In addition to these young people, many established leaders like Pauli, Dirac, and Yukawa were more or less frequent guests at the Institute. The superb, permanent staff, assembled by Oppie, included Placzek, Dyson, Pais, and Lee and Yang, who did their revolutionary work on parity non-conservation at the Institute.

Concern for Science and Culture

In his Princeton period, Oppenheimer became deeply concerned with the relations between the various sciences and, even more, with the interrelations of the sciences with our culture in general. The inevitability of increasing specialization in the sciences made communication between neighboring fields of knowledge more and more difficult. Still harder, he felt, was the communication of the impact of science to intelligent man (" . . . thus progress in learning about the world of nature has changed rather profoundly not only what we know of nature, but some of the things that we know ourselves as knowers.") He had "a strong conviction that this experience is one which we would gladly extend beyond the range of limited technical communities." Oppenheimer was also eager to acquaint the non-physicist with the generality of the idea of complementarity, introduced originally by Niels Bohr: " . . . an atomic system . . . may have billions and billions of atoms in it, but always it is a finite part of the world; and in order that you can make an observation of it, you must use the rest of the world for the machinery with which you do it." Especially Bohr has pointed out the analogies between this situation of complementarity and familiar traits in life: "He has had, I think, a double purpose: one to illuminate the situation in physics and one to reinforce our interest in complementary aspects of human life."

Oppenheimer also emphasized the limitations of science. " . . . The sense of having to live and act in response to tradition, good judgement, and wisdom, which we have now, will not ever be alleviated by any development of the sciences." Still, he hoped that science and the scientist can and will contribute "to the making of a world which is varied and cherishes variety, which is free and cherishes freedom, and which is freely changing to adapt to the inevitable needs of change in the twentieth century and all centuries to come, but a world which, with all its variety, freedom, and change, is without nation states armed for war and above all, a world without war."

As an apostle of international cooperation in general, science in particular, Oppie played an important part in the years 1947 to 1949 in the discussion which, finally, led to the establishment of CERN, the European organization for nuclear research, in Geneva.

His post-war ordeal which resulted in the withdrawal of his security clearance has been discussed time and again. Finally, however, our government made proper amends. In April 1962, President Kennedy invited him to a White House dinner for Nobel prize winners. And in 1963, just after taking office, President Johnson presented Oppenheimer with the highest honor given by the U.S. Atomic Energy Commission, the $50,000 Enrico Fermi award. In his acceptance remarks Oppenheimer said, "I think it is just possible, Mr. President, that it has taken some charity and some courage for you to make this award today."

Oppenheimer's work continues to live in the accomplishments of his many students and friends. His truly brilliant mind is best described by his long-time friend, C. C. Lauritsen, "This man was unbelievable. He always gave you the answer before you had time to formulate the question."

In this essay, which first appeared in the National Academy of Sciences report, "Applied Science and Technological Progress," ORNL Director Alvin M. Weinberg shows how the resources of large laboratories might be brought to bear on problems having both social and technical components. The first part of this essay, in which the "Technological Fix" is described, is presented in abbreviated form since it was published in full in *The ORNL News*, June 17, 1966.

Social Problems and N

By Alvin M. Weinberg

WE ARE handicapped in dealing with social problems not only because they are inherently so difficult but also because our resources for attacking social problems are incomparably smaller than our resources for attacking technological problems. Herein lies a serious dilemma: there is a severe mismatch between the government's magnificent scientific resources for attacking *technological* problems, and the seemingly *social* character of the problems that the government is trying to solve. It is almost as though the government, in addressing itself sharply to these broad social questions, finds itself the victim of a kind of technological obsolescence. Its laboratories, and its contractors, dominated so much by their original military missions, are by-and-large hardware-oriented, whereas many of the problems which must be solved are social.

Is there any way of bringing the largely technological resources of the government to bear on these social problems? I believe there are two related avenues to achieving this end. In the first place, many problems that are traditionally viewed as being primarily social possess stronger technological

ational Socio-Technical Institutions

components than one at first suspects.[1] They therefore may admit of technological palliatives or even "fixes" which hopefully can buy the time necessary to get at the "cause" of the social problem. And secondly, to the extent that these social problems admit of technological solutions, I believe the country's technologically oriented instrumentalities—its laboratories and hardware contractors—can be modified and then mobilized to find partial solutions to deeply important social problems.

Technological Components of Social Problems

Can we identify technological components in some of the "social" problems to whose resolution our Great Society is now dedicated? If these technological components are sufficiently well defined—if, for example, they find their expression in the invention of a single device—then to this extent the underlying social problems become more tractable than is the case if we cannot identify such technological components. For, in general, a technological invention is easier to make and put into use than is a social invention.

What are some of the Technological Fixes that one sees on the horizon? I shall list a number of obvious ones. Since those social problems that already have an identifiable technological component are the ones that are most readily dealt with by technological means, I shall first list social problems that have a large technological component.

Air Pollution and Nuclear Energy: Take the matter of air pollution. Our air is polluted mainly by the combustion of fossil fuels. Ten million tons of sulfur dioxide pour into the air each year because many of our large central power plants burn soft coal that contains 1–4% sulfur.

Until very recently no remedy to this problem was apparent. But now, as the result of a major breakthrough in reactor technology, it looks as though pollution from fossil-fuel burning, central power plants can eventually be eliminated, and at the same time the price of electricity can be reduced.

[1]This point has been stated very well by Richard L. Meier, *Science and Economic Development: New Patterns of Living*, 2nd Ed., 144, The M.I.T. Press, Cambridge, Massachusetts, and London, England (1966).

For example, the 2200 Mw Browns Ferry Boiling Water Nuclear Plant being built by General Electric for TVA will produce electricity at 2.4 mills/kwh, almost 0.5 mill/kwh less than a coal-fired plant at the same site. The power plant will emit no noxious fumes, and even the chemical plant that reprocesses fuel elements can be designed so as to emit no toxic gases.

Nuclear Desalination: Another major social problem with strong technological implications is water. Here the underlying difficulty centers around the allocation of a natural resource that is abundant in some places, scarce in others. How does one decide whether water is to be used for watering a lawn or for manufacturing steel; or whether the Colorado River is to supply Arizona or Los Angeles? And indeed, in most discussions of water policy, the implicit assumption is made that our supply of water is limited, and that its use by one group would deprive another group of it.

At least part of this attitude toward water policy ought to change as a result of the great advances being made in nuclear desalination. For large cities that are close to the sea, and are not too high,[2] desalted water should be available at about the same price as is now paid for municipal water from conventional sources—around 20¢/1000 gallons. This technological solution to the water problem is now feasible only in very large-scale plants. But the technology is moving fast and water from the sea at 10¢/1000 gallons—a price which is feasible for certain kinds of agriculture—appears to be a reasonable, though difficult, long-term goal.

The Safe Car and Traffic Safety: Perhaps the prototype of the Technological Fix is the safe automobile. Traffic safety had, until recently, been viewed primarily as a social problem. Laws were passed and enforced, drivers were educated, safety campaigns were launched, and yet the traffic death toll remained high. Ralph Nader's argument—that it is easier to improve the car (a technological problem) than it is to improve the driver (a social problem)—has a kind of transparent logic that I find appealing.

Technological Mechanisms for Stabilizing the World Order: The H-bomb is a peacekeeper in the sense of its having made large-scale war irrational. Yet this is not sufficient; if technology is to offer a means for stabilizing the world order, it will have to make small wars irrational, and it will either have to invent some new mechanisms, other than war, for achieving social change, or create a generally affluent world in which pressure for violent social change is much reduced.

Is it at all likely that technology can make small wars irrational undertakings? Obviously, the technological solution to guerrilla or small-scale war is far more complex than the simplistic "solution" offered by the H-bomb, and may even be impossible. And yet, as our experience in Vietnam seems to show, technology can make guerrilla warfare more and more difficult to wage. Whether it can make it difficult enough to persuade all concerned that some technique other than war must be used to settle human controversy is a moot point which I think must at least be explored vigorously.

The "Social" Problems

What about the problems that are much more obviously social and that seem to have very few technological components such as crime, or race relations, or urban development? Can we discern new technological components in these social problems that enable us to make some progress on them?

Crime is the problem perhaps most amenable to a technological approach.[3] Dr. A. V. Crewe, former director of the Argonne National Laboratory, has pointed out that the resources of modern technology have hardly been tapped in society's attempt to make crime totally unprofitable. For example, Crewe suggests that some of the methods developed for automatic scanning of bubble-chamber plates could be used to identify fingerprints much more accurately than can now be done. Or, with modern miniaturized electronics, one could mass produce personal "burglar" alarms that would considerably increase the risk a prowler would have to accept in accosting his intended victim.

Apprehending, say, 90% of all criminals in cities ought to sharply reduce crime in the city, but it does nothing to eliminate the causes of crime: poor environment, poverty, broken homes, and the like. Yet reducing the overt expression of these scars on our society can only help, not hinder, the slow and painful process of reducing such social disfigurements. To persuade bitter, frustrated individuals

[2]If electricity is available at 2 mills/kwh, the cost of the energy needed to raise the water 100 meters is about 0.2¢/1000 gallons.

[3]This possibility was alluded to in President Johnson's State of the Union Address, January 10, 1967. See also, A. V. Crewe, "The Scientific Control of Crime," *Chicago Today IV*, 51–54 (Winter 1967).

that crime does not pay, to deter them from a life of crime, can only prove helpful to them, as well as to the community that suffers because of their hostility.

It was Huntington[4] who pointed out that race riots seem to be correlated with hot, muggy weather. Certainly our racial disorders seem to peak in the summer; and, I would suspect, for two reasons—during the winter it is often too cold to go out; and second, if one lives during the summer in an unappealing, hot apartment, it is more comfortable to be outside. Thus, if the Negro's home surroundings could be improved, especially in hot weather, he would be less prone to spend time on the streets. The most obvious improvement would be air-conditioning equipment; thus, in the various projects to rehabilitate Negro housing—such as the efforts in Wilmington, Delaware—I would give air conditioning a high priority.

This technological approach to race relations is aimed simply at reducing violence, at preserving an atmosphere in which social solutions can be worked out. To many they may have too much flavor of the Roman Circus, as a heartless means of keeping the masses subjugated, while the classes attend banquets. Yet I cannot accept this caricature of America. I am persuaded that we are moving rapidly in race relations, and that one of the main dangers comes from the violence that has been injected into the situation. Let technology render racial violence irrational. I see much more hope for a satisfactory outcome to our racial problems in a calm atmosphere than in one marred by violence. As with all Technological Fixes we shall be buying time which, if we are wise, will be used to root out the causes of our social problems.

The Role of the National Technical Institution

I have tried to show that many of the social problems that we are now mobilizing around have stronger technological components than may at first be apparent. This is not to say I believe that for every social problem there is a Technological Fix; it is rather that where a Technological Fix is available we ought to get on with developing it as urgently as the importance of the problem demands.

The Technological Fix will almost always be only a partial answer to the social problem. For example, the problem of civil defense obviously has many important technological elements: can blast shelters be designed to resist fire and bacterial warfare? Can shelters be interconnected so that families may be reunited in relative leisure below ground rather than frantically seeking each other above ground? Can the shelter system be designed to serve some constructive civilian purpose, such as conveyance, or parking, or as a utility pipe tunnel?

But in addition to these technical questions there are innumerable nontechnical issues: acceptability of civil defense, or predictability of behavior in a shelter, or organization of the population for civil defense. What is needed in a complex, socio-technological matter like civil defense, is a "*coherent doctrine*"—that is, a set of precepts and viewpoints, some from the technological sciences, some from the social sciences, some not from science but rather drawn from common sense and experience, that constitute a rational, integrated approach to the problem.

In many instances, development of a coherent doctrine would involve, or might even center upon, one or a few pieces of hardware—as for example, the approach to air pollution via development of nuclear energy. In other cases the coherent doctrine would be much less dependent upon the Technological Fix. The essential point is, however, that the problem under consideration must be looked at as a whole, and the remedies must be sought widely rather than being unnecessarily restricted to traditional disciplines.

Such a coherent doctrine, especially if it contains strong technological components, is best developed in large multidisciplinary institutions whose purpose is clearly the establishment of such doctrine. Examples of such institutions are the Atomic Energy Commission's mission-oriented laboratories—Los Alamos, Livermore, Argonne, Oak Ridge. The weapons laboratories, together with Sandia, have been remarkably successful in their development of nuclear weapons. Moreover, much of the doctrine we now follow in our deployment of atomic weapons, and the concepts of atomic warfare, can be traced to viewpoints developed at these laboratories. In much the same way, our successes in civilian nuclear energy can also be traced to the multidisciplinary laboratories, along with the Bettis Laboratory of Westinghouse and the Knolls Atomic Power Laboratory of General Electric.

[4]Ellsworth Huntington, *Mainsprings of Civilization*, New American Library, New York (1959).

The water-moderated line of reactor development, on which almost the entire nuclear energy enterprise in this country is based, traces its origin to early work done at Oak Ridge and at Argonne: the essential features of the system were conceived there, and were then developed by the big industrial atomic power laboratories. Moreover, the development of nuclear energy has required more than technology. Economic and public safety aspects have had to be taken into account in the formulation of overall strategy, and these, along with the necessary technological considerations, have been synthesized in the reactor laboratories into overall doctrines.

I recognize several elements in the AEC laboratories that have played an important part in their success. Perhaps most important, the laboratories, at least in their earlier days, were viewed as institutions rather than as a collection of small projects operated puppet-like from a remote station in Washington. The entire responsibility for achieving the H-bomb, for example, was placed squarely upon the Los Alamos Scientific Laboratory. This is to be contrasted with the method of letting a multitude of small contracts from Washington, a practice that is desirable and necessary for basic research or when one is casting about for completely original ideas but is insidious when aimed at developing a specific device or formulating a coherent doctrine. For coherent doctrines can be developed only by coherent institutions. I can hardly think of a greater catastrophe befalling us than would have occurred had we tried to develop the H-bomb by letting many separate contracts, each of which dealt with a small piece of the entire job. Yet this practice of letting many small contracts to get an applied job done is very prevalent now.

If an institution is given the entire responsibility, and if in responding to this responsibility it deploys itself coherently and solidly against the problem, then the institution will need strong and informed management. In some sense, the director of the big institution is the key to the achievement of the coherent doctrine. If he is forceful and energetic and enthusiastic he will be able to mobilize his people around the task at hand. But I believe he should have another quality: he should somehow be in a position to ask, always, whether his entire enterprise makes sense, whether the tasks that the institution is involved in are in fact in the interest of the country. This feeling can come only from contact, personal as well as formal, with those who make science policy in our country. For this reason I would recommend that the President's Science Advisory Committee always have among its members a couple of directors of our major national scientific institutions—not necessarily for the insight that they might bring to the deliberations of PSAC, but more for the education that they will receive and that will be manifest in the relevance to our nation of the activities of the laboratories these directors lead.

But, if big laboratories are to attack social problems, even those susceptible to Technological Fixes, they will have to acquire more appreciation of the social components of such problems. Thus I would visualize mission-oriented institutions that combine the characteristics of RAND or the Brookings Institution and of Los Alamos. There would be both "hardware" and "software" types with the former exploring technical means of achieving socially desirable ends, and the latter investigating the consequences of such technical inventions, posing social questions, perhaps articulating the coherent doctrines that are developed by the institution.

What I am describing is really not so very different from some existing institutions; the Stanford Research Institute perhaps comes most readily to mind. Many corporations already have this interplay—between market analysts on the one hand and, say, insecticide chemists on the other. My proposal amounts to establishing, in those areas of *social* concern that clearly have technological components, multidisciplinary institutes that address themselves to these problems. Thus as new agencies with broad social responsibilities, like the Water Resources Council, or the Environmental Science Services Administration, or the Department of Transportation, or the Department of Housing and Urban Development, are set up, one of their first tasks ought to be to establish the nuclei of such multidisciplinary laboratories. And, of course, the first task of such nuclei would be to see whether there are points of departure, particularly those having technical content, that the laboratories can get their teeth into.

Can existing mission-oriented, multidisciplinary laboratories be redeployed to advantage around these social problems? Fully $4 billion of the federal government's research and development budget goes for support of all these government laboratories, and, if some of them could be redeployed in this manner we would be the better for it. However, I can see three difficulties in such redeployment. First, some public opinion to the contrary not withstanding, many of these laboratories are still heavily involved in matters of the utmost importance, such as development of the breeder reactor. Second, an existing laboratory may not have the necessary skills to redeploy: could Argonne take on the job of crime, or NASA-Houston the job of developing the artificial heart? Actually I am rather optimistic in this regard. These laboratories tend to be isomorphic; they all have physicists, chemists, engineers, and mathematicians. Some of them have biologists, and a few even have social scientists. Naturally, in any redeployment, jobs ought to be assigned where skills exist or can be mobilized. Thus Sandia, a fine weapons laboratory, might take on the important job of small-scale warfare, or Lincoln Laboratory, the job of improved surveillance. We at Oak Ridge have become a full-fledged water laboratory without having to hire an appreciable number of chemists or engineers: heat transfer in a multistage still is similar to heat transfer in a boiling water reactor, and the rejection of salts by membranes is closely allied to chemical separation by ion exchange.

But there is another, perhaps more serious, difficulty in redeploying our government laboratories around the new set of social problems. We really do not have any *government* laboratories; rather, we have government *agency* laboratories. An agency laboratory is supposed to work on missions assigned to its sponsoring agency by Congress. But agency missions have a way of becoming obsolete, especially, as Harvey Brooks puts it, when the agency is organized around a technology. NASA possesses many of the finest laboratories in the country; what is to become of this apparatus after the Apollo mission has been completed?

As matters now stand, it is dangerous for an agency laboratory to deploy itself too strongly around problems which are of interest to an agency other than its own. For, in so doing, the laboratory management makes public its belief that the agency for which it is working either is no longer very important, or that it has more scientific resources than it really needs. Moreover, if a laboratory allows itself to become truly "national" by redeploying around urgent problems outside its agency's own responsibility, it may soon find itself in a position where no agency feels responsible for it *as an institution*. And, as I have already stressed, coherent doctrines are framed only in coherent institutions: if the institution becomes a collection of separate, precariously supported pieces, there is little likelihood that it will develop a coherent anything—either doctrine or hardware!

Yet precisely herein lies one of the great strengths of the multidisciplinary "national" laboratory. By virtue of its position as a developer of a coherent viewpoint, it can reintegrate at the working level the parts of a national problem that so often become fragmented among many different agencies or different parts of the same agency. The most rounded and most coherent view of a complicated techno-social problem often resides in the expertise in the laboratory rather than in the central headquarters. This integrative function of the laboratory is to my mind a most precious attribute of these institutions, one which we should try hard to preserve and promote.

Despite these difficulties, some redeployment has already occurred. And indeed in its 1960 report to the Joint Committee on Atomic Energy, the U. S. Atomic Energy Commission stated: "From time to time, the Commission will utilize these laboratories . . . for urgent tasks . . . of importance to the nation". Some of the AEC laboratories have undergone a partial redeployment: ORNL for example is now an arm of the Office of Saline Water, of the National Institutes of Health, and of the Office of Civil Defense. Although we have had some rough going in our efforts to redeploy, I believe the redeployment, on the whole, has been successful. I would therefore urge that such rather informal redeployment be encouraged wherever it seems to be expedient. In most cases the judgment of expediency can best be made by the laboratory management. Eventually one would hope that, after many more laboratories have redeployed informally, some government-wide policy (perhaps involving a holding company for government laboratories such as was suggested in the Bell report) can be formulated to give these redeployed laboratories a home in government.

The other possibility would be to create ad hoc, new laboratories devoted to each of these newly identified social problems. Whether in any given instance a new institution is better than a redirected older institution one cannot say. I suppose I have an aversion to creating new laboratories, especially when I see fine older government laboratories preoccupied with matters that to me seem no longer to be as centrally important as they were when the laboratories were created. On the other hand, new organizations have the advantage of tending to break up old habits of thought, and of

Aerial view of Oak Ridge National Laboratory at X-10. The steam rising in the distance is from Oak Ridge Gaseous Diffusion Plant, five miles to the west, at K-25.

bringing fresh blood into top management. Yet I think the issue cannot be prejudged. The important point is that big public problems, and this includes big social problems that have strong technological components, are best handled in big, mission-oriented, government-supported laboratories. Whether we set up new laboratories or redeploy older ones is a matter of tactics to be decided case by case.

I have said nothing about the role of the university in the resolution of these big problems. Of course the university will participate. Individual professors and their students ought to be enlisted to help, particularly in the most delicate and deepest thinking that must underlie any "coherent doctrine." And within the universities a coterie of specialists must be created who will be prepared to devote their lives to the relevant fields. But I cannot visualize the university, as an institution, taking the responsibility for, say, the problem of crime, or of civil defense, or of urban renewal. This does not in any sense preclude the establishment of mission-oriented, multidisciplinary laboratories as adjuncts of universities like, for example, the Jet Propulsion Laboratory at Cal Tech, or the Lincoln Laboratory at M.I.T. But the connection with the university is peripheral, not central. The laboratory having responsibility for a given job must be ready and able to focus wholeheartedly on the job. To the extent that a connection with a university helps the laboratory get on with its mission, as by enabling it to recruit better people, such a connection is valuable.

Nor have I mentioned the role of "private" industry in this mobilization around these broad questions. I use quotation marks around the word "private" because most of the issues we are now addressing, being social, hardly lend themselves to profit, at least initially. But the real difficulty is that the means available to enlist private industry on public problems, the short-term contract, simply is too fragile to work well on open-ended problems whose solutions are never very clear cut. How do we know when our cities are renewed; or our civil defense adequate; or our crime rate acceptable? Thus, there are few criteria available for determining in such situations whether or not the private firm is doing a good job. Under the circumstances I should think there might be a tendency to give the contracting officer the answer he wants, rather than developing an independent, and possibly unpopular, "coherent doctrine."

Thus, insofar as such doctrines can be developed best in a viable institution whose existence is not always at stake (as is the case with many small, private "think-factories"), I would argue that, on the whole, these institutions should be set up as long-term, government-owned entities. This doesn't mean that they could not be operated under contract by either an industry, or a university, or a combination of universities. But the exact arrangement in this regard is a secondary matter.

Dangers and Second Thoughts

The burden of my argument is that, in attacking social problems, we ought always to strive for establishing what I call "coherent doctrines." The easiest such coherent doctrines are those that can be embodied in the Technological Fix. Insofar as such Technological Fixes can be a priori identified, their development can best be accomplished in big national laboratories. In cases where the Technological Fix cannot be a priori identified it is still worthwhile to deploy technologically-oriented institutions around social problems, since modern social problems, almost without exception, have some technological components, and these components are best identified in the environment of a big laboratory.

Are there any dangers in following such a course? The first, and most obvious, is that by placing responsibility in a big technologically-oriented institution we may overestimate the importance of the technological component of social problems. As the social scientists are fond of saying, the technologists "are too simplistic" in their approach to social problems; technology can never replace the arduous job of the social engineer. And of course this is true. It is for this reason that I visualize these national laboratories for social problems to be seasoned, especially in the higher management, with software as well as with hardware types. One would hope that each could keep the other honest.

There is another danger. Will the laboratories, the developers of coherent doctrine, become too powerful? This is not an idle concern; I believe that some people, both within and without the armed services, consider RAND to be dangerous simply because it is so successful. Many of our strategic doctrines, and certainly much of the language in which the dialogue concerning strategy is conducted, can be traced to RAND. Since these matters touch upon some of the most sensitive areas of our society's concern, it is somehow disconcerting that they are formulated by experts who, at least from the outside, appear to sit apart and to operate on their own.

I suppose I have only one response to this sort of concern: establish in each case not one but rather two competing institutes that will keep each other honest. This worked very well with Livermore and Los Alamos, and with Oak Ridge and Argonne. I should think it would work well in every case where the issues of concern are sensitive, and where, because of technical complexities, they cannot be easily subjected to public debate.

And finally, I would leave a different word of caution. In committing ourselves to serious attacks upon our great social problems, we have perhaps unwittingly assumed that the methods of science—of analysis, of objectivity, of sharp definition—are going to work. But in this we make a great and unprovable assumption. As a physical scientist I can only say that physics and chemistry and engineering have worked in the past to solve technical problems. Whether science will also work for social problems, even those seeming to have technological components, cannot always be ascertained a priori; all we can say is that thus far we have no alternative to the hypothesis that science is effective. Yet we must not confuse putting a problem into the laboratory for solution with getting a workable solution to the problem. It would be tragic if we became so enchanted with our techniques and technologies, our Technological Fixes, and our coherent doctrines that we neglected to make as much progress as we could through the traditional instruments of government and by our own good common sense.

For in the final analysis, we shall have to depend on our good common sense. I recognize that Technological "Fixes" include such monstrous perversions as the ovens at Dachau: that a coherent doctrine can become a perverted doctrine if the instruments of power are captured by evil men. There is always danger that somebody will seize upon a partial truth developed by science to serve as the basis of a coherent doctrine which is tragically in error.

National institutions that combine broadly the viewpoints of both the natural and social sciences, and in which the differing viewpoints are allowed to compete, would seem to me to be less susceptible to being captured by a pet and erroneous doctrine than would inbred government bureaucracies. But one still must ultimately have faith that our tradition of decency and enlightenment will thwart any among us who are tempted to misuse the fruits of our new socio-technology, and that, on balance, we shall continue to move toward a more humane and rational society.

When the United States needed a really catchy exhibit for the first Atoms for Peace Conference in Geneva, an ORNL scientist "dreamed up" an idea. But that was only the start of a highly hectic, often amusing, and ultimately historical chain of events.

Project Aquarium

By François Kertesz

WE LIVE in an age in which everything—from military operations to social welfare projects—is designated by a catchy code name. The Second World War gave us the famous "Operation Overlord"; and perhaps the best known of the early postwar atomic tests was "Operation Crossroads."

Since then, we have been bombarded in newspapers and magazines by hosts of code-word-designated operations or projects. It is not surprising, therefore, that many people including some at Oak Ridge National Laboratory who were closely connected with it, are not able to identify "Project Aquarium." This descriptive code name designated the construction and operation by ORNL staff members of a swimming-pool-type reactor for the First Geneva Conference in 1955.

François Kertesz, who joined ORNL in 1951, is presently the coordinator of more than a dozen Laboratory Information Centers. Before his present position in the Director's Division, he filled assignments in the Chemistry Division, Reactor Experimental Engineering Division, and Technical Information Division. Kertesz was awarded the Ch.E. degree from the Institute of Technology in Stuttgart, Germany, and the D.Sc. from the Sorbonne. His professional affiliations include membership in American Chemical Society, American Society for Metals, American Nuclear Society, and American Society for Information Research. His linguistic ability, arising from his cosmopolitan background, made his contribution to the Geneva Conferences in 1955 and 1958 especially valuable. At both conferences he trained the guides who escorted visitors through the U.S. exhibits.

Until 1955, atomic energy had developed in utmost secrecy. Its practitioners had little contact with their colleagues in universities and industry. But with President Eisenhower's famous Atoms for Peace speech at the United Nations and the subsequent decision to hold the first truly open international nuclear conference, scientists the world over became hopeful that fruitful personal and professional contacts might be achieved.

Over-all preparations for the conference were placed in the hands of an organizing committee that appointed "scientific secretaries" representing most of the scientifically active countries (Robert Charpie, former ORNL Assistant Director, was one of them). Each country had its own committee. During the feverish preparations before the conference, every nation attempted to marshal its best scientific papers illustrating recent achievements and also to develop eye-catching exhibits for the simultaneously scheduled scientific show.

Obviously, it is quite difficult to prepare a scientific exhibit that is of interest to experts and laymen alike. American scientists submitted one proposal after another for the U.S. exhibit. Many were accepted and the organizers blocked out the necessary space, within the limitations arising from the structure of "Hall Fifteen" assigned to the United States at Geneva's Palace of Nations, built as a political meeting arena, during the dying days of the old League of Nations.

As a whole, most of the proposals represented excellent technical achievements but were definitely not spectacular enough to capture the imagination of the public. The country where atomic energy was born was expected to present something quite significant and never before seen by the public. Therefore, the suggestion forwarded by an ORNL scientist, Tom Cole, was received with great enthusiasm.

Cole who had helped to design the first swimming pool reactor, the Bulk Shielding Reactor, was at that time working on the control system of the ORNL Research Reactor. Being familiar with pool-type reactors, he recognized that they are doubly well suited for public display. First, their operation is very safe, especially at the low-power level he proposed. Also, this type of reactor is shielded by a transparent material, water, that makes it possible to observe the spectacular "blue glow" of Cherenkov radiation.

Clearly, presentation of such a reactor would offer an opportunity to demonstrate the reliable operation of automatic control systems, while the reactor itself could be used to carry out a number of neutron-physics experiments. This was considered to be of special interest to scientists from smaller countries who did not yet have access to an operating reactor.

The most important single feature of the proposal was that the exhibit would demonstrate to the international public that peaceful nuclear energy had an important role in society, that it was in competent hands, and that it could be lived with.

The story goes that Cole conceived the idea for the exhibit in a dream, and the next morning he energetically started his rounds to convince his colleagues. In short order, his proposal received the endorsement of ORNL management, and in their turn, the AEC officials who were charged with the preparation of the exhibit adopted it enthusiastically.

This, however, was not enough. The organization committee of the conference still had to be convinced, then objections of the Swiss federal and Geneva municipal authorities had to be overcome. These negotiations of a more-or-less diplomatic character took time, but they were successfully carried out and "Project Aquarium" came into existence. The word "aquarium" describes fairly closely the general type of the reactor. It was a system containing water, and people were supposed to see what was inside.

After the United Nations and municipal officials approved the project new problems arose. Obviously, the reactor was too big and too awkward to be placed in the marble halls of the Palace of Nations; therefore, construction of a separate building was considered. Inasmuch as the conference was of international scope, every participating country had to have access to the same facilities. Consequently, a similar offer was made to other nations, including the Soviet Union, advising them that each could present an operating reactor if it so desired.

While these diplomatic negotiations were carried out, work was started at ORNL and proceeded rapidly. There was a vast storehouse of information on this subject at ORNL because our Laboratory pioneered construction of this type of reactor, and ORNL metallurgists were among the country's leading experts in manufacturing the required fuel elements (in fact, for a long time, the rolling mill of Metals and Ceramics was the world's only manufacturer of swimming-pool-type fuel elements).

No difficulties were foreseen—after all, our backlog of experience was one of the cornerstones of Cole's proposal—and for a while none were en-

Lowering of the tank into the ground. The building was constructed around it while the reactor was being installed.

countered. Construction of the reactor went on with no more than the expected amount of trouble. The reactor was designed at top speed, construction was started, and assembly of the control system was well under way.

Then, like a bolt of lightning out of a blue sky, troubles were encountered in manufacturing fuel elements. Actually, this was more a legal than a technical problem. The MTR-type elements fabricated at our rolling mill were made of a uranium-aluminum alloy placed in an aluminum sandwich. The uranium in the alloy was enriched to a level exceeding 90 percent. Unfortunately, the 1954 Atomic Energy Law prohibited exporting uranium containing more than 20 percent U^{235}. The lower level of enrichment required an increase of the uranium-aluminum ratio resulting in a mixture with undesirable mechanical properties.

After some unsuccessful tests with such alloys, it was decided to use uranium dioxide mixed with aluminum powder, fashioning the mixture into compacts by powder metallurgy techniques. This method worked well in the laboratory, but a large number of the finished elements had to be rejected in pilot plant operation. Examination of rejects revealed the UO_2 reacted with the aluminum powder, forming the compound UAl_4—this crystal continued growing until it ruptured the protective aluminum plate.

This situation, needless to say, created concern at the Laboratory. Negotiations were pursued to overcome United Nations resistance, and Swiss authorities were assuring them that the reactor would operate safely. AEC people were assured that the ORNL staff knew how to design and build the reactor; they were promised the whole project could be completed without further delay, once official word was given. So, it was rather awkward to find out at this stage that we were not quite sure whether the necessary fuel elements could be successfully fabricated.

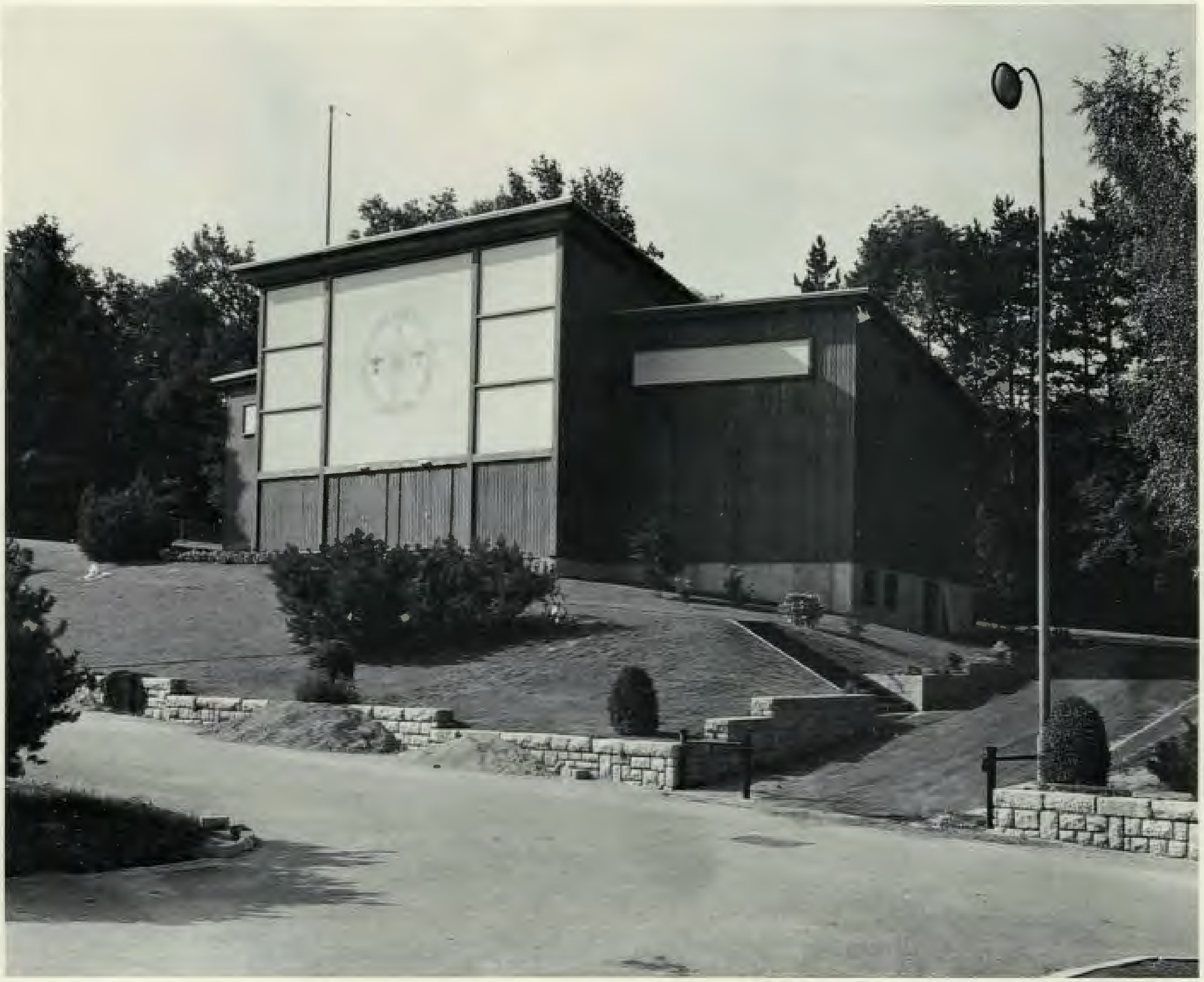
The Laboratory was fortunate to have experts in the metal-ceramics field. Only a short time before, Metals and Ceramics Division researchers had encountered a similar problem with stainless steel-uranium-dioxide powder, which exhibited an increased rate of attack.

Sintering was tried first to increase particle size, but this did not solve the problem satisfactorily—the agglomerates tended to break down. After some feverish experimentation and several seven-day work weeks for the ceramic laboratory staff, the problem was solved. Large hydrated uranium trioxide ($UO_3.H_2O$) crystals, made by an autoclave technique, were reduced to large-size UO_2 crystals. Use of these crystals yielded satisfactory fuel elements. The particle size was the most important quality control parameter, and the size-control method was excellent.

Externally, the UO_2 grains resembled their UO_3 parents, but their size was reduced by two-thirds. However, during the scaling up of operations to the pilot plant stage, no large production autoclaves were available. Thanks to design engineer ingenuity, a makeshift autoclave was made from large-diameter pipe. Quite naturally, it became known as "Genevieve." After some trial runs with Genevieve, the large-scale fabrication of fuel elements was started.

By this time, Russia and other countries decided

Construction of the reactor building on the grounds of the Palace of Nations in Geneva.



The building completed and ready for visitors.

they would not build a full-size operating reactor. They may have thought (with some justification) that nobody could perform the task during the short period remaining before the Conference.

Considering the bulkiness of the reactor and the large amount of auxiliary equipment, it was agreed that a separate building would have to be constructed to house it. The marble floors of the Palace of Nations could not be broken up, not even for a reactor. The Secretariat was prevailed upon to assign a suitable location.

The original plan, designed by Union Carbide Corporation's architect, called for a simple house to shelter the reactor. The architect's experience as chief designer for the Corporation's industrial exhibit program was very helpful in bringing out the spectacular features of this modern machine. The plan called for an elevated platform, housing the superstructure and reactor tank, to be spotlighted in an otherwise dark room. The glass front of the building, modeled somewhat after a Swiss chalet, was intended to act as a giant show window, allowing passers-by to see the reactor from a distance. Unfortunately, it turned out that it was not possible to find a glass pane of the desired size in Switzerland within the allotted time. Therefore, it was replaced by an opaque front, carrying the Atoms For Peace emblem. Even so, the building attracted considerable attention.

Project Aquarium obtained a good location on the Palace grounds, close to the exhibit hall and to the main meeting rooms, and everybody was happy—at least for awhile. However, when construction started, legal experts checking old documents discovered the original deed to the land assigned to the reactor building covered only surface rights. The question was, how many feet of digging into the subsoil would violate this requirement? After some diplomatic haggling, the technicality of a centuries-old document was overlooked and construction of the building was started in April 1955. A Geneva contracting firm was in charge of the work, under the supervision of an ORNL engineer.

One can imagine the problems facing this American engineer, who had to learn foreign practices in a short time, supervise a construction project by Swiss workers accustomed to metric units, and using American plans in English units. The construction boss also had to become accustomed to work habits of European craftsmen. The job called for a combination of talents, ranging from that of a slave driver to that of a suave diplomat. But thanks to the splendid cooperation between Swiss and Americans, the building was finished on schedule. Credit must be also given to the young, English-speaking Swiss foreman who, in no time, closed the gap between Swiss and American project personnel. The construction company manager's son, a young Swiss engineer, at that time a graduate student at MIT (and later an ORNL employee), was also of considerable assistance in overcoming the cultural differences between local people and visitors.

Organization of work in Geneva was greatly facilitated because Geneva was the headquarters of Union Carbide Europa, S.A. Inc. (pronounced in one word as UCESA), the European office of Union Carbide Corporation. It did an excellent job of locating contractors, smoothing out local difficulties, finding quarters for Oak Ridge personnel and assisting in the hiring of auxiliary personnel, such as interpreters.

While all this was going on in Europe, the project was formally organized in Oak Ridge. Proposals concerning exhibits to be installed near the reactor and experiments that could be performed during the reactor's scheduled two weeks of operation were considered. Health physics matters were emphasized, and one of the more prominent exhibit panels carried the pithy slogan "Radiation is Detected—Personnel Are Protected."

Because the Conference was sponsored by the United Nations, everything in English had to be translated into three of the other official languages—French, Spanish, and Russian. Luckily, they did not insist on also translating the material into the fifth United Nations' language, Chinese.

There was considerable discussion on how terms which had developed in secrecy should be translated into the other languages. A request to translate the word "scram" was answered by a French expert that this American slang word has no French equivalent. He was obviously not aware of the specific technical meaning of the word.

In Oak Ridge, meanwhile, the crew completed construction of the reactor, but the assembly went critical at a somewhat lower U^{235} content than calculated. An open house was then held for Laboratory personnel, the Geneva reactor story was announced and Life magazine published a photograph of it, as it appeared in the BSF pool.

After the critical experiment, the reactor was disassembled, crated parts were loaded into two giant C-124 Globemaster planes, and the reactor started its long trip across the ocean, accompanied by eleven AEC guards.

Moving the 22-foot-long, 10-foot-wide steel tank through the city streets to the site was quite a complex enough job. However, as the tank was being gently lowered into the hole in the ground which had previously been prepared for it, one of the supporting cables broke. The tank plunged into the hole and came to rest, undamaged but in a somewhat inclined position, like an inverted Tower of Pisa. As the tank was filled, the water level reached the top of the cylinder at one point while being several inches lower in relation to the tank on the opposite side. Because of the shortage of time, the tank could not be lifted and readjusted. The problem was ingeniously solved by a tour de force: the top of the tank was sliced off in such a way that the tank's top rim became horizontal. The walls, of course, were not quite vertical, but this posed no engineering or safety problems, and nobody noticed it.

By now only weeks remained before the start of the first conference on "Peaceful Uses of Atomic Energy."

The work really began to be hectic. As the exhibit building began to take shape, the Oak Ridge crew, with the assistance of Swiss craftsmen, uncrated and assembled the reactor.

The assembly was not as simple as hoped for, considering the reactor had already been put together successfully in the BSF swimming pool.

The bottom grid plate was adjusted to an exactly horizontal position before filling the tank with water. However, after filling, the weight of the water caused the bottom to buckle, and the plate had to be readjusted under water to a horizontal position by means of a socket wrench at the end of a 25-foot pole.

Our truly international crew (including some Italian laborers) started out working somewhat awkwardly, but within a very short time feelings became quite friendly. Excellent personal relations prevailed, and a strong team spirit developed between local workmen, laborers, and overseas engineers.

The building was supervised by the Oak Ridge AEC guard force during the day, and Marine guards took over the night watch. Although the Marines were in civvies, they could be easily identified by their crew cuts, broad shoulders, blue serge suits, bow ties, and straight military bearing.

The reason for this complex arrangement was to guard the reactor against malicious mischief. After all, at the time the original arrangements were made, the "Geneva Spirit" that pervaded international relations after the Big Four meeting was not anticipated. As it turned out, there was no reason to fear malicious mischief, and it was well that the relations were friendly because the main electrical switchboard serving the reactor building was located in an area of the Palace of Nations assigned to the Soviet Union. Whenever we blew a fuse, we had to ask the Russians for permission to go through their exhibit to reach the switchboard.

By the time the reactor was assembled, the attention of Geneva, and perhaps the whole world, was focused on the "Big Four" conference. Just before that conference began, the first American reactor in Europe went critical at 9:47 a.m., July 18. The exact time was checked on a wrist watch because our otherwise magnificent control board did not possess a clock.

Extraordinary safety measures were taken during the Big Four meeting—Geneva was full of secret service men from all four countries. In addition, the Swiss police and army, in field uniform, with submachine guns in hand, occupied strategic positions near the reactor building when President Eisenhower came to visit July 20. The importance of the event was heralded when White House staff members and secret service men arrived. They were followed by a horde of newspapermen and photographers who set up large flood lights, overloading the circuit. The electricians were kept busy changing fuses. Newsmen climbed all over the place, stood on exhibits, and it was a miracle no one fell into the pool and no serious damage was done to the equipment.

A tactless remark by a minor official, who gave loud orders to keep all men in work clothes out of sight, caused some understandable resentment among Swiss workers. To appease our hard-working Swiss friends, we appointed the foreman Personal Microphone Carrier for the President. He rushed home, changed into a suit, and was the proudest man in Geneva as he walked with the President.

The presidential visit was a great success. It was written up extensively in local and international newspapers and focused much attention on our exhibit. President Eisenhower showed keen interest in the reactor, which was operating two weeks prior to the conference opening, making our crew very proud.

After the President's visit, there was a slight breathing spell before the conference officially opened. We did not have to compete for the services of the few available craftsmen and could relax while other countries' exhibit staffs worked feverishly.

The reactor was open to special visitors, which included U.S. Consulate, Union Carbide Europa employees, and the staff of the U.N. agencies. Their visits provided "field experience" for the seven girl guides carefully trained during the previous weeks. The seven girls were students at the well known Interpreter's School of the University of Geneva. Each of them spoke at least three languages, and they ranged in age from 19 to a mature 23. They looked very decorative but, of course, did not have much background in reactor physics and engineering. Within a very short time, however, they were guiding people around expertly, and many visitors complimented us on our good-looking physics students.

Of course, everybody working around the reactor during those early days considered himself an expert when guiding personal friends. I recall a Marine who was showing a beautiful Swiss girl around, explaining the reactor to her in approximate French. One of the real experts was about to offer his services to explain the operation more correctly, but her expression revealed that it did not really matter what the Marine was saying.

A group of Swiss customs officials were admiring the assembled reactor that they had seen earlier in crated form. A transparent plastic cover had just been placed in position on top of the pool, and somebody put a large nail on it to call attention to the presence of this otherwise invisible sheet. One of the customs inspectors was puzzled. He couldn't understand how that heavy iron nail was floating on water. The electrician explained it to him: "It's heavy water, you know." "Of course, of course," said the customs man, and he went away happy that he had learned some more about the mysteries of the atom.

In spite of the fact that the reactor was ready two weeks before the conference opening, last minute problems kept popping up. The original name of the reactor was "Geneva Conference Reactor," but before the beautiful sign could be put up, the name was changed to "U.S. Research Reactor." And sign painters hurriedly painted the new name in four languages.

After feverish activity during July, the opening ceremony was something of an anticlimax. The reactor was duly visited by U.N. and American officials, and the official host of the conference, President Petitpierre of Switzerland, spent nearly an hour inspecting everything.

Mrs. Fermi, Enrico Fermi's widow, was the official historian of the conference. Her book, "Atoms in the World," contains several references to the reactor.

Many world-famous scientists were among the visitors, and their presence presented problems. We wanted to avoid the embarrassment of girl guides trying to explain reactor principles to Nobel Prize winners or other famous people who contributed to the development of this branch of science. The reactor attracted such luminaries as Professor Bhabha, chairman of the conference; Professor Hahn, the discoverer of fission; heads of delegations; Profes-

Francis Perrin, High Commissioner of the French Atomic Energy Commission as he starts operation of the reactor. Behind him, l. to r., J. W. Hill, S. H. Hanauer, an aide, and the author.

E. P. Epler and L. B. Holland show the reactor to President Eisenhower. He said later in his speech," . . . I hope that everybody who gets a chance to see this (reactor) will learn that there are really many, many ways in which atomic science can be used for the benefit of mankind and not for destruction."

sor Perrin, the French High Commissioner of Atomic Energy; and other chairmen and members of national atomic energy commissions.

Scientists were also given an opportunity to operate the reactor. Of course, this was more of a ceremonial activity since the servomechanism took over after the operator pushed a button. President Eisenhower was the first such honorary reactor operator. Among the others was the head of the Russian scientific exhibit, Professor Ryabchikoff, who thus can claim the distinction of being the first Soviet citizen to operate an American reactor.

The reactor was operated from 9 a.m. through 4 p.m., daily for conference delegates and newsmen. The general public was admitted from 4 p.m. to 10 p.m. Because of the large number of visitors, carefully prepared experiments sometimes fell by the wayside—there simply was no time to perform all of them.

Many television and radio broadcasts were prepared at the reactor site. The crew was interviewed in every possible language, and "men in white from Oak Ridge" became well known to European TV viewers and radio listeners.

As the conference ran its course, the glamorous days of the reactor also came to an end. To climax negotiations between the AEC and the semi-governmental Swiss group, Reactor Ltd., title to the machine was transferred to the Swiss in a formal ceremony August 20, becoming effective after the close of the conference.

Admiral Strauss and Miss Willis, American ambassador to Switzerland, signed for the United States. The two directors of Reactor Ltd., Professor Scherrer, Zurich Polytechnic Institute, and Dr. Boveri, well known Swiss industrialist, accepted the reactor for Switzerland. The Swiss received a "slightly used" reactor, and the American crew did not have to worry about packaging and transporting radioactive components back home. Everybody was happy!

The Swiss also took over the obligation of tearing down the building and replanting two trees which had to be replaced according to our agreement with the United Nations.

Sunday, August 21, the last day of operation was very quiet! The conference closed, and delegates were leaving. The few visitors consisted mostly of tourists and townspeople. At 7 p.m. the sign was removed from the front of the building. Somebody had scribbled "sold," and "vendu" on it. The doors were closed but reopened an hour later for a party to which everybody who had anything to do with the construction was invited. This was a somewhat sad occasion of farewell. The people who worked so feverishly for months did not, in all probability, expect to meet again.

Next morning a big blue sign was still at the entrance of the Palace of Nations, but on closer inspection it turned out it was not the old one—it announced the beginning of the International Conference on Penology and Prison Management.

By noon the reactor was disassembled. Components and instruments were lying all over, and everything that was radioactive was in the pool, which was covered and locked to be "transported" to Switzerland's atomic center. After being built and assembled in Oak Ridge, crated, flown across an ocean, re-assembled in 11 days, shown to scientists, presidents, ex-kings, and tourists, the reactor was officially inaugurated as the Geneva Reactor on May 17, 1957, at the Swiss Federal Institute for Reactor Research in Wuerenlingen, where it continues a second, useful, if less dramatic, career.

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