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Eighth Semiannual Report

OF THE

U.S. ATOMIC ENERGY COMMISSION

July 1950

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LETTER OF SUBMITTAL

WASHINGTON, D. C.
31 July 1950

SIRS: We have the honor to submit herewith the Eighth Semiannual Report of the United States Atomic Energy Commission, as required by the Atomic Energy Act of 1946.

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION
THOMAS E. MURRAY
SUMNER T. PIKE
H. D. SMYTH
GORDON DEAN, *Chairman*

The Honorable
The President of the Senate

The Honorable
The Speaker of the House of Representatives

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CONTENTS

	Page
FOREWORD	ix

PART ONE

CONTROL OF RADIATION HAZARDS IN THE ATOMIC ENERGY PROGRAM

I. RADIATION SAFETY—THE PROBLEM, THE PROGRAM, AND THE RECORD	3
The Hazards of Radiation	5
Methods of Radiation Control	8
Permissible Limits on Exposure	10
The Record of Radiological Safety	15
Cost of Protection	17
The Protection Policy	18
II. RADIATION SAFETY IN PRODUCTION OPERATIONS	20
Processing Raw and Feed Materials	20
Production of Plutonium	22
Radiation Protection in the Pile Buildings	24
Protection in Chemical Separations Plants	30
Protection in Plutonium Metal Work	41
In Case of Disaster	41
The Role of Health Physics in Hanford Plants	42
Gaseous Diffusion Plant	45
Nuclear Hazard Prevention	46
Contamination and Radiation	48
Radiation Control at Los Alamos	48
Protection Operations	49
III. SAFE HANDLING OF RADIOISOTOPES	53
Radiation Protection During Production	54
Reactor Loading and Unloading	54
Handling a Typical Beta Emitter	56
Handling Gamma Emitters	57
Radioisotope Processing Area at Oak Ridge	58
Radioisotope Analysis	59
Storing, Packing, and Shipping Radioisotopes	60
Protection of Radioisotope Users	71
Protection Through Standards and Controls	72
Training Courses for Radioisotope Users	73
Advisory Field Service	75
IV. CONTROL OF RADIATION IN RESEARCH AND DEVELOPMENT	79
Protection in Laboratories	79
Choice of Building Materials	82
Protection Against Gamma Rays	83
A Typical "Hot Cave"	85
Remote Control Engineering	87
Particle Accelerator Work	92
Accelerator Shielding Problems	93
Controlling Reactor Radiation	96

5000950

V. Environmental Safeguards
Keeping Watch Over Radiation
Raw and Feed Materials
Hanford Safeguards
At Los Alamos
Protection at Research Laboratories
Reactor Safeguard Committee
Contaminated Solids
Handling Liquid Wastes
Water Wastes at Hanford
Los Alamos Liquid Wastes
Oak Ridge Liquid Wastes
Plans for Brookhaven's Liquid Wastes
Controlling Gaseous Wastes
Control of Hanford Gaseous Wastes
Radioactive Gases from Reactors

VI. Control of Hazards at Weapons Tests
Radiological Safety Group
Controls Established in Advance

VII. The AEC Program for Radiation Control
Health Physics History
Health Physics Under AEC
Health Physics Administration
Health Physics Training
AEC In-Service Training
University Training Programs
Contributory Training
Contributions to Civil Defense
Assistance from Other Agencies

VIII. Detection Instruments for Radiation Protection
Today's Instruments
How Instruments Are Used
Instrument Calibration and Maintenance
Present Trends in Radiation Detectors

IX. The Costs of Radiation Protection
A Sample Case Study
Comparative Construction Costs
Comparative Operating Expenses
Added Cost of Research
Some Sample Costs

5000951

PART TWO

HIGHLIGHTS OF PROGRESS IN 1950

	Page
X. MAJOR DEVELOPMENTS, JANUARY–JUNE, 1950	165
Production of Fissionable Materials	165
Weapons Production and Development	166
Nuclear Reactor Development	167
Construction of New Facilities	170
Developments in Research	171
The Fellowship Program	174
Private Enterprise and Self-Government in Communities	175
Labor-Management Relations	177
Inventory of Facilities	177
Provisions for Security	178
Information Services	178
Control of Atomic Energy Information	179

APPENDICES

1. U. S. Atomic Energy Commission, Principal Staff, and Managers of Operations Offices	181
2. Membership of Committees	182
3. Major Research Centers of the U. S. Atomic Energy Commission	192
4. Distribution of Isotopes from Isotopes Division, Oak Ridge, Tenn	195
5. Fellowship Boards for AEC Fellows for 1950–51	197
6. AEC Contract Research on Radiation Effects and Radiation Protection	200
7. Radiation Detection and Measurement Instrument Patents Available for Licensing	209
8. Radiation Detection and Measurement Instruments Manufactured for Use by AEC	215
9. Report to the President by the Atomic Energy Labor Relations Panel—Nov. 1, 1949 to May 31, 1950	220
10. Information Control Policy of the U. S. Atomic Energy Commission	227

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FOREWORD

The past 6 months were a time of diversified activity in the national atomic energy project. The rate of current operations accelerated, and at the same time major decisions were taken on the future course of development.

Fissionable material production proceeded at the lowest unit cost and highest output on record.

Work on experimental reactors of designs considerably in advance of any now in operation reached the development and construction stage. The two reactors under construction are research units; two others in the design stage are primarily designed to advance the naval application program.

Research work in basic nuclear phenomena, in biological and medical fields, and in radiation effects was expanded with the completion of new laboratories and equipment and the strengthening of the technical staffs of the operating contractors.

Construction proceeded on schedule both under the plant expansion program undertaken in late 1949 and under programs previously authorized. Work continued on long-range research and development and on improved types of production facilities.

Development of design for the intermediate power-breeder reactor at Knolls was deferred and many of the engineers and scientists at the Knolls Atomic Power Laboratory were reassigned. Much of the knowledge gained in studies on this project will be brought to bear on the problems of an intermediate submarine reactor, the second machine for submarine propulsion in the current program. The Commission feels that this concentration of effort on propulsion reactors will at the same time advance progress toward stationary power reactors.

On January 31, the President announced that he had directed the Commission "to continue its work on all forms of weapons, including the so-called hydrogen or super-bomb." In this connection adjustments were made in various phases of the program, requiring a substantial expansion of facilities and work projects. These actions have been taken in close coordination with the Department of Defense. The first estimates of cost for these facilities are contained in a supplemental appropriation request for 260 million dollars which the President sent to the Congress on July 7.

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In making the request, the President forwarded a letter from the Director, Bureau of the Budget, stating:

> This appropriation request is primarily for the construction of additional and more efficient plants and the necessary related facilities. These additional plants will provide materials for weapons—either the atomic bomb or the hydrogen bomb, should it prove feasible—or for fuels potentially useful for power purposes. The plants will be of advanced design and their operation will provide new knowledge that will speed the progress of the atomic energy program.

The President in a general public statement further said:

> The expansion in the scope of our atomic energy program gives added emphasis to the fact that atomic energy has great potentialities both for destruction and for the benefit of mankind. From the very outset we have stood, and we continue to stand, firm in our desire for effective international control of atomic energy to insure its use for peaceful purposes only. This is a fundamental objective to which this Government and the vast majority of the United Nations have committed their best efforts. Agreement on this goal would make the facilities of our atomic energy enterprise fully available for peaceful purposes. Until this objective is achieved, however, we must strengthen our own defenses by providing the necessary atomic energy production capacity.

With attention centered always on the paramount objective set out in the Atomic Energy Act of 1946—assuring the common defense and security—the Commission has tried in its administration of the program to promote as well the peace-time uses of atomic energy. With the added impetus of military requirements, power reactor development is moving at a vigorous pace. The production and distribution of radioisotopes and stable isotopes for a multitude of uses in improving knowledge, health, food production, and industrial techniques has steadily grown. Domestic off-project isotope shipments totalled 3,295 in the past 6 months, some three times the distribution of the first year of the isotope distribution program and a 36 percent increase over the preceding 6-month period. A new handling and shipping plant became necessary and was put in operation at Oak Ridge in February of this year. Special support to cancer studies with the use of radioisotopes has been given.

In the present state of international affairs, the requirements of secrecy do not permit the full utilization of the American talent for research and invention, outside as well as inside the atomic energy program. To mitigate these limitations and to open as many fields as practical for the use of science and industry, the Commission has attempted a number of steps which, while limited in scope, should help to broaden the familiarity of outside groups with the atomic energy enterprise. In the last 6 months, there has also been evidence of increased interest in the atomic energy program on the part of such groups. One university group, for example, has submitted a proposal for building and operating—with its own financial

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resources—a low power research reactor. Such initiative is welcome and encouraging.

During the past 6 months, several changes occurred in the membership of the Atomic Energy Commission. Two original members, David E. Lilienthal, the first Chairman, and Lewis L. Strauss, resigned to return to private life. In May, Thomas E. Murray became a member of the Commission.

Continuing the pattern of previous midyear reports to the Congress, this Eighth Semiannual Report of the Atomic Energy Commission reviews in some detail one major phase of the national atomic energy program. The chief subject reported here is control of radiation hazards. The report is designed not only to inform the public generally but to make available information useful in civil defense activities.

The radiation safety record of the 8 years of atomic energy operations is cause for pride. Under the Manhattan Engineer District through 1942–46, eight overexposures and two fatalities occurred from radiation accidents; since January 1, 1947, there have been no deaths and but five injuries from radiation. Protection of the environment has been an important consideration in all atomic energy research and operational activities. Radioactive materials and wastes have been closely controlled to prevent radiation damage to property and people inside and outside the program. The Commission believes that the heavy expenditures devoted to radiation protection measures and to research in this field have been soundly invested.

Much of the available information on radiation protection can be published without endangering the national security or defense, and consequently the report (Chapters I through IX) can be broader and more detailed than would be possible in some other phases of the atomic energy program. Chapter X gives some highlights of other programs. Complete information on these and other programs, which, for reasons of security, cannot be included in a public document, is regularly reported to the Joint Congressional Committee on Atomic Energy.

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Part One

Control of Radiation Hazards in the Atomic Energy Program

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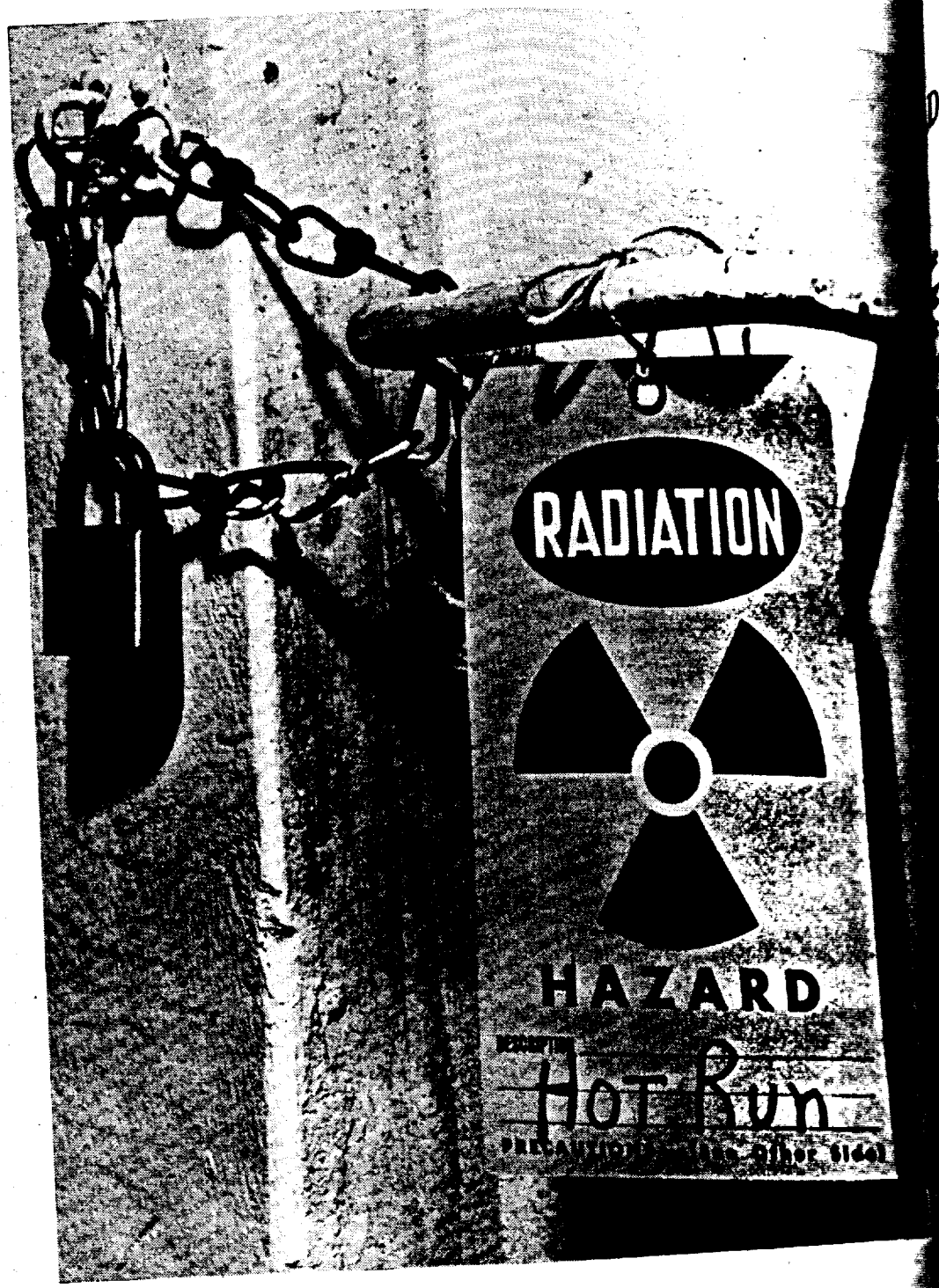

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RADIATION SAFETY—THE PROBLEM, THE PROGRAM, AND THE RECORD

In the Atomic Energy Act of 1946, the Congress directed the Atomic Energy Commission to protect the health of employees and of the public in carrying out its program of research, production, and weapons testing.* This report summarizes the results of work done and the means used to protect employees, the public, and all others who might be exposed in any way to the potential hazard of nuclear radiation originating in the national atomic energy program.

In testimony before the Senate's Special Committee on Atomic Energy after the close of the war, the administrator of wartime science programs termed the atomic energy program "by long odds the most dangerous manufacturing process in which men have ever engaged." The record of the Manhattan Engineer District, wartime operators of the atomic energy program, was before the committee at the time. It showed that, except for two accidents, the MED safety methods had prevented any worker from being injured by radiation from the inception of the program in 1942 up to 1946. A similarly rigorous standard of safety has been maintained by the Atomic Energy Commission.

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*Throughout the Atomic Energy Act of 1946, there are provisions relating to safety and the protection of health in the atomic energy program. Examples of such provisions are the following:

Sec. 3 (a) The Commission is authorized and directed to make arrangements for the conduct of research and development activities relating to — (5) the protection of health during research and production activities. . . .

Such arrangements shall contain such provisions to protect health, to minimize danger from explosion and other hazards to life or property, . . .

Sec. 4 (c) (2) (Production of Fissionable Materials): Any contract entered into under this section shall contain provisions . . . obligating the contractor . . . to comply with all safety and security regulations which may be prescribed by the Commission.

Sec. 5 (c) (2) . . . The Commission shall not distribute any byproduct material to any applicant, who is not equipped to observe or who fails to observe such safety standards to protect health as may be established by the Commision . . .

Sec. 12 (a) In the performance of its functions, the Commission is authorized to — (2) . . . establish by regulation or order such standards and instructions to govern the possession and use of fissionable and byproduct materials as the Commission may deem necessary or desirable to protect health or to minimize danger from explosions and other hazards to life or property; . . .

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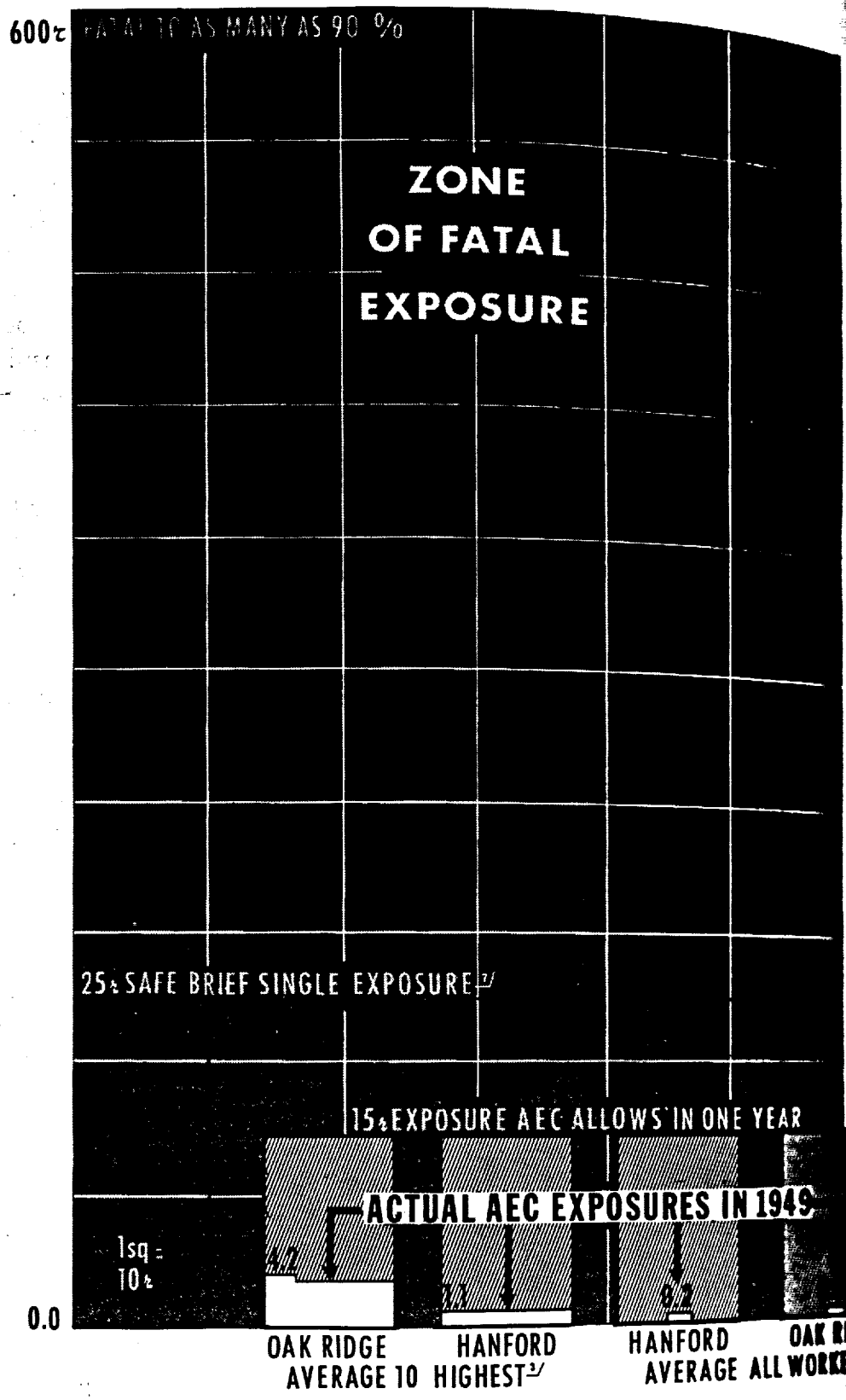
RADIATION LEVELS & AEC RECORD

SCALE: ONE SQUARE = 10 r ROENTGENS [1]



[1] The roentgen (*r*) is a unit used in measuring the ionizing, or damaging, power of
tion. [2] Safe exposure as estimated by international conference, Chalk River, Ontario,
tember 1949. [3] Official daily records at AEC installations.

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The Hazards of Radiation

The tradition of radiological safety was established by the MED the face of unprecedented problems. Some experts believed that clear reactors would create so much powerful radiation that it would impossible to protect the operators by any means. They were wrong, but their fears indicate the scope of the problems the first mic energy workers faced in 1942.

Until that year, virtually all experience with radiological hazards came from experiments in nuclear physics and medical use of radium and X-rays. Industrial use of radiation and radiomaterial was extremely limited. Although the amounts of radiation were small, many injuries and deaths had occurred during 50 years of this work. Slowly, during the 1920s and 1930s, standards of protection were established. They provided valuable guidance, but the radiological problems faced by the founders of the atomic energy enterprise in the early 1940s were many times greater than any ever encountered before. In place of a few radium dial painters doing standardized work and an occasional operator of a testing machine, thousands of workers were to perform hundreds of tasks in the vicinity of materials releasing much more radiation than men had known before. In place of a few doctors and hospital and laboratory technicians handling minute quantities of radium and 15,000- to 50,000-volt X-ray machines, hundreds of scientists and technicians were to do laboratory work with material thousands of times more radioactive than radium and with particle accelerators with voltages running to tens of millions.

Instead of about 3 pounds of radium under human control in the entire world, there would be radioactive materials equivalent to millions of pounds of radium. There would be, not one kind of radiomaterial, but literally hundreds comprising nearly every known element and others previously unknown, such as plutonium. Instead of X-rays, the chief danger of which had been a skin burn, there would be gamma rays and neutrons able to deliver heavily damaging radiation deep within the body.

Nuclear radiations are inseparable from the atomic energy program; actually, they are manifestations of atomic energy. One form of nuclear radiation—the neutrons released in fission—is used at Hanford to manufacture the fissionable material, plutonium, from which atomic weapons are made. Other forms—beta particles and gamma rays emitted from radioisotopes manufactured at Oak Ridge and elsewhere—make it possible to use radioisotopes for medical diagnosis and

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treatment, and for experimental problems in research which m
unsolvable by other techniques.[4]

In large concentrations of material, either naturally radioac
made so in various operations of the program, these same t
radiations create potential hazards. Workers must be pr
against them when they are generated in manufacturing pr
The public must be protected by safe handling of the unique
trial wastes. Special safeguards must be set up and mainta
research that involves radioactive material or release of rad

The Nuclear Radiations

Nuclear radiations are invisible and undetectable by the
senses; they cannot be seen or felt. They are of two genera
(*a*) bits of nuclear matter (from the nucleus or core of atoms)
that they probably never will be seen—the neutrons, beta an
particles; and (*b*) electromagnetic waves, of the same gene
as light, heat and radio, but of extremely short wave leng
gamma and X-rays. Their basic characteristics may be tabu
follows:

Alpha particles—large, positively charged particles. They are unable
trate the unbroken skin but if an element liberating them is deposited
body they may cause extreme damage.

Beta particles—moderately damaging, moderately penetrating, negativel
particles. At most, they will go through about a third of an inch of ti

Gamma rays—highly penetrating. They are less damaging, quantity
tity, than the above types of radiation, but, because they penetrate
a major problem.

Neutrons—uncharged, penetrating, highly damaging particles. Dep
their speed, they can penetrate several feet of tissue.

X-rays—similar to gamma rays, but less penetrating.

How Radiations Cause Damage

Nuclear radiations cause damage by a process called *ioni*
which the particles or rays disrupt the atoms and molecules of
stance they strike—air and concrete, steel and human bodie
cause atoms to divide into positive and negative parts called
destroy the delicate electrical balance of molecules.

[4] The fact that the radioactive form of a chemical element can be detected a
by instruments is used in "tracer" research, was reported previously: Fourth
Report to the Congress, July 1948, 35 cents: Sixth Semiannual Report to the Co
1949, 45 cents; Isotopes, A Three-Year Summary of U. S. Distribution, Aug
cents; Superintendent of Documents, Washington 25, D. C.

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In the human body, this disruption takes place within the individual cells. A cell ordinarily recovers from light damage, but severe injury can cause it to die. Other damage to tissue and body fluids may occur from radiation, but cell destruction seems to be the chief one. If enough cells are destroyed, the body receives detectable injury.

Beta particles, although they cannot penetrate deeply, can cause severe burns if in sufficient concentration. If a person received a very heavy exposure to radiations that penetrated deeply into his body and affected the functioning of internal organs—gamma rays, X-rays or neutrons, for example—enough damage might be inflicted to make him ill or, in an extreme case, to cause death. These are the hazards of radiation that strikes the body from outside.

Internal injury is also possible. Some radioactive materials, if inhaled, deposited in a wound, or taken in by the mouth, cause injury or death if enough of them remain long in vital parts of the body. Alpha particles emitted by such materials as radium and plutonium have too little penetration to burn the skin, but their great ionizing power can cause heavy local damage inside the body. Beta and gamma radiation, emitted by almost all radioisotopes—and there are hundreds of them—can cause heavy internal damage if sufficient quantities of the emitters are lodged within the body.[5]

Where the Hazards Arise

The potential hazards from radiation within and around atomic energy installations vary with the work being done in each place. The chief external hazard is from gamma rays except in a few places where neutrons may escape. The internal hazards are more diverse.

Nuclear reactors generate large amounts of radiation of all kinds. A fission reaction, starting in an accidental assembly of too much fissionable material at installations where quantities are handled, would throw off heavy radiation. Dry radioactive dusts and sometimes mists present both external and internal hazards wherever radioactive materials, particularly uranium and plutonium, are worked with. Equipment, machinery, and other materials can be impregnated with radioactive substances and become hazards.

The industrial radioactive wastes generated at atomic energy installations present special problems in protecting the environs of plants and laboratories. These wastes include (*a*) reactor cooling and plant ventilating air and process gases, containing limited quantities of radioactive gases and airborne radioactive material; (*b*) reactor cool-

[5] A fuller discussion of the biological effects of nuclear radiations is given in the AEC Fifth Semiannual Report to Congress, July 1949; available from the Superintendent of Documents, Washington 25, D. C.; 45 cents.

5000963

ing water and process waste water, containing some radioactive m
rial; (*c*) liquid and solid waste materials from nuclear reactor f
elements, containing a wide variety of radioisotopes; and (*d*) mis
laneous contaminated material, such as machinery, tools, equipm
cleaning materials, clothing, laundry wastes, and other things th
must be disposed of safely.

Methods of Radiation Control

In the presence of highly penetrating radiation, safety is maintain
by massive shielding, by distance of workers from the radioacti
source, by time limits of exposure, or by combination of the thr
Protection from materials that cause damage inside the body is acc
plished by controlled ventilation that keeps dusts, gases, and vap
out of the air in and near atomic energy installations, and by rigor
industrial housekeeping to prevent and control radioactive conta
nation. Where it is not feasible to build sufficient protection i
operating equipment, workers wear respirators or other protect
devices (see photograph, opposite).

Not relying on equipment and routines alone, the operators of A
plants and laboratories make regular and special radiation meas
ments in and near atomic energy centers. Every worker in a radiati
area wears instruments that measure his exposure, which is record
at the end of each working day and double-checked by periodi
medical examinations.

The release of industrial wastes from atomic energy reservation
rigidly limited as to kind and quantity, and their discharge—w
they are released at all—is continuously and carefully metered
regulated. In and near all installations, continuous surveys and st
ies insure that all precautions are kept functioning properly.

Gaseous and airborne wastes are controlled by filtration and di
tion with air; mildly radioactive liquids by holding them for a ti
while they decay into nonradioactive forms, and by filtration
dilution with uncontaminated water; more dangerous liquids
concentrated and run into safe storage; miscellaneous contamina
materials are buried; incinerators are being developed.

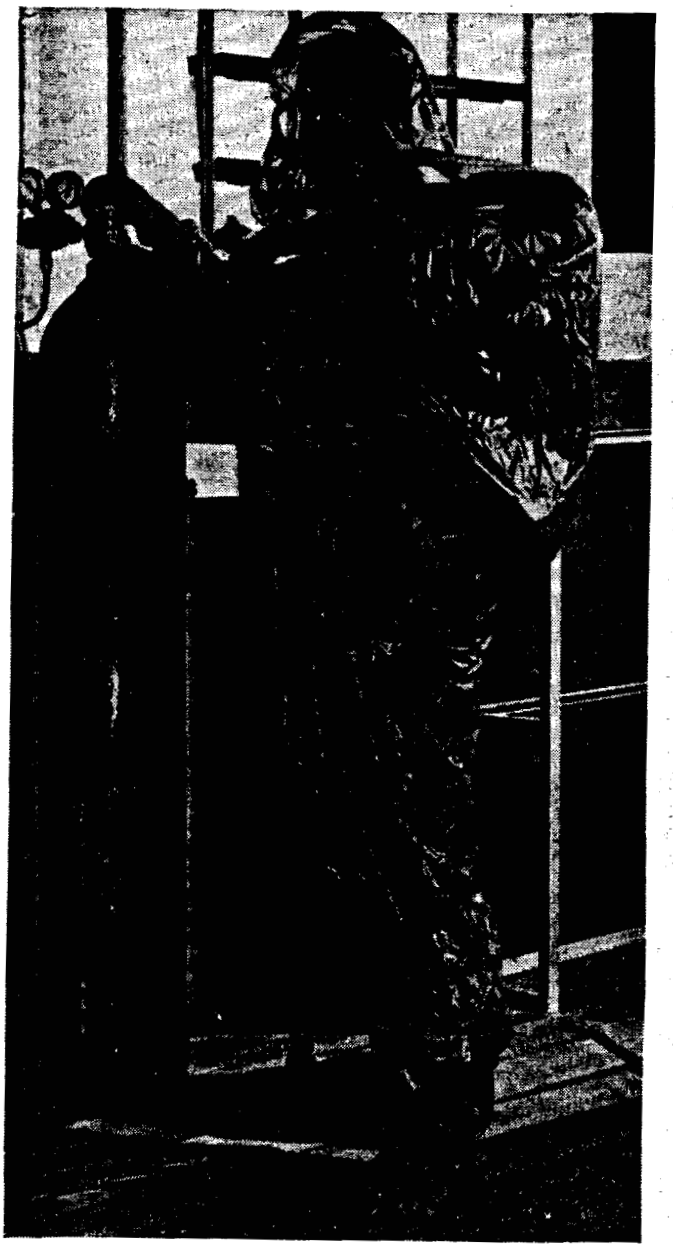
The Scope of Radiation Protection

The necessity for radiation protection influences almost every as
of atomic energy work. It is an important factor in develop
manufacturing processes, in designing plants and equipment, and
planning and scheduling work. It influences employee medical p
grams, selection and training of personnel, establishment of w

5000964

routines, the clothing that workers wear, and even the way they wash their hands and where they can eat or smoke.

All operating officials have responsibilities for radiation safety. Engineers, scientists in many fields, and the workers themselves all play a part. Studies in AEC laboratories or under AEC contract in universities and other institutions contribute to the development of



Where the surrounding air may be dangerously contaminated, the worker is protected against any contact with the air. One of the types of suits used at the Los Alamos Scientific Laboratory to protect workers in these circumstances, shown here, is made entirely of plastic, with seams that "zip" together to form relatively tight joints. Air from a tank on the workman's back is released through a nozzle in the upper part of the suit to give the workman air to breathe and to keep a slightly positive pressure inside the suit so that air can leak out of any openings and prevent contaminated air from entering.

remote-control tools for factory and laboratory and instruments for detecting and measuring radiation. Research provides greater knowledge of the effects of radiation and its control.

A corps of specialists in the new profession of health physics carries out many specific tasks, such as monitoring for radiation; maintaining full records of radiation surveys and personnel exposures; developing and maintaining radiation detection instruments; pre-

5000965

scribing safety equipment and routines; and advising operating personnel in all aspects of radiation protection.

Administering the Program

The Atomic Energy Commission, acting through its Division of Biology and Medicine, has primary responsibility for fixing standards of protection, for guiding and coordinating research, and for watching over radiation safety throughout the enterprise. Specifications and methods for safe handling of wastes are developed by the sanitary engineering and chemical engineering groups in the Reactor Development Division. Direct control of radiation safety is in the hands of the AEC's operating contractors—such as Union Carbide and Carbon at Oak Ridge, General Electric at Hanford, University of California at Los Alamos Scientific Laboratory, and University of Chicago at Argonne National Laboratory—under the supervision of the respective AEC Operations Offices.[6] All but a few of the health physicists are contractor employees, and research in radiation safety also is a contractor task. The program is necessarily as widespread as the enterprise itself, but its implications are even broader.

Assistance to Civil Defense

Already, for example, the experience gained in radiation control work in the atomic energy project is assisting in planning for civil defense in event of war. Much technical information has been presented to the National Security Resources Board, which has primary responsibility in this field, and to other Government agencies concerned. The contribution to civil defense, the history and administration of the radiation safety program, the supporting research, and the educational programs of the AEC in this field are reported in Chapter VII; development and progress with radiation detection instruments are reviewed in Chapter VIII.

Permissible Limits on Exposure

In small amounts, radiation is a phenomenon of nature to which every living creature is subject: cosmic rays strike the earth everywhere, and materials such as radium in the earth's crust emit radiation. In large amounts, radiation is injurious to all living things. Before any systematic program of protection could be set up, it was necessary

[6] At Oak Ridge, Hanford, Santa Fe, and Chicago. Other AEC contracts are supervised by AEC offices in New York, Schenectady, and Idaho, and by the Raw Materials Operations Office in Washington.

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RADIATION MEASUREMENTS USED IN HEALTH PHYSICS

Radiation units of measurement are related to the *roentgen* (symbol *r*), which applies to the ionizing effect of gamma and X-rays with which radiological workers have had the most experience including clinical evidence.

A *roentgen*, by definition, is a quantity of gamma or X-rays that will produce 2 billion ion pairs in a cubic centimeter of air under standard temperature and pressure, and amounts to a delivered energy of 83 ergs.

A *rep* (roentgen equivalent physical) is a quantity of any radiation that will deliver an equivalent amount of energy (83 ergs) to one gram of tissue. This amount of radiation energy will produce about 1.6 million million ion pairs in tissue.

A *rem* (roentgen equivalent mammal, or man) is a measurement of the damage caused in tissue by one *rep* of gamma or X-rays. One *rep* of another type of radiation, delivering an equivalent amount of energy, would create more *rems* of damage than would one *rep* of gamma or X-rays, as follows:

Gamma or X-rays	1 *r*=1 *rep*= 1 *rem*
Beta particles	1 *rep*= 1 *rem*
Protons, neutrons	1 *rep*=10 *rem*
Alpha particles	1 *rep*=20 *rem*

to decide precisely what quantities and rates of exposure could safely be permitted. From the outset it was necessary for first the MED and then the AEC to set standards for the permissible exposure of atomic energy workers and limits on the release of radioactivity into the environment. Such limits were set by determining the day-after-day radiation exposure that experience and research indicated to be harmless, and then applying a liberal safety factor—on the order of 10 or more. The limit thus fixed is stated in terms of a unit which measures the ionizing power of gamma radiation—the *roentgen* (see table, Radiation Measurements Used in Health Physics).

The program-wide rule today is that no worker shall receive more than three-tenths of one roentgen (0.3 *r*) in any week. This adds up at most to 15 *r* a year, a rate of exposure at which the experts who set the figure do not believe that any damage would be done even if it were continued throughout a lifetime.[7]

"Exposure," therefore, as used in this report, does not mean injury. Even exposure far above the permissible limit does not signify injury so far as experience indicates. The least exposure that can cause even minor blood changes, which the body soon repairs, appears to be 25 to 50 roentgens in a single quick dose. The lower figure is 83 times the amount of radiation which any atomic energy worker is allowed

[7] The 0.3 *r* per week level was recommended by the National Committee on Radiation Protection, sponsored by the National Bureau of Standards and comprising leading radiological, biophysical, and medical specialists. This level is concurred in by the Canadian and British atomic energy specialists.

5000967

to receive in an entire week. It is nearly twice as much as the AEC standard permits him to receive in a year.

Low though this limit for atomic energy workers is, the limits on releasing radiation and radioactive materials into the environs of plants and laboratories are many times more strict.

The Evolution of Standards

Determining levels at which permissible exposures should be set is a task to which the AEC and its contractors devote extensive research. As knowledge grows more precise, limits are changed. The permissible limit on exposure of the hands and forearms to beta radiation is now somewhat higher than formerly, for instance, whereas the limit on whole-body exposure to gamma rays is lower.

In setting permissible levels, the Commission draws upon the experience of others working in radiation protection and upon research in universities and hospitals in this country and abroad. A group of the best qualified British, Canadian, and American workers is cooperating in this endeavor. In a conference at Chalk River, Canada, in September 1949, representatives of the Radiation Protection Committees of the three nations agreed upon permissible tissue exposure limits of all types of radiation for the whole body, for points within the body, and for the hands only. They agreed on limits for radium, plutonium, thorium, and strontium. They also agreed that for operating purposes it would be desirable and safe to express the permissible limit for whole-body exposure as 0.3 *r* per week instead of 0.05 *r* per day.

The limits adopted at the beginning of the atomic energy enterprise were based almost exclusively on experience with X-rays and radium—the former for radiation striking the outside of the body, the other for radioactive material inside the body.

External exposure. The limit for external radiation, first set by the MED at 0.1 *r* for an 8-hour day, had been adopted by the Committee on Radiation Protection in 1936. It was based upon the observed fact that workers with X-rays who did not exceed one roentgen of exposure a day showed no evidence of injury. For complete safety, the limit was set at one-tenth of this level. In March 1950, on recommendation of the same committee, the AEC formally changed its limit to 0.3 *r* per week. Two considerations were involved in the change: (*a*) radiation in the atomic energy program is commonly more penetrating than that on which the first standard was based, and (*b*) biophysicists envisaged the possibility that there might be some cumulative and so far undetected effect of radiation on the germ plasm.

5000968

This standard for gamma rays is applied, by the use of conversion factors, to all types of radiation that strike the body externally. The roentgen, as the table (p. 11) indicates, applies only to the ionizing power of gamma- and X-rays in air under certain standard conditions. Beta particles cause about the same amount of ionization in tissue as gamma rays; neutrons, 10 times as much; alpha particles, a strictly internal hazard, up to 20 times as much.

In applying the standard limit on external exposure, AEC installations equate these various potencies of radiations to the 0.3 *r* limit for gamma rays and, consequently, permit less exposure to neutrons than to similar amounts of gamma rays.

Internal exposure. The permissible exposure for internally deposited radioactive material first adopted by the MED was that generally accepted at the time: the equivalent of one ten-millionth of a gram of radium lodged inside the body.

This limit applied correctly only to materials which had the same biological half-life as radium—that is, remained in the body an equivalent length of time—and lodged in the same places in the body, emitting the same energies of alpha, beta, and gamma radiation. Efforts were made to calculate permissible exposures to other materials by figuring rough equivalents of radium. Since there is a great variety of unfamiliar materials in the atomic energy program, many adjustments have been made in the permissible exposures to internal radiation as knowledge has advanced.

Hundreds of Radiomaterials

Assembling the basic facts about the biological effects of the various types of radiation is only a first step in arriving at the levels of permissible exposure. It is necessary also to work out a separate standard for each one of the hundreds of radioactive materials because no two of them behave exactly alike.

Radiocarbon, for example, would be built into virtually any part of the body structure like stable carbon, and unless excreted it would emit soft beta radiation during the lifetime of the victim (radiocarbon takes nearly 6,000 years to lose half of its radioactivity by natural decay). Radiophosphorus, in contrast, would not be so extensively distributed, would be more quickly eliminated from the body (have a shorter "biological half-life," in other words), but would deliver more energetic beta radiation for a much shorter time. Radioiodine would concentrate in one small location, the thyroid gland, where its strong gamma and beta radiation might affect the gland's functions and hence the health of the entire organism. Plutonium

5000969

would concentrate in the bone and be excreted very slowly; its long-lived alpha radiation would be dangerous in the extreme.

In setting permissible levels for all these substances, biophysicists relate the damage each could exert to the known damage from radium in the body; they then translate this figure into the quantity that can be safely permitted in air, water, or other medium that might carry it into the human body. This work calls for continuing research. Investigations of radiation effects on animals are carried on at Argonne, Oak Ridge, Hanford, Los Alamos, and Brookhaven (a list of contractors assisting in this work will be found in Appendix 6).

The Task of Determining Limits

The complexity of the task of fixing permissible exposures is illustrated by the 7 years of research on the biological effects of plutonium. Plutonium, like radium, is an alpha emitter that, inside the body, becomes fixed in the bone. Its effects were expected to be similar to radium, which can cause bone destruction and bone cancer and, in larger amounts, anemia and death.

International study has established the amount of radium the human body can safely retain as one-tenth of a millionth of a gram—one-tenth the amount ever observed to cause harm. Since plutonium emits only about one-fiftieth as much alpha radiation as radium, the conclusion might have been drawn that people could tolerate plutonium up to 50 times the permissible radium level. Experiments were undertaken with animals to find whether or not this rough relationship between radium and plutonium poisoning would hold good. It did not. Large doses of plutonium appeared, quantity for quantity, almost as injurious as radium, and chronic damage appears similarly comparable. The reasons still are not well understood, but apparently are biological rather than radiological. One suggestive bit of evidence is that plutonium distributes itself in more sensitive parts of the bone than does radium, and thus delivers its alpha radiation where the most actively reproducing blood cells are located.

Translating the Results

Further difficulties enter when the attempt is made to translate results observed in animal experiments to theories about what plutonium will do in human bodies. No data on human poisoning with plutonium are available and interpretation is confused, for example, by findings like the fact that quantities of radium that would severely injure a human being apparently have no effect on laboratory animals. Further studies are necessary to track down the reasons for this.

5000970

Even when, on the basis of research, it became possible to fix on a permissible exposure to plutonium (the level set was one-half of a millionth of a gram, or five times the limit for radium), the task of setting standards for plutonium was incomplete. A whole new series of studies was necessary to determine what concentrations of plutonium might be permitted in the air a man breathed or in the water he might drink. Experimenters need to find the answers to such questions as: If plutonium were taken in by the mouth, how much of it would be excreted and how much absorbed into the blood stream from stomach and intestines? What is the effect of solubility? How much plutonium breathed in the form of fine dust would be deposited in the lungs and how much would pass through into the blood stream and be deposited in the liver and the skeleton? How would these quantities be affected by variation in the sizes of the particles? How would changes in the concentration of plutonium in air or water affect the amount concentrated in the body; that is, if a man breathed in twice as much per hour, would he wind up with twice as much in his bone structure, or one-third again as much, or how much? Extensive experimentation with animals is under way in many laboratories, notably at Argonne National Laboratory, to find answers to these questions.

Modification of Levels

Levels of permissible exposure are adjusted as such research gives clearer indications of the amounts of various types of radiation, both internal and external, which the human body can accept over long periods without harm. To set a permissible level, it is necessary to know beyond all reasonable doubt that it is safe. When knowledge of the effects of many kinds of exposure is fragmentary and incomplete, as it is today, the only safe procedure is to include very large safety factors.

The Record of Radiological Safety

The Manhattan District explored the problems, improvised solutions, laid down many principles and techniques, and set standards which still assist radiological safety in 1950. In a largely empirical operation, often conducted in temporary and even makeshift quarters, and under wartime pressures, the MED hung up a nearly perfect record.

In 1942, 1943, and 1944, there were no radiation injuries. On two occasions in critical mass experimentation, once in 1945 and once in 1946, accidents caused a fission reaction to start. One accident killed one man and exposed eight others; the other accident killed one man.

5000971

Similar injuries could not occur today since experimenters would be protected by remote control equipment and techniques developed since the war. Except for these, MED, in more than 4 years of operation, recorded no radiation injuries.

The Atomic Energy Commission has had five radiation injuries. In 1948, four men at Eniwetok weapons tests burned their hands when they moved beta-contaminated material without using safety equipment which was provided. Later that year, another man burned his leg handling a beta-contaminated shipment.

Daily exposure records and frequent medical examinations were made routine throughout the program expressly to detect, not only injury, but any exposure above the conservative safety standard. Yet, except for these cases, no radiation injury, however slight, to any worker in any operation has ever been detected.

These casualties represent an extremely low incidence among the thousands of persons employed in atomic energy work. Under AEC management since January 1947, injuries of all kinds in all AEC plants and laboratories, including those in construction, have averaged less than half the rate for all American industries.[8] In two of these years, there were no radiation injuries at all. The five minor injuries in 1948, the only radiation casualties since the AEC was set up, accounted for six-tenths of one percent of total lost-time injuries from all causes in the program in that year.

At Hanford, Washington, and Oak Ridge, Tennessee, two key installations, the average radiation received by all workers is less than half the amount that residents of Rocky Mountain cities receive from cosmic rays (see table, Radiation Exposures Compared, etc.). In the neighborhood of atomic energy installations, extensive and continuous surveys demonstrate that radiation is held to levels comparable to those which exist in nature. Sample measurements indicate that the radioactivity level in the air at Oak Ridge, for example, is no higher than that in Knoxville, some 20 miles away.

The exposure of most atomic energy workers does not come even close to the 15 *r* a year permissible limit. The average for workers in an entire year is considerably less than that received by many people from natural sources—externally from natural radiation, internally from breathing natural radon gas released from the earth or from drinking radioactive mineral waters. The average for the 10 persons with highest exposures during 1949 at Hanford was 1.1 *r*, or 93 percent below the permissible limit; at Oak Ridge the average of the 10 highest was 4.2 *r*, or 72 percent below the limit. The 0.2 *r* yearly

[8] National Safety Council rates for all industries, lost-time injuries per million man-hours, 11.3; AEC figure for all atomic energy installations, on the same basis, for the same three years (January 1947–December 1949), 5.2.

5000972

RADIATION EXPOSURES IN AEC PLANTS COMPARED TO NATURAL AND DIAGNOSTIC EXPOSURES

Source of Radiation	Amount of Radiation
Cosmic rays, average	0.1 *r* a year.[9]
Cosmic rays, Denver, Colorado	0.5 *r* a year.
Average annual exposure of *all* Hanford-Oak Ridge workers	0.2 *r* a year.
Average 10 highest exposures of Oak Ridge workers	4.2 *r* a year.
Routine chest X-ray [10]	0.5 to 5 *r* per exposure.
Routine gastro-intestinal X-ray [10]	1.0 *r* per exposure.
AEC permissible dose (for 20 years of exposure)	15 *r* a year at a rate of 0.3 *r* a week.
Fluoroscopic examination [10]	10 to 20 *r* a minute.
Cinefluorography (X-ray movie) [10]	25 *r* per examination.
Estimated lethal dose for 50 to 90 percent of those exposed	400 to 600 *r*.

average for all Hanford and Oak Ridge workers was 98.7 percent below the permissible limit. Practically speaking, comparisons between the figures at the two installations are probably meaningless. The 15 *r* standard was chosen because it was believed to represent negligible exposure, and all exposure below this level may safely be regarded as insignificant.

Cost of Protection

Radiation safety has not been achieved without considerable cost. The research work is Nation-wide and much of it is as laborious as the plutonium studies cited above. In operations, radiation protection is a governing consideration not only in scheduling work but also in choosing processes and building facilities. The increased cost is encountered in all operations, from the processing of feed materials to the handling of finished products and wastes.

These costs sometimes pyramid. In a laboratory, for instance, the need to erect shields of lead brick—expensive in themselves—gives rise to the need for a workbench many times stronger than an ordinary laboratory bench, and it follows that the floor and substructure of the building must be designed to carry loads more typical of heavy industry than of ordinary research laboratories. A single shielded enclosure which enables scientists to work in safety with extremely dangerous materials may cost as much as $80,000, compared to $2,000 in an ordinary laboratory, and work done in such a "hot cave" may consume

[9] *r* signifies *roentgen*, a unit of measurement of the ionizing power of radiation, which is the factor that causes damage to living things.

[10] These exposures are to parts of the body. All others are whole-body exposures.

5000973

five times as many man-hours as work with materials that do not require such devices for safety.

For one kind of plant that handles large amounts of radioactive material, estimates of original construction cost ran about 12 times what they would have been for a similar plant handling nonradioactive material; and nearly two-thirds of the operating expenses for such a plant, including depreciation, would be incurred solely because radiation was present (this sample study is reported in Chapter IX).

The direct cost of the radiation protection work of health physicists takes between $3 and $4 of every $100 spent for operations in the program. In such a comparatively simple task as laundering contaminated work clothes, the costs may be half again as much as for ordinary laundering.

The AEC and its contractors continually seek safer and more economical methods. Experience and new knowledge may reduce the cost of radiation protection in the years ahead, but savings will be limited so long as the present stringent standards of exposure must be enforced.

The Protection Policy

Numerous institutions and establishments outside the atomic energy project permit substantially greater radiation exposure than is allowed in the AEC program and consider their standards to be entirely safe. There is valid reason to question whether the lower costs and greater operating efficiency coming from a less stringent exposure standard might not safely be realized. The answers can come only out of research and experience. In the view of the Commission, upward adjustment of permissible levels of radiation can be allowed only if it is determined with reasonable certitude that higher exposures will be harmless. In the absence of exact, complete knowledge, the AEC adopted throughout the program those standards that were believed to insure against harm from radiation, and laid upon its contractors the responsibility for conforming with these standards. It has preferred to err on the side of safety and it is still possible that some standards may need to be tightened with the increase of knowledge about the long-range effects of radiation.

The AEC believes that radiation limits should be set in the future by a national standardizing agency. It has worked closely with the National Bureau of Standards to broaden the participation of the National Committee on Radiation Protection in determining permissible exposure limits.

5000974

Benefits of Safety

Whether or not it proves possible in the years ahead to relax the limits now placed on radiation exposure, there can be no question that the founders of the Manhattan District were wise in establishing a tradition of rigorous safety. The fact that so few atomic energy workers have ever been injured by radiation is of great assistance in getting the work done. The confidence that employees feel in the protection system has made it possible to accomplish difficult repair and maintenance jobs that otherwise might have been almost impossible; it has assisted recruitment of production personnel and laboratory craftsmen. Furthermore, hazard pay is not necessary in the plants and laboratories, and life insurance is available to workers at rates comparable to those in other industries.[11]

The atomic energy industry employs forces that are as yet imperfectly understood; it is being developed at an unprecedented rate without benefit of the years of experience gained in other large industries; it is owned and controlled by the people of the United States; and it promises to be vitally important in the future of mankind. All these reasons justify a resolute effort to keep it a safe industry for its workers and its neighbors.

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[11] Very few people employed by the AEC and its contractors have to pay any extra premiums on life insurance because they work on the atomic energy program. In fact, no more than 2 percent have any surcharges in the rates paid and these are no greater than for comparable jobs in industries such as the heavy chemical industry.

5000975

II

RADIATION SAFETY IN PRODUCTION OPERATIONS

The record of more than 5 years of production operations in the United States atomic energy project demonstrates that ionizing radiation may be controlled as completely as any other industrial hazard. In the manufacture of fissionable materials and nuclear weapons, nearly every kind of potential radiation hazard is encountered. Tens of thousands of workers are engaged. Yet comprehensive records of radiation exposure show that no injuries have occurred in production operations.

The production of fissionable materials and nuclear weapons is carried on in a great many plants, large and small, located in all parts of the country and operated by a number of industrial contractors. There are a score of different operations in the manufacturing chain, ranging from the processing of ores to the separation, manufacture, and processing of fissionable materials. Each step presents its own problems and has distinctive requirements for radiation protection.

PROCESSING RAW AND FEED MATERIALS

Like all isotopes of the elements above lead and bismuth in the atomic scale, uranium is naturally radioactive. By emission of alpha particles, uranium 238 decays into an isotope of thorium. This in turn decays by emitting beta particles and very weak gamma rays. The process is so extremely slow, however (the half-life of uranium 238 being 4½ billion years), that the amount of radiation met with in feed-material processes is tiny compared to the quantities in later stages of production. Nevertheless, problems of radiological safety do arise in the chain of operations that starts with uranium ore and ends with delivery of feed materials—uranium metal to Hanford, uranium hexafluoride to the gaseous diffusion plant at Oak Ridge.

The Hazards to be Controlled

Mining and handling of uranium ores usually present no special problems, except that adequate ventilation and dust control are

5000976

more important than in other metal-mining operations. Uranium ore contains small quantities of radium, one of whose decay products is radon, a radioactive gas. Dust from uranium ore is slightly toxic as well as radioactive, and precautions are taken to keep dust from getting into the lungs or digestive system.

As the ore moves through the routine of drying, crushing, and sampling, and thence to various chemical and metallurgical processes, the chance of radioactivity exposure arises at several places. This presents no serious difficulty in processes that can be performed on wet materials. Dust is harder to manage; coping with it involves such measures as enclosed operations, forced ventilation to carry dust away from the air that plant workers breathe, and the use of respirators. Ventilated loading systems also keep down dust contamination.

In process steps where beta and gamma radiation are present, work is carried on behind shields. Some jobs are remotely controlled. Jobs where hazards are more severe are rotated to hold down individual exposures, and work areas are monitored for radiation and air contamination. Precautions of these types are reported in detail in the section on plutonium production.

Small Plants

While the refinery operations in the preparation of feed materials employ only a few hundred persons, a combination of circumstances has made this a difficult sector of the atomic energy program in which to achieve high standards of radiation safety.

The feed materials chain was originally improvised under extreme wartime pressure to build an atomic bomb as quickly as possible. Much of the work still is done by small contractors scattered from the Mississippi to the Atlantic Coast.

The potential risks in the handling of uranium compounds are not as acute as those existing in the operation of a nuclear reactor or in the handling of fission products, and these operations were originally set up on the premise that the work might be ended in a short time, thereby limiting the time during which any person could be exposed to radiation. For short-term operation, extreme precautions were not necessary, but when it became apparent that the plants would operate for a much longer period than was originally anticipated, steps were taken to correct conditions which, though satisfactory on an interim basis, would not meet AEC standards for prolonged exposure over a period of years. The AEC-wide reduction in gamma radiation permissible levels from 0.7 *r* per week to 0.3 *r* per week increased the degree of improvement that was necessary in the wartime feed materials plants.

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The AEC Program of Control

Shortly after taking charge in January 1947, the AEC initiated studies of processes and plants looking toward a more permanent, efficient, and safe feed materials chain. Since the wartime setup was still under pressure for high production, the AEC created in May 1947 a special division in the New York Operations Office to study radiation and industrial hygiene in the existing plants and to foster improvement. The New York office provides many of the necessary services for the feed materials contractors because the plants are too small to be completely self-sufficient with any degree of economy.

As a result of a review of research data obtained by the University of Rochester Atomic Energy Project operating since 1943, the permissible operating exposure limits on uranium have been reduced. It was found that soluble uranium was only a slight radiological hazard but that its toxic effects could damage the kidneys. Consequently, the allowable concentration of soluble uranium in the air was cut from 150 micrograms per cubic meter to 50 micrograms. Where insoluble dusts of uranium were concerned, experiments with animals indicated that sufficient quantities could accumulate in the lungs to cause radiological damage. Therefore, the allowable concentration of insoluble dusts also was reduced, from 500 micrograms per cubic meter of air to 50 micrograms.

Radiological safety records in the feed materials operations have improved under a regimen of stricter standards, safety supervision, and assistance to contractors. A rigid program of periodic medical examinations has disclosed no evidences of radiation injury or uranium poisoning.

New and safer construction. The continuing research on feed materials processing has begun to pay off in more efficient and safer plants. Six months ago, in the Seventh Semiannual Report, AEC announced: operations in a new plant to make brown uranium oxide, construction under way on a new uranium metal plant, plans for a hexafluoride plant, and design studies for a green salt plant. This entire improvement program is moving steadily forward. Major changes are moving rapidly ahead to improve conditions in ore handling and warehousing. These facilities incorporate newly developed techniques in enclosed processing, and are designed to meet the AEC standards for radiation safety. As the new plants go into production, old plants are shut down or consigned to stand-by condition.

PRODUCTION OF PLUTONIUM

The health physics and medical records of the Hanford plutonium works provide the most thoroughgoing proof possible that radiation

5000978

can be effectively controlled in industrial operations. Hanford deals with radiation in wholesale quantities, greater than are known to exist anywhere else in the world. In fact, if all of the radioactive materials that have ever been accumulated outside of Hanford—the natural materials such as radium and the radioisotopes from all known cyclotrons and nuclear reactors—were to be added to a single batch of material going through the plutonium plants, the increase in radioactivity would scarcely be noticeable. Hanford handles radiomaterials in tons, not grams.

Several thousand people work daily in plutonium production, not in a single plant but in half a dozen plant areas, widely separated from one another. Each plant has its own organization for worker protection. In each, there are several different processes involved and a multiplicity of different jobs for workers to do. Since 1944, Hanford has been producing fissionable material; and during that time plants have been maintained and repaired, new plants have been put into operation, unforeseen emergencies have been met.

From the start, complete records have been kept on radiation exposures. No Hanford worker has ever been injured by radiation; in fact, very few of the workers accumulate as much exposure over an entire year as they could get while having their chests X-rayed.

A Tradition of Safety

The 15 *r* annual exposure (0.3 *r* per week or an average of 0.05 *r* per working day), standard throughout the program, was set at Hanford at the start as a working limit, though at that time the internationally accepted standard for safety was twice that amount. In setting up a manufacturing process that necessitated handling radioactive materials in carload quantities, the Manhattan Engineer District and the first Hanford contractor, the E. I. du Pont de Nemours and Co., Inc., spared no effort to protect workers.

During the past three and a half years, the AEC and the present contract operator, the General Electric Company, have maintained this take-no-chances tradition. In both the design of new plants and the operation of the old, they have made the radiation protection system more secure. The average exposure of workers has steadily decreased.

Furthermore, the General Electric Health Instrument Divisions, which conduct the radiation protection program at Hanford, have developed a many-sided program for the protection of the Hanford environment, a program that includes the constant monitoring of land, air, and water over a large area and the study of the possible effects of radiomaterials on the living organisms of the region, from aquatic algae to large mammals (see Chapter V).

5000979

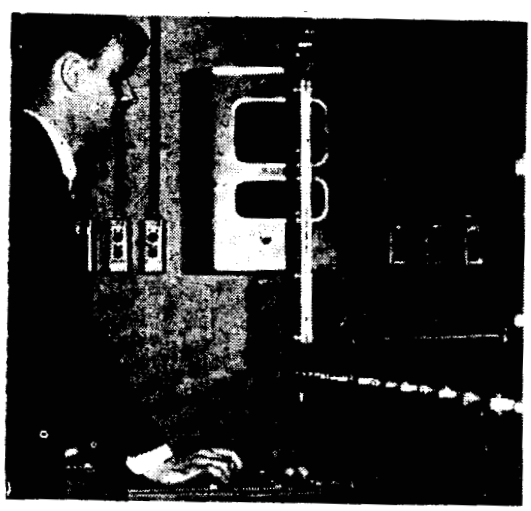
All Kinds of Radiation

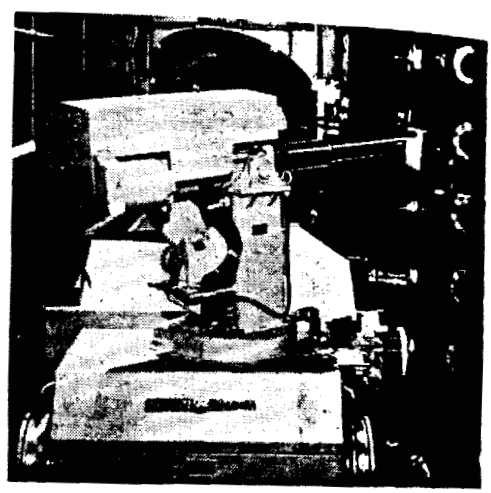
In the several stages of the Hanford process, nearly all varieties of ionizing radiation are met with. There are alpha and beta particles, gamma rays, and neutrons—each in a wide range of energies.

In the first step, uranium metal is fabricated into fuel slugs. The radiation protection problems are similar to those encountered in fuel materials processing. The high intensities and quantities of radiation peculiar to Hanford are first met with at the next processing step—at the nuclear reactors .

Radiation Protection in the Pile Buildings

A Hanford reactor (there known as a "pile") is a massive cube of graphite pierced by many hundreds of horizontal tubes for the uranium fuel. The uranium slugs are loaded into these tubes by the thousands. Within the pile there is enough uranium to form a critical mass—a quantity sufficient to bring about a nuclear chain reaction. Neutrons split the nuclei of the uranium isotope, U 235, producing more neutrons, which repeat the process. Other neutrons bombard the nuclei of the more plentiful uranium isotope, U 238. This latter reaction results in the transmutation of U 238, through two intermediate steps, into





With the development of remote-control handling equipment, work in the plutonium production plants becomes easier and safer. This Hanford "tool dolly," somewhat resembling a deck gun mounted on a railroad handcar, works in areas made unsafe by radiation, performing a variety of tasks—operating machinery, opening and closing doors, moving objects of all sizes, and even, if necessary, handling fire hoses or other emergency equipment. At left, the operator, shielded from radiation, controls the movements of the robot from a panel equipped with lights to indicate the position of the tools when he cannot see them directly. For jobs such as the turning of a valve, right, the machine is equipped with electric "feelers' to indicate whether the valve handle is properly centered in the grasp of the turning tool.

5000980

plutonium 239, which is the Hanford end-product. The slugs discharged from the pile contain three major components: (*a*) plutonium; (*b*) fission products, a great variety of newly created isotopes that result from the splitting of the U 235 atoms; and (*c*) a part of the original uranium (both the U 235 and the U 238 isotopes) which has not been affected by the chain reaction.

Sources of Radiation

The interior of a high-power pile during operation is an inferno of radiation, exceeded nowhere on earth except possibly in an exploding atomic bomb. Alpha, beta, and gamma radiation and neutrons are all present in states of extremely high energy. To carry away the heat alone requires a water supply great enough for a large city.

Virtually every substance bombarded by neutrons in a chain reaction becomes radioactive in greater or lesser degree, emitting alpha particles, beta particles, gamma rays, or some combination of these. Thus the following objects and materials coming out of the pile are all radioactive in varying degree—

The discharged slugs—containing the fission products, such a variety of active materials that they give off alpha, beta, and gamma radiation in all energy ranges, and glow with a bluish light in the dark.

Any piece of equipment—fixtures, fittings, tubing, piping, etc.—removed from inside the pile; violently radioactive, as a rule.

The control rods of a neutron-absorbing material, which are used to control and stop the chain reaction.

The air forced out of the casings or "thimbles" in which the control rods slide (neutron bombardment renders certain gases of the air radioactive).

The cooling water pumped through the pile, containing minerals which the neutrons have made radioactive.

"Contamination"—finely divided material such as dust or moisture that has been irradiated. It is generally invisible to the eye and may be on any surface or in the air. It may emit penetrating gamma rays; its alpha or beta radiation is not generally penetrating, but is extremely dangerous if it gets inside the body.

The worker in the pile building must be protected against both external and internal radiation exposure—*external exposure* from the chain reaction itself, the discharged slugs, irradiated pile equipment, the control rods, and the cooling water pipes; *internal exposure* from radioactive gases and contamination in the air.

Protection Against External Radiation

The principles of protecting personnel against external radiation, by shielding, by distance, and by time limits on the exposure, are all

5000981

important in the pile buildings, at the stage in the Hanford process where radiation protection first becomes a major requirement.

Protection by shielding. Unprotected, a man could not safely come within a quarter mile of such a nuclear chain reaction as takes place in a Hanford pile. The pile is so shielded, however, that workers move about freely right next door to the storm of radiation. Dense material many feet thick stops the alpha and beta particles and all but a negligible proportion of the gamma rays. Special layers of material slow down and absorb the neutrons. The pipes that carry away the radioactive cooling water are heavily shielded with concrete, as are the control rods which move in and out of the pile. The worker is actually safer when the pile is operating than when it is shut down. Ports in the shielding, though opened only during shut-down still emit powerful beams of gamma rays.

The discharge face of the pile, where the irradiated slugs come out of the process tubes, is shielded by a concrete wall. Workers may observe this discharge operation through periscopes, and through the "fly's eye," a cylindrical chamber filled with water set into the wall as a shield and fitted with glass lenses. When the slugs are pushed out, they fall of their own weight and come to rest at the bottom of a deep pit full of water. The slugs, clearly visible but harmless in their water shielding, are sorted and moved at the bottom of the pit with remote handling apparatus. In this pit the slugs are "aged," to allow the decay of some of the more troublesome radiomaterials, notably the gaseous iodine 131. When they are ready to be moved along to the next processing stage—the chemical separations plant—another set of remote handling devices goes into operation. Still under water, the slugs are loaded into a container for transportation to the separations area.

Portable and temporary shielding is much in use for repair and maintenance work. Nearly every kind of material used in the structure of a reactor is made radioactive by neutron bombardment; a piece of equipment removed from inside the unit emits energetic gamma and beta radiation. Such a piece of equipment, if it must be left temporarily in a position where personnel will pass near, is usually walled in with a shield of lead brick and posted with warnings. Portable shields of various shapes are sometimes devised for repair jobs, to enable mechanics to approach radioactive equipment or open ports in the pile shield. In general, however, experience has proved that such jobs can be done more quickly, and often with less exposure, by maintaining distance between workers and the radiation source and strictly limiting the exposure time of each worker.

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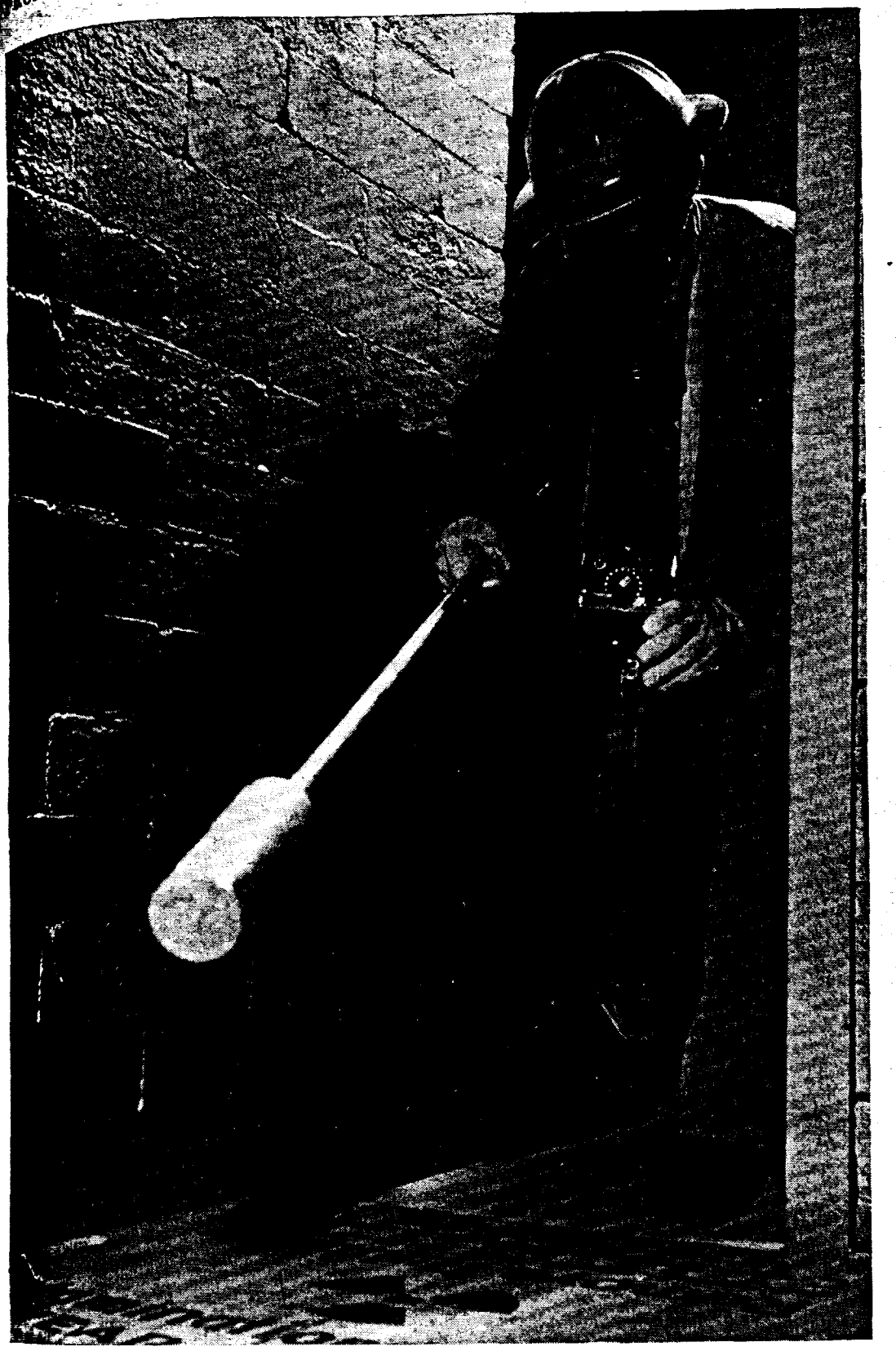

Radiation protection equipment used in a production plant. The worker above is surveying a plant area for radiation, using a counter with long-handled "probe." For protection against contamination by radioactive material he wears hat, coveralls, gloves, rubbers, and respirator. At the marked boundary, he must remove rubbers to prevent spreading contamination into "clean" area beyond.

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Distance from the source. The exposure that a man receives from a point source of radiation varies as the inverse square of his distance from it; that is, if he doubles the distance, he receives only one-quarter as much radiation; if he triples the distance, he gets only one-ninth as much; and so on. A worker might want to shift the position of a small plumbing fixture, for example, that had been irradiated in the pile and was so "hot" that he would get his full permissible daily exposure in one second if he picked it up. By using tongs a foot long, he could hold it half an hour. With 6-foot tongs he could hold it all day in safety. Therefore, the pile mechanics have devised a great variety of remote handling tools and equipment such as saws and cutting torches that can be operated at distances up to 10 and even 15 feet.

Limits of exposure. Whatever his distance away from the source, the radiation that a man receives is carefully measured, and when he has received his permissible exposure he is through for the day. Therefore repair crews have spare members, and repair jobs are carefully prepared in advance. It is typical in the pile building for the planning of repair jobs to take far longer than the jobs themselves. A pile shutdown is of limited duration, and detailed planning for repairs usually begins a week in advance. Ingenuity in developing repair methods, invention of special tools, and exhaustive rehearsal of unfamiliar jobs—all have been required to keep the reactors running.

On one occasion, for example, it became important to replace a part of the mechanism used in discharging slugs, but it appeared that such a job would take at least 8 hours. A maintenance foreman, however, felt that he could do better. He designed special tools and assembled a picked crew of mechanics. These men practiced and drilled for many days. When the pile was shut down, and the necessary time for "cooling" had elapsed, they replaced the part in 3 hours.

Protection Against Internal Radiation

To protect the worker against taking radiomaterials into his body, with consequent internal radiation exposure, both air and surface contamination are rigorously controlled in all plants.

Air contamination control. Air contamination may consist of radioactive gases or of airborne radioactive particles, solid or liquid. All three kinds exist in the pile buildings, but the danger from air contamination at this stage is not great compared to that in later operations. Greatest precautions are taken in the plutonium metal

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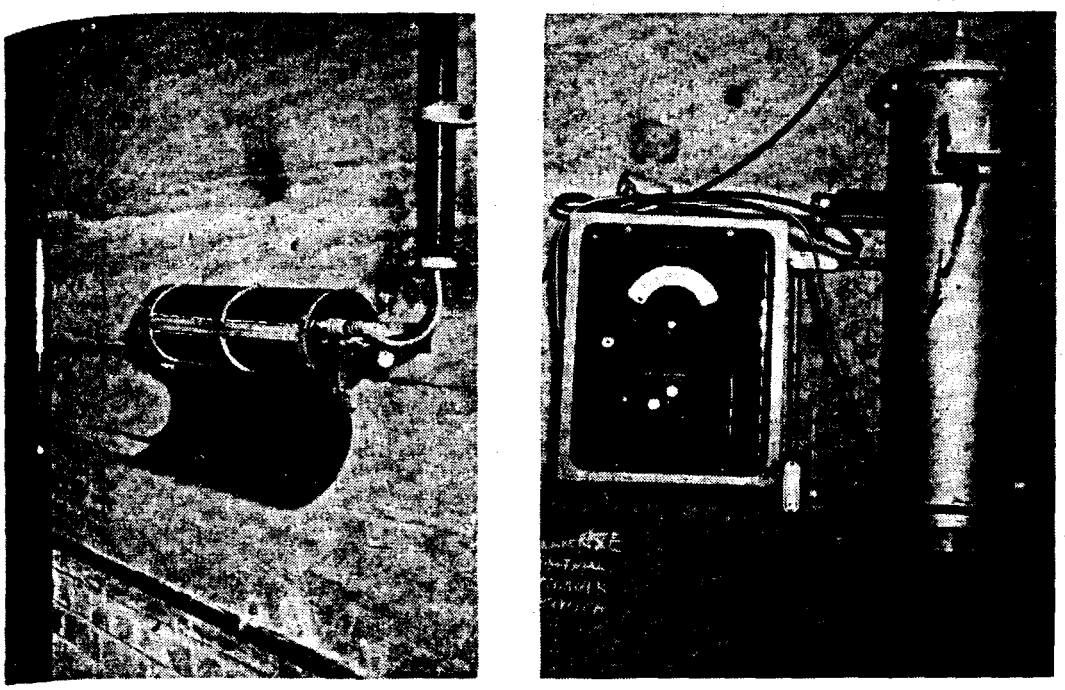
working plant, where ventilation is a major item in the cost of the structure.

Any air allowed within the chain-reacting pile itself is made radioactive by the neutron bombardment of such atmospheric gases as nitrogen and argon. When a control rod is pushed in, it displaces air that has been subjected to neutron bombardment. Also, from this and from many other sources, radioactive particles in the form of dust or moisture get into the air in the pile building. The major remedy, as in all the other plant areas, is ventilation. The air from around the pile is pumped through ducts and out a high stack. Automatic recording and alarm devices continually monitor the air for contamination (see photographs).



Two types of fixed ionization chambers which constantly monitor plant air for contamination—radioactive dust or moisture. Instrument at left reports activity at point inside shielding wall for benefit of workers who must enter the area. The more elaborate equipment at right pumps air through chamber for continuous sampling in bulk; it shows activity on dial and continuously records measurement on distant chart in central control room.

When a worker must go into an area of contaminated air, he wears a respirator—an "assault mask" if only particles are present, an oxygen mask if there are radioactive gases to contend with.

Surface contamination control. Control of radioactive contamination consists basically of preventing its transfer from one place to another, and of cleaning contaminated surfaces. Any movement of workers, equipment, or materials that might spread contamination must be carefully controlled, as is reported in the following description of "canyon" operation.

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Protection in Chemical Separation Plants

In the chemical separations plants, the "canyons," the slugs are dissolved and processed, through a series of stages, to extract the plutonium product.

Nearly all of the great variety of atoms created by the splitting of U 235 in the chain reaction are radioactive. These waste products, along with unconverted uranium must be separated from the plutonium. The plant must handle the greatest aggregation of assorted radiation sources ever processed. Direct radiation from the material is penetrating, with high-energy gamma rays and beta particles. Some of the fission products are in the form of radioactive gases. Contamination of all process equipment and of the air in the process chambers is extreme. Every piece of equipment that has been used in this process is radioactive, not in its own substance like things irradiated in the pile, but from the contamination of its surfaces and pores—contamination which is usually so great that the equipment never can be cleaned safely.

Although the emphasis is different, the same principles of protection are applied in the chemical separations plants as in the pile buildings: shielding, distance, time limits, ventilation, and control of contamination. These are only principles, however. Putting them into practice on a giant industrial scale is a complex, many-sided, and expensive operation—a task that begins before the plants are built and never ends as long as they are in operation. It involves the development of plants and equipment that are unique, work routines that have never been followed before, types of instruments that did not exist 10 years ago. It requires vigilance against a hazard that cannot be seen and can be detected only with special instruments. It necessitates the careful selection and training of personnel. And it calls for the constant day-by-day, job-by-job cooperation of the operating personnel and the radiation safety men.

The way in which all these elements combine in practice to protect personnel can best be explained in terms of the daily activities of the workers who are being protected.

The Radiation Worker

One of the "canyon operators" may be taken as typical, for in his daily work as a member of the operating staff of one of the chemical separations plants he may make use of nearly every kind of protection against radiation. Perhaps he is a man who formerly worked in an oil refinery, or in the chemical industry. He is used to doing his day's work through the remote control processing of materials that he never

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ness. Chosen for his job, he is by temperament steady and somewhat deliberate and not in the habit of picking up a tool or throwing a switch before he knows just why he is doing so.

The operator has attended the regular group meetings held in his plant, at which his operating supervisors and the area radiologists (Health Instrument Divisions engineers or "H.I. men") have presented radiation protection problems. He understands the nature of radiation and how he is protected. He is at home with the sometimes laborious way he must do jobs for his own protection, and the rigid routines he must follow. He knows how to use long-handled tools, how to remove protective clothing without contaminating himself, and how to use radiation detection instruments to monitor himself and the area around him for contamination. He has never been hurt by radiation—nor has anybody he knows—but he respects it nonetheless.

Radiation Protection During Routine Operation

At the gate of the plant in the morning, the operator receives from the guard his personal monitoring instruments: two pocket ionization chambers ("pencils") and his personal film badge, which he must wear throughout the day and turn in when he leaves. His first stop inside the plant is at the lunch room, where he must leave the lunch bucket he has brought with him. Although the plants are a long way from home and restaurants, there is no cooking done in these areas. The lunchroom is a "clean" area, where monitoring for contamination is continuous. Plant personnel especially assigned to the duty check the tables and all other surfaces with Geiger counters for beta and gamma radiation and with a "Poppy," the special portable survey instrument for alpha particles. Once inside the canyon, the operator may neither eat nor smoke because of the possibility of getting invisible radioactive particles into his mouth.

On this morning, he is first assigned by the chief operator to a station in the plant where he will have charge of one stage of the chemical processing. He first procures safety glasses, hat, and gloves—equipment to protect him against possible acid spills, not radiation. At his assigned station, he is briefed by the man he is replacing. Then he takes over. First he logs in the "run book" the readings from the battery of gauges on the panel before him.

As he stands at his desk watching the gauges, the operator has charge of huge amounts of radioactive material comparable to hundreds of pounds of radium. It is well known that even a tiny amount of radium is a deadly thing; in fact, the loss of an almost invisible quantity in a hospital or laboratory is an occasion for great concern—for the sifting of large dumps of waste material and other extreme measures.

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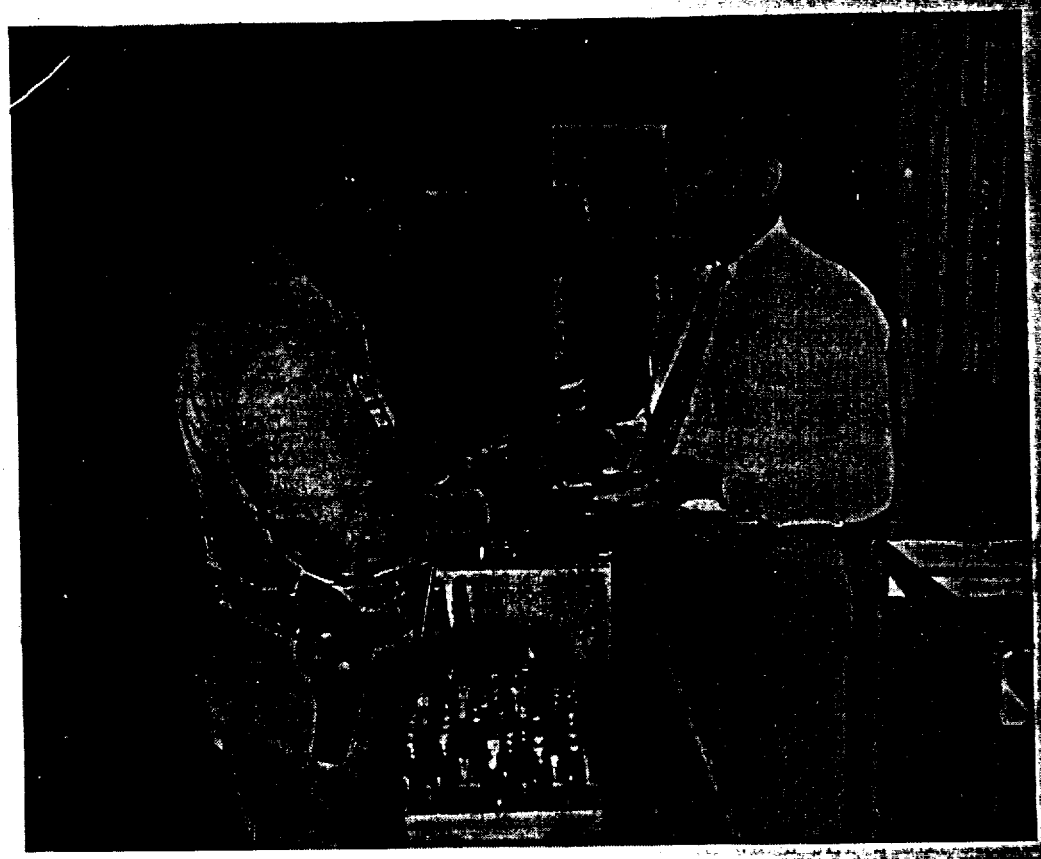

Personnel monitoring at Hanford. Everyone passing through the gatehouse on a plant area receives two pocket ionization chambers—"pencils"—and an identification badge containing radiation-recording film, riveted in place. These he must wear throughout the day and turn in when leaving the plant. They will then be "read" to determine his radiation exposure—the pencils immediately, the film badge at the end of the week.

The total amount of radium produced in the world to date is some 1500 grams (only about 3 pounds), or, in terms of radiation, 1,500 curies. For comparison, the material in the process under this operator's control may contain tens of thousands of curies of radiation and also give off radioactive gases. The reasons the operator can do his work in safety lie in the design of the plant.

Plant design for safe operation. Each one of the Hanford canyons contains enough concrete to build a 30-mile highway. The operator at his instrument panel faces a wall many feet thick, a solid wall in which there are no doors or other openings. On the other side of this wall is the canyon proper, a huge cavernous sealed-in area containing the chemical process equipment and some of the shielding and remote handling apparatus essential for repair and maintenance work.

Where the operator stands no harmful radiation can penetrate. The air is clean; he wears no mask. He does his work by turning valves—

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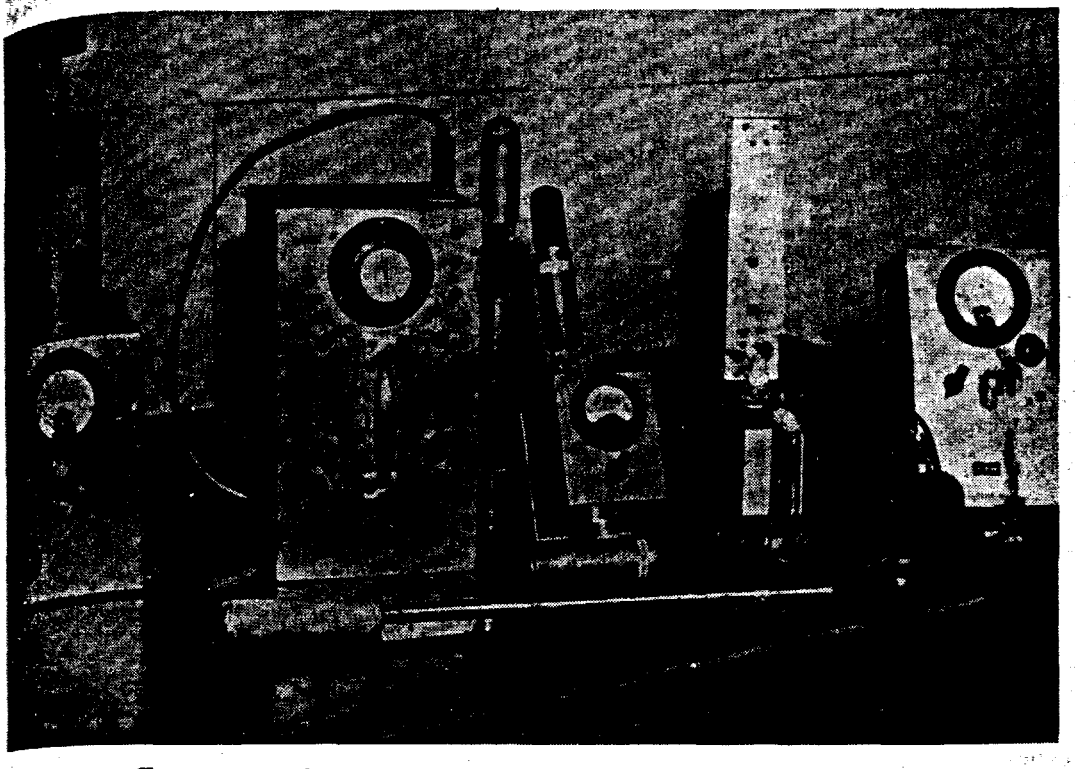
ves for adding acids to his batch of material, for transferring the terial from one processing vessel to another, for running off wastes, nd for other operations. For his guidance he has, not only a battery f gauges—for measuring process variables such as volumes, tempera-ures, and radioactivity—but also a meter to detect any unusual vibra-ion of moving equipment and even a loudspeaker through which he an hear process noises.



Developing efficient portable instruments for radiation survey is one of the most mportant tasks of health physicists at all AEC installations. Above are five nstruments developed at Hanford; left to right: (1) a meter for recording fast eutrons, known as "Neut;" (2) a Geiger counter with "scale of eight," capable f accurate measurements of quantities of radiation; (3) a beta-gamma meter ith interchangeable long and short probes; (4) a meter to detect the presence f alpha-emitting substances on flat surfaces; and (5) a "Juno," the widely used eneral-purpose meter that can detect alpha radiation as well as beta and gamma.

Protecting him while he works are two instruments connected to ecording devices and alarm mechanisms: an ionization chamber for letecting direct radiation and a machine that continually samples the ir for contamination. In addition, an H.I. man, or one of the plant perating personnel assigned to monitoring duty, periodically visits is station to take readings with a radiation survey instrument.

Nearly all of the connections between the operator's station and the rocessing tanks—all pipes and all electrical and instrument lines—ere cast in the massive concrete shield at the time the plant was built. lost of this equipment can never be replaced, and its repair is usually

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impossible; therefore multiple lines were laid at the beginning to take care of failure of any one.

All processing equipment which in an ordinary chemical plant, such as an oil refinery, would be lightly cased or even placed in the open, must be housed in massive concrete trenches and cells. The whole structure must be designed for high-efficiency ventilation, and the ventilating system must be supplemented by elaborate filtration equipment to prevent release of radiomaterials to the outer air. The lines carrying liquid and solid wastes to disposal points must be as strong and troublefree as it is possible to make them. In fact, the entire plant must be constructed as though it were expected to operate for a hundred years, with a reliability far beyond anything ever considered practical in the chemical industry generally.

An Emergency Repair

Yet all machinery needs repair occasionally; and, in the Hanford plants, remotely controlled maintenance equipment must be provided along with the operating equipment. It may happen, for example, that the operator, when he attempts to move process solutions from one vessel to another, finds that he cannot do so; something is clogged in the processing area. In such a situation the chief operator and the plant supervisor might decide that the clogged unit had to be repaired or replaced. A complicated job would then be initiated, one that involved two kinds of preparation.

Plant design for maintenance. To begin with, no man could safely go into the region where the trouble lies. It is necessary that the piece of equipment containing the faulty unit be detached and removed from its normal position and placed in a position within the sealed canyon where men can work and still be shielded from the radiations emanating from the process area. First, a work crew, properly clothed and protected, makes a quick trip into the canyon to lay down and tape heavy paper on the floor at a chosen spot, so that the piece of equipment, when removed, will not contaminate the concrete surface. Then the crane in the canyon goes into operation.

This remote-control crane is able to reach any point in the huge canyon area, and to detach and lift out any designated piece of equipment from amidst a maze of machinery. Also, it lifts, gently and accurately, the protective shielding needed to safeguard the workers—blocks of concrete weighing up to 36 tons. The operator who does these things can have no direct view of his work. In the moving cab where he works, he must have remote viewing and magnifying apparatus, powerful lighting, shielding of both concrete and lead, and even his own air supply.

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When the crane has finished, the piece of equipment that is to be worked on is lying in the prepared spot; the area around it is shielded from the other processing equipment; and fences have been erected to prevent personnel from moving into danger areas. The piece of equipment itself, however, is a radiation source; being highly contaminated with process solutions, it is broadcasting powerful gamma rays in all directions.

Plant procedures for maintenance—the "SWP." Therefore the mechanics who are to repair it will do their work only for calculated times and at calculated distances. If the job is not a familiar one, it will be rehearsed in advance.

There are, of course, tasks to be done in the canyon that are routine. The crew that prepared the floor in this instance took standard precautions and monitored the area about them with radiation survey instruments. All Hanford workers in such situations do this. Even normal operations—the sampling of process materials, for instance—call for routine visits to the canyon; but the movements of workers, the protective clothing they wear, and the tools that they use have all been developed to make sure that they are not exposed to significant amounts of radiation, either external or internal. Men doing this kind of work carry cards that must be punched to show amounts of radiation exposure received. These become part of their personal radiation exposure records.

An unfamiliar repair job, however, calls for detailed study and agreement in advance on the steps to be taken. The plant supervisory personnel, and the men who are to assist them, practice the operations they expect to perform, using an uncontaminated piece of equipment identical with the one that the crane detached and put in place inside the canyon. The mechanics study the tools that they will use. They may have to devise special ones. The H.I. engineer of the plant estimates in advance as closely as he can the length of time that each man will be able to work on the job, in the light of the expected intensity of radiation, the length of the handles on the tools, and the daily permissible radiation exposure allowed. It is decided how many spare mechanics shall go along with the crew.

As they make these plans, the men fill out a form: the Special Work Permit, or "SWP." The SWP is several things at once: a plan of the job, an agreement on the radiation protection precautions that are required, and a ticket of admission to the canyon. Later it will become a record of what happens. When prepared, it shows:

Description of the job and its location.

Survey readings of radiation expected.

Maximum time limit per man in each working position.

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Safety equipment required.

Special instructions; for example: "No cuts or abrasions on hands or fo . . . . Notify H.I. if splashed by process water."

Names and numbers of all the crew members, and opposite these the spa recording the exposure time of each.

And finally, the "Approval to Start Work," which must be signed by the sible representatives of the three divisions involved: operating, maintenan H.I. Their signatures indicate that the job has been thoroughly planne contingencies have been anticipated insofar as is possible, and that they agreement upon the radiation conditions to be expected and the plans ma dealing with them.

Anticontamination clothing. The typical work crew for su assignment might consist of the plant supervisor with one or two operators, the maintenance foremen with perhaps three or fou chanics, and—always—an H.I. man. When everything is ready go to one of the clean change rooms, where they strip to the ski put on special clothing. For this job they wear white coverall pairs; gloves, two pairs, one rubber and one leather; cloth hats f ing tightly over the hair; and rubbers over the shoes. To preve breathing of process gases they wear masks which supply thei oxygen.

The limited exposure. Entering the danger zone, the H.I. en goes ahead of the rest of the crew, inspecting the locality for active contamination with his radiation survey instrument. H ries a notebook to set down the history of the job. The othe carry some of the tools and spare parts required, although th which prepared the floor has already set out and arranged all th dicted tools" called for by the SWP. The H.I. man approach piece of equipment that is to be repaired and reads the radiati tensity from all angles. After surveying the position, he corre estimates as necessary and sets the lengths of time that the me work in different spots about it. The operator whose day's act are being followed may be a member of this crew, serving as keeper—being responsible for timing every man's exposure. maintenance foreman sizes up the job and turns it over to th chanics, who begin detaching the plugged-up unit from the r the assembly, using tools with long handles.

These mechanics are now receiving direct radiation in a me amount, but each man's exposure will be kept within safe limit is said that new men on this job imagine they feel the radi sometimes as a prickling sensation in their bodies. Of cours do not feel it, but they know that they are getting it and mus their supervisors and the H.I. personnel to see that they do n too much. It is of immeasurable assistance to operations that n at Hanford has ever got too much.

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Contaminated equipment. It develops that the men cannot unplug the unit without disassembling it. They put their special tool to use. Before the unit has been disassembled the timekeeper motions to one of them, meaning that in the position where he has been working he has used up his time; he has received all of the radiation that is permissible. The mechanic retires and a reserve man takes his place. Still the unit cannot be unplugged, and the supervisor decides that it must be discarded. A spare unit is at hand, and this is satisfactorily installed.

The unit that has been discarded will never be used again; it is too contaminated to be worked upon. It will be removed to the burial ground outside the plant, by way of the crane and other remote-handling equipment. The man in the crew who has received the least exposure goes to work quickly to wrap it up and tape it, and then establishes a danger zone around it by putting up a fence. In some instances when there is no space for fencing a piece of contaminated equipment, it is necessary to use lead bricks to build a wall around it and cover it completely. These little mounds or cairns of lead bricks are a common sight in the contaminated zones of the Hanford plants.

Decontamination of tools. To make clear another step in radiation protection, it may be assumed that a second complication has ensued. A special wrench has been broken, and the maintenance foreman decides that it is worth repairing. Most of the tools used on repair jobs are kept in the exclusion area itself. But this wrench is to be taken out to the shop and therefore must be decontaminated. The operator and the H.I. engineer stay to do this job after the rest of the crew leave the canyon. The operator carries the wrench with tongs to the decontamination station in the canyon and holds it with tongs while he works on it. He swabs it with nitric acid and then dumps it into a bath of water and finally wipes it off with rags—rags which will be disposed of in the burial ground. The H.I. man is standing near him and continually monitoring the radiation he is receiving. Now the H.I. man tests the wrench to see if it is clean. He shakes his head and says try it again. The other repeats his swabbing with acid, rinsing, and wiping. This time the H.I. man decides that the tool is clean enough to take out with them, but nevertheless they wrap and tape it before they leave.

Decontamination of personnel. As they leave the canyon, the men of the repair crew are potentially contaminated from head to foot. In this condition, they cannot go into a clean area. Evidently, there has to be a decontamination area in between. At an established boundary, they kick off their rubbers and step across into an intermediate zone. There they undress, in a supervised change room. Gloves,

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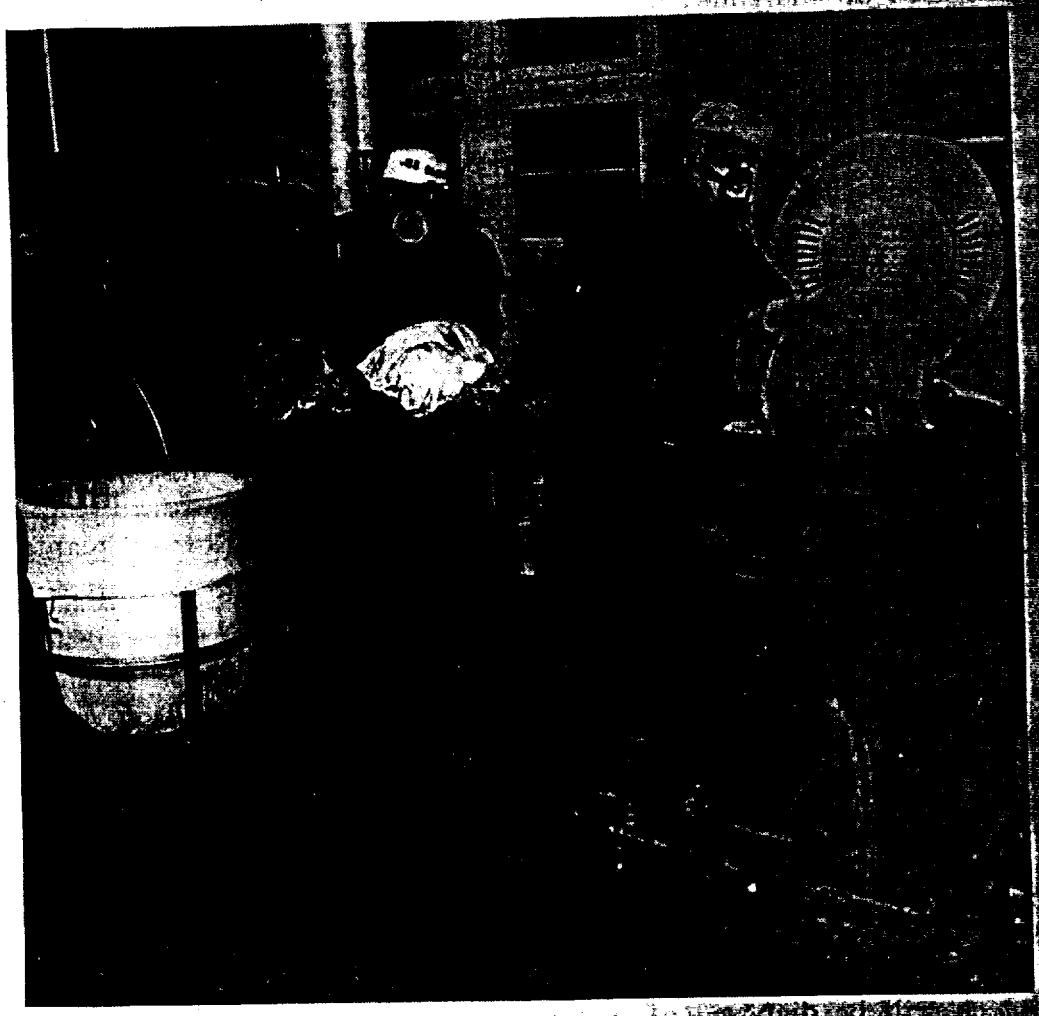
hats, coveralls, masks—all go into separate containers destined for the decontamination laundry, where they will be cleaned and tested for use again. The handling, laundering, and testing of contaminated clothing is carried out on an undeviating routine by trained personnel.



Scene in a decontamination laundry. Protective clothing worn in contaminated areas—coveralls, hats, gloves, etc.—is worn only once before being sent to a special laundry, where it is washed and checked carefully with radiation detection instruments before being reissued. Clothing that cannot be decontaminated is disposed of by special means.

Next the men take a shower bath; then carefully monitor themselves for contamination, using a Geiger counter for beta and gamma radiation, and a "Poppy" for alpha particles. They dress in the clean area where they left their clothes; and, having finally tested themselves at the "hand and foot counter" and recorded the readings shown on their "hand score cards," are ready for reassignment (see photograph, p. 146).

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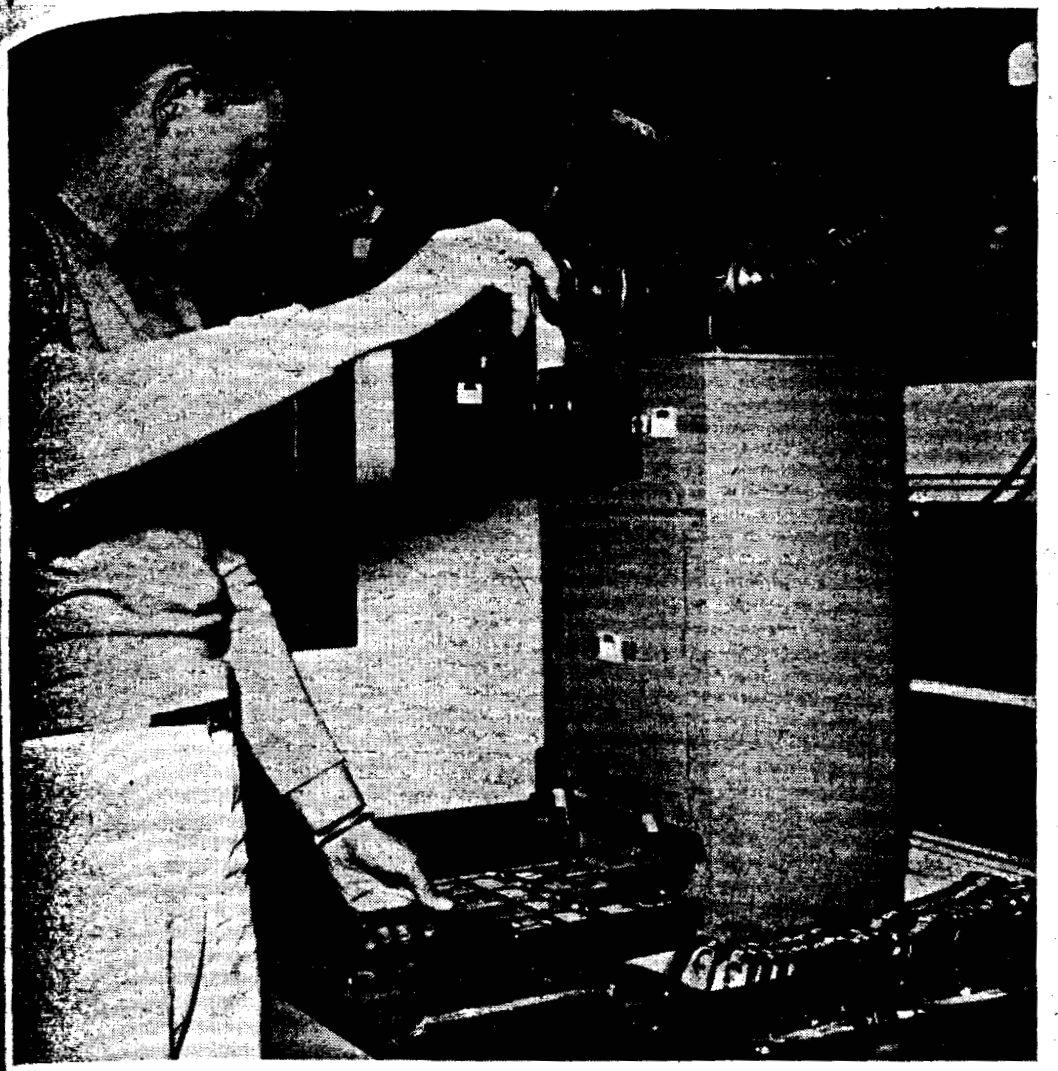
Personal decontamination is typically as simple as this, but com-ications sometimes are involved. If contamination gets onto a man's nds, for example, they will be scrubbed with tincture of green soap, odium bisulphite, potassium permanganate, or other cleanser. The



The film badges worn by all Hanford workers to measure the radiation they receive are checked weekly by a mobile servicing unit which moves from plant to plant. Here a health physics worker uses a special X-ray machine to expose on fresh films the payroll numbers of employees to whom the badges will be assigned. This insures correct identification later.

scrubbing may have to continue until the skin is sensitive. The H.I. man may take a dozen readings during the process, and he keeps a record of the whole procedure.

Personnel Monitoring Records

This particular SWP is now terminated; it is no longer good for entrance into the canyon. The H.I. engineer reviews it and com-

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pletes all data regarding radiation exposure of all the men, including himself. As the operator leaves the plant at night, he will again record his hand and foot count on his hand score card, then give up his film badge and ionization pencils.

The pencils will be taken upstairs to the personnel monitoring instrument servicing station in the gatehouse. There the electrical charge in the chambers will be measured; the amount that it has decreased during the day is a measure of the radiation the wearer has received. A faulty or "leaking" pencil, however, may be discharged for other reasons; hence the extra one for each worker. If both pencils indicate significant exposure, the worker's film badge is immediately obtained from the rack downstairs and developed, and if it also shows that he has received more than half his permissible exposure, an immediate investigation of his activities during the day will get under way. Normally, film is a very reliable indicator of radiation. Two films of different sensitivity are used in each badge, riveted in to make tampering or loss impossible. Ordinarily, film badges are developed once a week.

The worker's personal monitoring does not end with these instruments. Periodically, his blood and urine are tested. Twice a year he goes to the hospital in Richland, where the Medical Division gives him a complete physical examination. Periodically also, a radiation counter is used to detect any possible accumulation of iodine 131 in his thyroid gland, since this gas is one of the fission products involved in the chemical separations process. No significant accumulation has ever been discovered in any worker, but the test is maintained.

Records. The Health Instrument Divisions thus have on file the following records concerning each worker in the Hanford plant area:

Daily accumulated exposure—from pocket ionization chambers.

Weekly accumulated exposure—from film badges.

Daily record showing absence of contamination on hands and feet of workers leaving plant—from hand score cards, recorded at hand and foot counter.

Record of exposure of workers entering exclusion areas—either on SWPs or on the passes of workers who occasionally enter these zones in the course of their duties.

Exposure under special circumstances—from finger film rings, neutron pencils and other special personnel monitoring instruments.

Medical and bioassay records from periodic tests.

Getting all this information involves some two and a half million separate measurements annually. From the various plant areas, data feed into a records center, where the radiation history of everybody who has ever worked—or even visited—at Hanford is on file.

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Complete records of this sort are considered essential in the atomic energy industry, where the potential hazards are still unknown quantities to the public in general and even to a large proportion of the medical profession. If a Hanford worker, or former worker, becomes ill, and the suggestion is made that radiation exposure is involved, the H.I. records make available his entire radiation exposure history, day-by-day and job-by-job; the Medical Division records give his medical history. No case of radiation injury has been found. Hanford workers receive no hazard pay; their earnings are the same as they would be for comparable work in the oil or chemical industries.

Protection in Plutonium Metal Work

Throughout the chemical separations process, the amount of radiation that must be guarded against becomes progressively less as the radioactive fission products are shunted off into the disposal lines and the plutonium becomes purer. The final stages of the purification process find the plutonium solutions in gleaming tanks with no more shielding than a glass case provides. The glass case has its protective function. Whereas direct radiation need no longer be considered, the hazard of internal exposure, here and in the metal-working steps to follow, has become great. Plutonium, with its long-lived alpha activity, is one of the most dangerous substances, medically speaking, ever manufactured by man.

Protection in the final stages of the Hanford process reduces itself to the single principle of prevention of any contact whatever between workers and the process material. This calls for a regimen of extreme cleanliness—of all surfaces and of the air—and a constant alpha-particle survey of every detailed part of the plants.

In the plutonium purification and fabrication plant at Hanford, the objective of keeping plutonium away from the personnel was a governing consideration in design and a principal item in cost. Operators use remote control equipment to work with the material from behind protecting walls. Every surface of the plant was planned with the problem of decontamination in mind. The ventilation system is unlike any that has ever been constructed. It was designed to keep the quantity of plutonium in the air at a level of not more than one in a million billion parts. Furthermore, the tremendous amount of air required to accomplish this must be filtered as it enters the plant and again as it leaves the plant.

In Case of Disaster

If for any reason the chain reaction in one of the Hanford piles were to "run away"—if the number of neutrons and of U 235 fissions

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were to multiply and remultiply out of the operators' control—the result would be a disaster in the plant area. There could not be a nuclear explosion like that of a bomb, but the excessive energy and heat would probably breach the structure of the reactor, producing an airborne cloud of fission products and irradiated materials. This is one of the chief reasons why the plutonium plant was located in a 640-square-mile desert reservation. This is the reason, also, why approximately 88,000 acres of the Wahluke slope, the region directly across the Columbia from the piles, must remain a part of the Government reservation. All points in this region are closer to the piles than the nearest inhabited area now existing.

The design of the piles makes a disaster virtually inconceivable except from such external causes as severe earthquake or successful enemy action. Besides the regular operating control rods, the pile is equipped with other quenching devices, each of which can stop the chain reaction. These devices do not depend upon human vigilance for their operation; any serious malfunctioning of equipment would set them in operation and automatically shut down the pile. The precautions against any such malfunctioning of equipment are similarly elaborate.

Unlikely as the event is, however, the operating and H.I. Divisions at Hanford have carefully planned the moves that would be made if a pile "ran away." Emergency transport is continuously available, and periodic drills are held. The H.I. Divisions maintain a 24-hour service of radio-equipped cars. In the Hanford patrol headquarters in Richland, a control center has been set up. Information could be radioed to this center concerning the spread of radioactivity; the extent and movement of any discharge into the air could be charted; and evacuation of the plants could be directed by radio. A 12-man emergency monitoring team has been established, equipped with kits of survey and protective equipment and trained in surveying, posting, and mapping the radioactive contamination that might exist in some critical area (see photograph, opposite).

The Role of Health Physics in the Hanford Plants

It is evident from the foregoing that the health physicist—the "H.I. man"—has a many-sided role at Hanford. Radiation safety, his primary concern, enters into the choice of a process to be used in a new plant and the selection of the site; it is involved in design of the structure, the installation of equipment and instrumentation, the staffing of the plant, the setting up of the operating routines, the training of the workers, and, indeed, even the cleaning of the floors. The health physicist, moreover, is intimately concerned with the problems of day-by-day operation.

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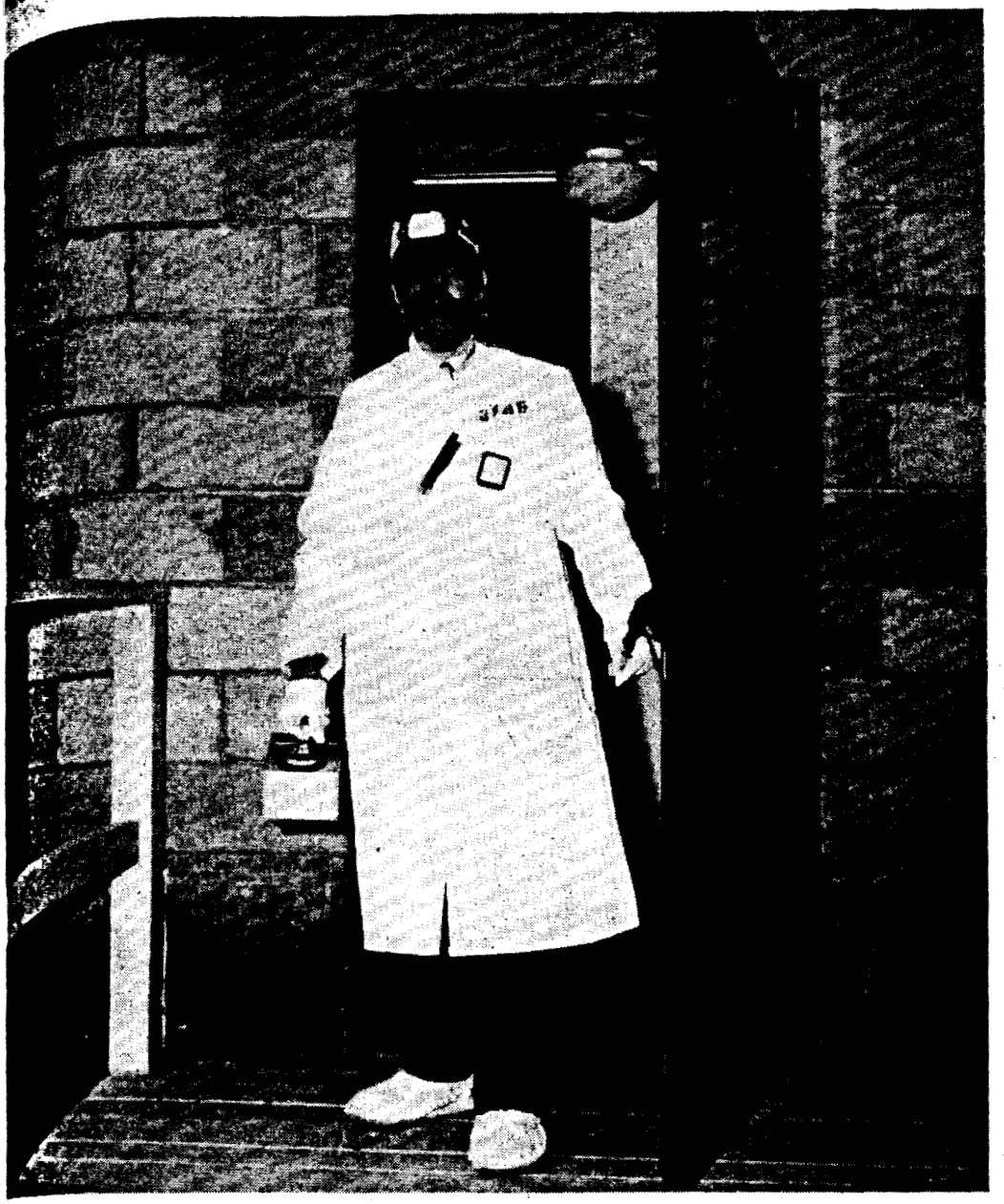

A member of Hanford's 12-man emergency monitoring team wearing the protective equipment and carrying the alpha-beta-gamma survey instrument he would use if he were called upon to survey a plant area for radiation in case of the accidental spread of contaminated material.

But once the problems within a given plant have been met and solved—the design executed and the work patterns established—the protection of personnel becomes an operating function. A workman is responsible to his plant supervisor for what he does or does not do, whether it relates to the carrying out of his duties or the protection of himself.

The H.I. Operational Division, therefore, acts in an advisory and service capacity at the Hanford plants; it does not have police responsibilities. If a mechanic in the pile building picks up a "hot" pipe

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Development of instruments for radiation detection at Hanford. Here an electronics expert operates a complex pulse analyzer, which is able to identify certain radioactive elements by the energies of the alpha particles that they emit.

fitting with his glove instead of with the tongs prescribed by the SWP, he is answerable to the plant supervisor. Following that, the incident is investigated by a subcommittee of the Special Hazards Committee.

The Special Hazards Committee. This permanent committee of the General Electric Nucleonics Department publishes bulletins which govern the conduct of all work involving radiation throughout the plants. It translates basic protection principles into specific operating procedures and is the means by which the various divisions obtain agreement in these matters. All incidents in which personnel have received exposure in excess of a chosen limit—or might have done so under slightly different circumstances—are discussed at special hazards meetings attended by plant personnel. Formal reports on such incidents are reviewed by the Committee.

H. I. Divisions' Direct Responsibilities

The direct responsibilities of the Health Instrument Divisions in the Hanford plants are similar to the typical duties of health physicists and engineers in all atomic energy establishments, as described in other

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rts of this report. Chapter VII describes the operating and train- activities of such AEC organizations. Chapter VIII recounts eir work in developing, providing, calibrating, and maintaining monitoring and survey instruments that are essential to the work. Chapter V is devoted to the survey and research work going into the protection of the environments around atomic energy installations, Hanford and elsewhere. Descriptions of health physics research re to be found throughout the report.

Health physics research at Hanford. During the war, little health physics research and development work was conducted at Hanford. In the past three and a half years, the Commission has built up a program, not of fundamental research, but of research and development required for direct support of the radiation protection work. New facilities, completed or projected, include an experimental animal farm, a biology laboratory, an aquatic biology laboratory, a control and development laboratory, and a personnel meters and records building.

Some of the Hanford research in the biological sciences and in geology and meteorology is reported in Chapter V. The research group in physics deals with such problems as neutron dosimetry; measurement of contact dose from solid and liquid materials; and the application of particle-sensitive films to dosimetry. Chemical work includes studies of the source and composition of radioactive particles from separations plant stacks; accurate analyses for plutonium and fission products in vegetation, urine samples, etc.; improved calibrations of particle-counting equipment; and retention of dissolved radioactive materials in soil. The workers in biochemistry are concerned chiefly with problems in toxicology, such as the transmission of radioactive contamination through wounds or intact skin; absorption of radioactive materials from the gastrointestinal tract; deposition of such materials in the liver, bone, and other parts of the body; and development of

The principal process material, uranium hexafluoride, is a potential radiation hazard because of the fissionable and radioactive properties of uranium, both of which become more significant as enrichment in U 235 increases. If U 235 were permitted to accumulate sufficiently, an accidental fission reaction could take place. While such an accident would not result in an explosion, there would be a serious radiation hazard. Enriched uranium is, therefore, processed and handled only in amounts and shapes which have been shown experimentally to preclude the possibility of reaching critical mass.

The chief potential radiation hazard at the gaseous diffusion plant is that workers may inhale, ingest or otherwise take uranium into their bodies. This hazard is controlled by the same general type of protective equipment and methods of preventing spread of contamination reported at Hanford.

From the beginning of operations, the two basic objectives of the radiation protection program have been met by:

a) Continued research on the safety provided by basic design factors in the operations.

b) Application of new experimental data to the operating conditions.

c) Education of operating personnel in recognizing hazards and understanding the methods of control.

d) Frequent check of all plant activities to verify that safe conditions are maintained.

Health conditions at present are as follows:

a) There is no clinical evidence of injury to any persons because of exposure to radioactive materials.

b) Plant contamination and radiation levels have steadily decreased and are well controlled.

c) Water used in the plant has never shown activity above permissible level.

Nuclear Hazard Prevention

The plant was designed to prevent any accumulation of a critical quantity of fissionable material. Several factors determine whether an amount of U 235 will become critical: the mass of U 235 in one place and its density; the amount of intermixed moderating (neutron-slowing) material, since the critical mass for slow neutrons is less than for fast; presence of neutron absorbers and reflectors; geometrical shape; and proximity of other accumulations of fissionable material. Soon after plant operations began in 1944, experimental work became

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ecessary to determine how the amount of U 235 constituting a critical ass depended on these variables and what conditions were most likely cause fission reactions. Critical mass experiments were started rly in 1946. The conditions for nuclear safety in the various processes undergo continuous re-evaluation.

reventing Critical Accumulations

The quantity of U 235 that will become critical is very large for a hape of unequal dimensions, such as a long cylinder or flat slab, and is smallest for a sphere. In the case of a cylinder, for example, there is a minimum diameter of an assembly of uranium which can become ritical. If the diameter is less than this minimum, the system cannot become critical regardless of the mass of uranium added to it in other directions, or of other conditions. Hence, an essential in the nuclear afety program is to keep equipment that will contain U 235 smaller han those dimensions that are necessary for criticality. Where small imensions of equipment cannot insure safety, the mass of U 235 in a single container must be limited. In these cases, a large safety actor is required, and rigid supervisory control is maintained.

afety in containers. A harmless shape and volume of U 235 in ingle containers will not prevent a fission reaction if two or more uch containers are placed too close together; neutrons leaking from ne might produce fissions in the others. Experimental data have een obtained on the relative positions of two individually sub-critical ontainers of U 235 which, taken together, form a critical system. ased on this information, procedures rigidly prescribe the relative ositions of parts of process equipment, and of methods of moving ne container in the presence of others.

In some instances, spacers are used to keep containers a predetermined safe distance apart, and to prevent containers in transit from pproaching too closely to containers in storage.

uclear safety organization. Nuclear safety practices are the responsibility of a committee composed of key plant personnel, and several uclear physics consultants who review the program periodically. ll changes in plant operating procedure are reviewed by the committee. An educationl program is maintained for supervisory and perating personnel, emphasizing the importance of safety rules. A roup of trained technicians surveys plant operations periodically for otential hazards.

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Contamination and Radiation

To meet the uranium hazard to the health of workers at the gase diffusion plant, radiation levels of all materials, equipment, and lo tions are kept below established permissible exposures. The degree actual exposure of any individual, however, depends on many facto such as personal hygiene and use of protective equipment as prescrib

As at Hanford, each employee has the primary responsibility his own safety to the same degree that he is responsible for ope tions. A concentrated effort is made to train all employees in pro health protection procedures through use of lectures, a film strip, on-the-job instructions in use of instruments, in recognizing haza and in applying control methods. Routine problems of controll radiation hazards from a health standpoint are delegated to organization. The supervisors are assisted by the Medical Dep ment and the technical health physics staff as necessary.

For the most part, U 235 production is carried on in completely closed equipment under partial vacuum which averts leakage of nium; thus normal operating conditions present negligible he hazards. During alterations, maintenance operations, or equipm failures contamination may occur through the necessity of opening process system. Decontamination is routine after jobs involv radioactive materials or after accidental releases; operating perso monitor their areas frequently; and regular checks are made by health physics staff.

Since diluted radioactive materials enter the Clinch River above point at which the plant area draws its sanitary water, the ente water is carefully monitored by both sampling and a continuous w monitor. No conditions above the permissible level have observed.

RADIATION CONTROL AT LOS ALAMOS

Some of the radiation safety problems and the procedures countered at Los Alamos Scientific Laboratory in research on fis able materials and in development of atomic weapons are repo here. While there are some problems that are unique to Los Al operations, the principles of protecting personnel are essentially same as throughout AEC operations.

Shielding and remote control are used in many operations, an operations, whether of a routine, research, or other nature, are m tored so as to reduce to a minimum the radiation exposure of perso Water supply areas near Los Alamos are monitored routinely to c on possible contamination.

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Protection Operations

The prime method employed by the operating contractor, the University of California, for protecting personnel from overexposure to radiation is to plan operations thoroughly in advance, using the same types of precautions reported previously. Shielding, and other built-in protections, are sometimes quite difficult when old buildings are used. In new buildings, safety devices are included, and radiological safety specialists participate in the preparation of building plans to assure this.

In limiting exposure of workers, chief reliance, here as elsewhere, is placed upon film badges and dosimeters worn by each individual, and upon monitors who check rates of radiation exposures throughout the installation. As a further check in certain operations, blood analyses are made at two-month intervals.

The contamination problem where large amounts of fissionable material are handled is similar to that in other AEC operations. In the rare cases where there is possibility of inhaling radioactive material, personnel are protected by placing the materials under force-ventilated hoods (see photograph, p. 50). As a further precaution, respirator masks are worn by the workers in the room.

The fission reaction hazard also must be guarded against. To prevent placing too much fissionable material in one place, specific rules and regulations are set up. These rules and regulations are based on remote control tests performed on the material in the worst configuration that one would ever encounter.

The rules for handling fissionable material allow a large safety factor so that a minor violation will not cause an accident. In addition, the safety group builds around each large accumulation of fissionable material an external safety cage to prevent addition of more material to a space already holding its allowed maximum.

Radiation Safety Groups

Because the Health Instruments Group of the Chemistry-Metallurgy Division at Los Alamos presents a good example of how radiation hazards are controlled and avoided in laboratory work, its organization and operation are reported here in some detail.

With a total staff now of 31 people, this group has very serious responsibilities for radiological safety and has adequate authority to stop any operation not considered safe. Seventeen persons are assigned to monitoring areas and equipment. Six others determine the amount of radioactivity in various samples and keep records of monitoring; five deal with a multitude of special problems. This last

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group's work in decontaminating special equipment puts back into useful service each month equipment valued at many thousands of dollars.

Six people are responsible for maintaining the hundreds of electronic and mechanical devices used in monitoring and in determining the amount of radioactive materials and the intensity of radiation to which the worker may be exposed. These people, together with four

When the chief potential radiation hazard is from contamination of the air, and shielding can be relatively light, such "dry boxes" as this at Los Alamos, are used: well-ventilated so that air flows from outside into the box, and out through filters; work done through rubber gloves that are sealed into the front of the box, and which provide adequate protection for the hands.

or five others, work continually to improve the instrumentation for monitoring and measurements of radioactivity.

The Chemistry-Metallurgy Division activities described above represent the work of only one division of the Los Alamos Laboratory. There is also a Health Division which watches over all potential radiation hazards throughout the Laboratory.

Careful indoctrination by the Health Division of new employees, firemen, and of maintenance personnel in the hazards involved and in precautionary measures is standard practice. Before any new experi-

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ment or operation begins, the group leader consults with the radiological safety men and then instructs all persons likely to be involved in the potential hazards which may be expected. Each person can then take proper safety measures.

In addition to regularly scheduled seminars and panel discussions on subjects related to radiation hazards, classroom courses are held.

In the special laundry at Los Alamos Scientific Laboratory, an employee uses an alpha-emitter detector to determine whether the clothing has been sufficiently cleansed of contamination.

Also, outstanding specialists in particular fields of knowledge are invited to lecture at Los Alamos.

Decontamination of Air

New problems occasionally develop and require special equipment to bring them under control.

For example, some operations at Los Alamos produced dusts or mists that contained radioactive substances in extremely small amounts. The air contaminated in this way had been filtered before entering the area so that it was very clean and the concentration of radioactive particles was of the order of 100,000 to 1,000,000 times less than dust concentration in ordinary air. Experimental attempts to remove such extremely small amounts of dispersed liquids and

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solids from moving air streams first led to the use of a vertical
with cascades of water and an air stream traveling against the
of the water. This was reasonably effective and was improved b
ing certain other features.

A standard commercial type of air-washing equipment,
called capillary air washer, was modified to incorporate the ne
tures that had been developed experimentally. Examinati
several independent engineering groups is evaluating the pract
and economic feasibility of the process.

Decontaminating Clothing

The wearing of protective clothing is mandatory in nearly
laboratory and plant of the Chemistry-Metallurgy Divisio
clothing becomes more or less contaminated with radioactive ma
and must be laundered after each wearing. If this clothing
laundered in an ordinary commercial laundry serving the rest
Alamos, radioactive materials would spread throughout the
town. To protect the community, the Los Alamos Laboratory
ates a special laundry for this clothing with a staff of 25 people
laundry handles over a half ton of laundry per day—between
and 80,000 garments a month (see photographs, pp. 38, 51). It
responsible for maintaining a supply of such other clothing as
cal-type gloves, other types of gloves, protective devices and r
tors, and for issuing them as needed.

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III

SAFE HANDLING OF RADIOISOTOPES

The radioactivity from radioisotopes used in research and in medical diagnosis and treatment is potentially hazardous to the people who produce, handle, and use them. More than 100 different radioisotopes are produced, processed, and shipped by the Atomic Energy Commission through its production and distribution facilities at Oak Ridge National Laboratory, operated for the Commission by Carbide and Carbon Chemicals Division, Union Carbide and Carbon Corporation. Most radioisotopes handled emit beta or gamma radiations (or both) with energies that range from 0.011 Mev to 3.58 Mev for betas; 0.039 Mev to 2.76 Mev for gammas; and half-lives that vary from a few hours to thousands of years. Since August 1946, when the Manhattan Engineer District distributed the first radioisotopes from Oak Ridge, over 11,000 shipments have been made to off-project users in all parts of this country and in 27 foreign countries. The total amount of radioactivity included in these shipments is about 850 curies, equivalent to about 2 pounds of pure radium.

The demand for radioisotopes continues to increase. To meet this demand a new plant costing 2.4 million dollars was opened at Oak Ridge during February. This plant will provide permanent and more efficient facilities for producing and packaging radioisotopes on a commercial basis. Shipments of radioisotopes during the first quarter of 1950 totalled 1,777, representing a 20 percent increase over the preceding quarter and nearly 35 percent more than the number of shipments in the corresponding period of 1949. Foreign shipments totalled 66. Of the 1,399 domestic shipments to non-AEC users, all were distributed free of production cost for work in the field of cancer. Total shipments of 2,213 during the second quarter showed a continuing upward trend.

The radioisotopes have been produced, shipped, and put to use by hundreds of workers—in the isotope production and processing facilities at Oak Ridge, on railroads, motor freight lines, and air lines, in laboratories, and in private institutions and industries—in safety and without a single reported radiation injury.

The techniques, devices, and procedures reported here for handling radioisotopes made this safety record possible.

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RADIATION PROTECTION DURING PRODUCTION

Nearly all of the radioisotopes distributed by the Commission are produced in the nuclear reactor at Oak Ridge National Laboratory. Broadly speaking, the neutrons from fission of U 235 in the reactor produce radioisotopes in three different ways:

a) By transmuting the atoms of one element into radioactive atoms *of a different element.*

b) By being absorbed into the atomic nuclei of an element and turning them into heavier radioactive atoms *of the same element.*

c) By splitting atoms of U 235 into radioactive atoms *of entirely different elements.*

Radiation protection during actual reactor operation is provided mainly by the heavy shielding of the reactor itself. In nearly 8 years of operation, none of the people working daily in and around the reactor building has ever exceeded the maximum permissible limit for exposure to radiation.

Reactor Loading and Unloading

When the reactor is loaded, when materials are thrust into the reactor to be irradiated, ports are opened in the shielding. The reactor is shut down before this is done, but even so the materials within the reactor continue to emit intense radiations. To protect the workers during the loading operation, the samples to be irradiated, sealed inside aluminum cans, are placed in a graphite block or stringer; the stringer is then placed in a thick, long lead tunnel which surrounds and covers the opening into the reactor as in the photograph. Through this tunnel, the stringer of samples is pushed into the reactor. Lead, one of the best absorbers of beta and gamma radiations, protects the workers from the radiations from inside the reactor. Throughout the operation, a health physics surveyor stands by and makes constant measurements of radiation levels. The amount of radiation is carefully logged so that a permanent record can be kept to make sure that no worker receives more than the maximum permissible limit that has been set.

After the materials have been irradiated in the reactor for the required length of time, the reactor is again shut down for unloading. This operation is essentially the reverse of the loading process, but the aluminum cans now have become intensely radioactive and workers are further shielded. This radioactivity has a very short half-life and virtually disappears in less than an hour.

After an hour, the remaining radioactivity comes almost entirely from the material inside the aluminum can. The amount of radiation

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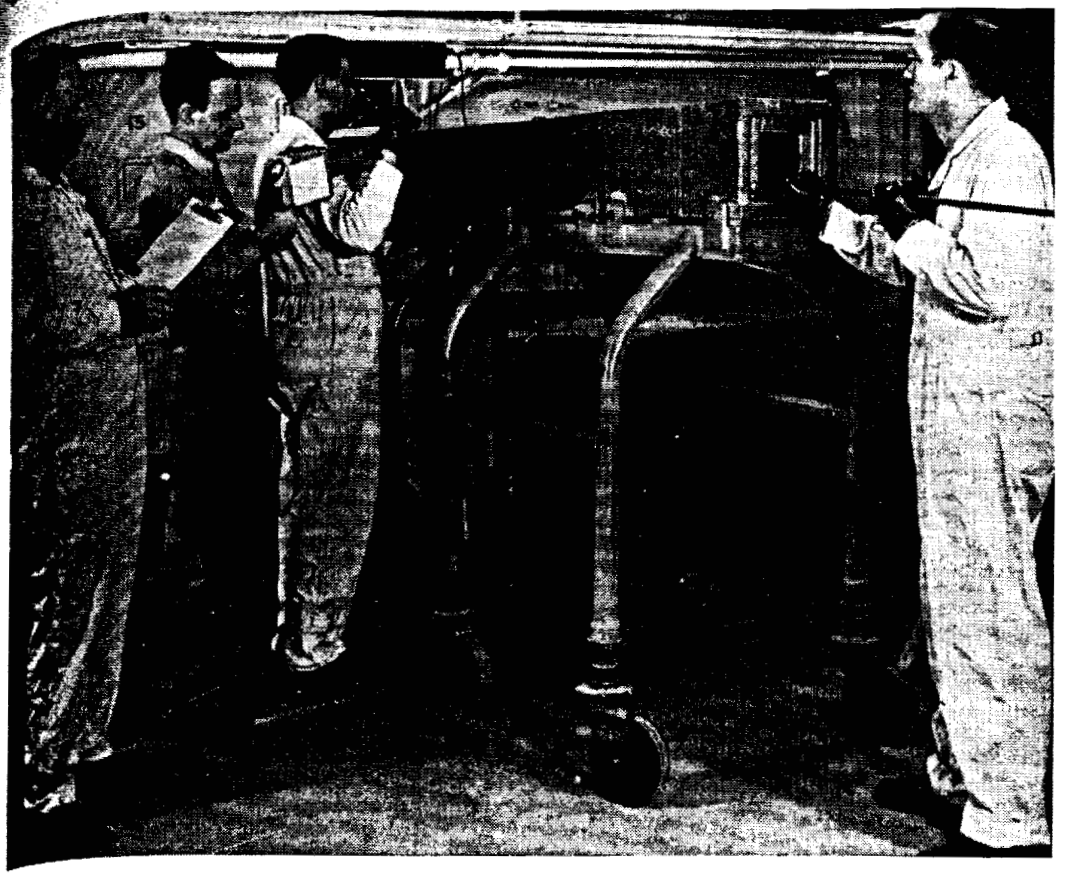

The graphite stringer bearing the irradiated material is withdrawn from the reactor by a long rod and pulled into the portable lead shielding tunnel. A health physics surveyor uses a detection instrument ("Cutie-pie") to read the amount of radiation in the vicinity of the unloading operation. Another worker records the radiation readings.

This aluminum can is used for irradiating materials that will require no further processing after the irradiation is complete. The remote control manipulator—not the one used at the pile—is shown just lowering a can into a wooden storage tray. At this stage, irradiation has been completed, the aluminum radioactivity has faded, and the can is being stored until it is to be shipped out.

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protection needed during the further handling of the radi depends on the particular isotope the can contains. Methods dling fall into two categories: (*a*) those for isotopes that en beta particles; and (*b*) those for isotopes that emit both gam and beta particles.

Handling a Typical Beta Emitter

One of the most widely distributed radioisotopes is phosph prepared by irradiating sulfur in the reactor for about 30 da first of the three methods by which radioisotopes are produ reactor (see p. 54). A small percentage of sulfur atoms i muted into phosphorus 32 atoms—actually only about millionth of an ounce of P 32 is produced from 5 pounds irradiated in the Oak Ridge reactor for 30 days. But this in mal amount, with special processing, can be chemically separat the parent mass of sulfur.

The radiation protection used in separating P 32 is typica handling of radioisotopes that emit only beta particles.

After most of the radiation from the aluminum container out, a worker may safely carry the can of irradiated sulfu end of an 8-foot rod. Phosphorus 32's 1.7 Mev beta radiatio fairly low penetrating power and are either completely abso the aluminum or by the 8 feet of air; likewise, the small am gamma radiation still coming from the aluminum or from im in the materials is reduced to a harmless intensity at 8 feet. carrying rod, the cans of irradiated sulfur are placed in a truc hauls them to the chemical processing area. A health phy veyor checks the radiation level about the workers during the t

The chemical separation of P 32 from the sulfur is accom by remote control behind the relatively light shielding ade stop its beta particles—to a large extent behind a transparen front of a chemical hood. All the processing steps—melting fur; extracting the P 32 with acid; purification; concentra P 32 by evaporation; radiochemical analysis—are made by m tion of mechanical levers that extend through the shield (rem trol apparatus is discussed in the next chapter). As a pr against the possibility of beta-emitting atoms entering the bod halation, ingestion, or other means, blowers draw a constant st air into the hood and up through an overhead system of pip leads to a central gas discharge stack.

When the processing is complete, the P 32 solution is pla storage bottle inside a lightly shielded wooden carrying case. point, with the radiation shielded by the carrying case, the

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ield can be opened and the case containing the P 32 carried by hand the storage barricade in the packing and shipping building.

Handling Gamma Emitters

Cobalt 60, with a half-life of 5.3 years, emits both beta and gamma ays; it is now coming into wide usefulness in research and medicine ecause it makes penetrating, 1.3 Mev gamma radiations available in a cheap and convenient form. Its production illustrates the second ethod of producing radioisotopes in a reactor—adding a neutron to he nucleus of a stable atom, thereby making the atom heavier and adioactive. In this case stable cobalt 59 metal may be prepared into eedles which are enclosed in small aluminum cans and irradiated in he reactor for varying lengths of time depending on the amount of adioactivity desired.

The aluminum cans are withdrawn from the reactor into the long ead tunnel as in the handling of P 32, and then transferred into a ead safe for storage. Long tongs and light shielding are not enough n this case. The gamma rays from the Co 60 are very penetrating nd require heavy shielding throughout. However, in most cases he cobalt needles are ready for shipment in the original aluminum an, as they come from the reactor. They are simply transferred, be- ind a barricade, to a heavy lead cylinder which is secured inside a out shipping box.

With its long half-life and penetrating gamma radiation, Co 60 ust always be handled carefully. Users of this isotope (and of all amma emitters) require adequate shielding of lead or a similar dense aterial, plus remote manipulating devices, to work with the isotope afely.

Iodine 131

A widely used radioisotope that emits both beta and gamma radia- ions, iodine 131, illustrates the third method of reactor production f radioisotopes—separation from the fission products of uranium. odine 131 results from the radioactive decay of another fission prod- ct, tellurium. The processes of separating this radioisotope from the arge amounts of uranium and scores of other radioactive fission roducts are intricate and potentially hazardous. Iodine 131 has a alf-life of only 8 days, so that speed in processing and shipping are ssential. All work is done behind heavy concrete barriers with emote control handling devices and indirect methods of viewing he work. All areas are constantly and thoroughly monitored, and very precaution is taken to prevent radioactive process materials

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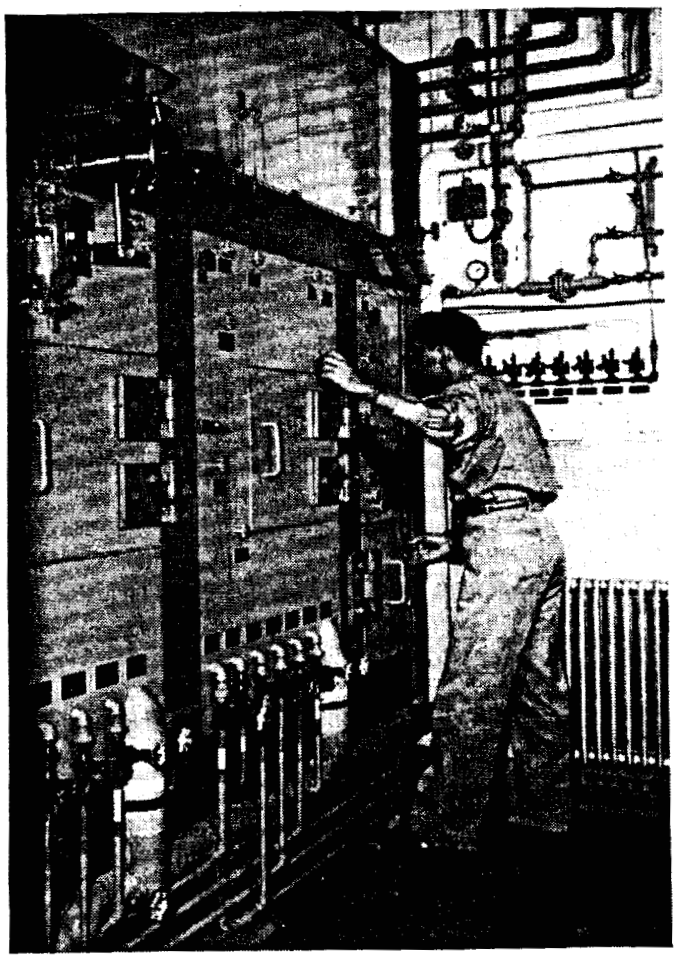
from contaminating the working spaces or from escaping into the atmosphere.

The actual set-up for separating I 131 is referred to as a "hot cell," which consists essentially of a chamber surrounded by several feet of concrete with remote control devices. The accompanying photograph shows a hot cell used for I 131 separation from fission products.



An Oak Ridge engineer is shown controlling the final hot-cell preparation of I 131. He is manipulating the remote-controlled equipment inside the thick-walled cell and observing the action in a mirror through an aperture in the lead face of the cell.

A unique feature of separating certain radioisotopes from uranium fission products is the use of long ion-exchange columns. The special "column" building at Oak Ridge National Laboratory contains a central 24-foot high framework of steel I-beams to support the heavy lead-shielded separation columns. Floors of steel grating are attached at 8-foot intervals on the framework so that workers can operate at all levels of the columns.

RADIOISOTOPE PROCESSING AREA AT OAK RIDGE

The new isotope processing area at Oak Ridge National Laboratory, completed early this year, is now in full operation. It consists of 10 process buildings, each especially designed for certain operations in safe handling of radioisotopes, and an administration building.

The large analytical building houses the facilities for analyzing, storing, packing, and shipping radioisotope preparations. A separate decontamination building with garage-type doors big enough to accommodate the largest heavy equipment provides for chemical washing and decontamination to eliminate radiation hazards.

Six special process buildings are used for various phases of radioisotope operations. The column building was described above; two buildings are equipped for handling high levels of radioactive materials; one for intermediate levels; one for processing carbon 14; and one for processing phosphorus 32. Carbon 14, like P 32, is a beta emitter and requires the same type of shielding and handling. However, the 0.15 Mev betas from C 14 are much weaker than those from P 32 (1.7 Mev), so that lighter shielding can be used, and handling is less hazardous.

The stack is 250 feet high and is equipped with fans, blowers, jets, filters, precipitators, and duct work to decontaminate and discharge the ventilating air and exhaust gases from all buildings in the isotope area as well as from other adjacent processing buildings within the Oak Ridge National Laboratory.

The individual process buildings are 25 by 30-foot, one-story structures (except the column building), built of aluminum sheeting on a steel framework. The concrete floors are topped with a special high density concrete for ease in cleaning, and have several special drains for catching radioactive wastes.

Filtered air is pumped into the buildings and kept slightly above atmospheric pressure to prevent entrance of dust which might carry contamination. The air is exhausted through the chemical hoods, and its flow is always away from the worker into the hoods, that is, from a space of lower airborne activity to a higher one. The air in these buildings is monitored constantly by stationary recording instruments, and the workers have portable instruments for periodically checking their equipment and clothing for any possible contamination. Each building is divided functionally into six 10-foot-square areas for separate activities in isotope processing.

The major difference between the high-level and low-level buildings is in the thickness and type of shielding needed around the processing equipment—lead bricks and concrete blocks in the high-level buildings, transparent plastic in the low-level buildings.

RADIOISOTOPE ANALYSIS

A last step in radioisotope processing provides an essential safeguard to the ultimate users of radioisotopes. The analytical building contains a chemical and radiochemical laboratory where samples of irradiated materials are analyzed after they have been chemically

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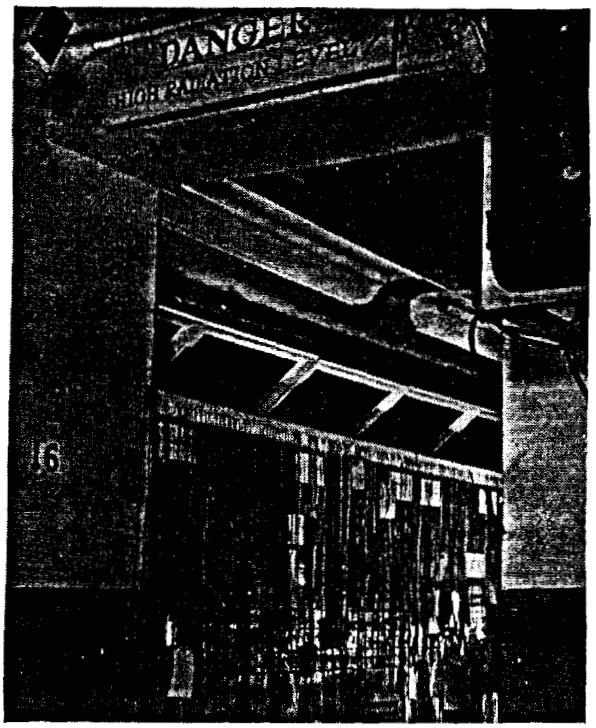
separated and purified. Here, the purity and concentration of each sample is determined, and its radioactivity is measured in terms of millicuries per cubic centimeter. Shipments are made in millicurie amounts of radioactivity, which can be measured by volume, knowing the rate of radioactive decay and the activity per unit volume.

In this laboratory, precautions are taken to keep all radioactivity under strictest control, not only as normal protection for the laboratory workers, but also to screen out all radiation other than that from the samples being analyzed.



Before construction of the new isotopes handling facility at Oak Ridge, the isotopes were stored behind this lead brick barrier. Strings and tags were used to locate the stored isotopes, which could also be viewed in the overhead mirror.

STORING, PACKING, AND SHIPPING RADIOISOTOPES

When the Government first began shipping radioisotopes in August 1946, the Oak Ridge National Laboratory (then known as Clinton Laboratories and operated by the Monsanto Chemical Company) already had experience in handling and shipping limited quantities of isotopes for research purposes within the atomic energy project. Facilities for handling the radioisotopes were severely limited. As the demand for isotopes increased, and shipments grew in number, makeshift arrangements multiplied in quarters that were designed for other uses (see photograph, above). The inadequacy and inefficiency, and to some extent the increasing hazard to operating personnel, became so serious that by 1948 it was obvious that an efficient, thoroughly safe system should be provided if radioisotope shipments were to keep up with the demand.

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The Commission's solution to this problem is seen today in the carefully planned new Isotopes Area at Oak Ridge National Laboratory. The processing buildings in this area have been described in the preceding section. The compactness and efficiency of this new set up is typified in the large section of the analytical building devoted to storing, packing, and shipping radioisotopes. In the following pages the operation of the so-called "Atomic Apothecary" is briefly reported in photographs. In sequence, are shown first the handling of high-level, gamma-emitting radioisotopes, and second the handling of low-level beta emitters.

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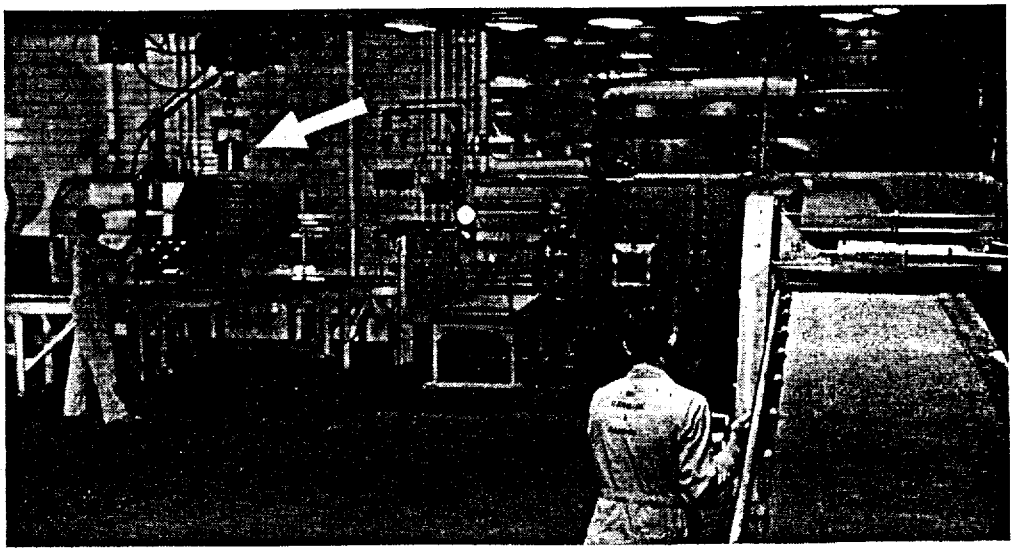
Shipping Gamma-Emitting Isotopes

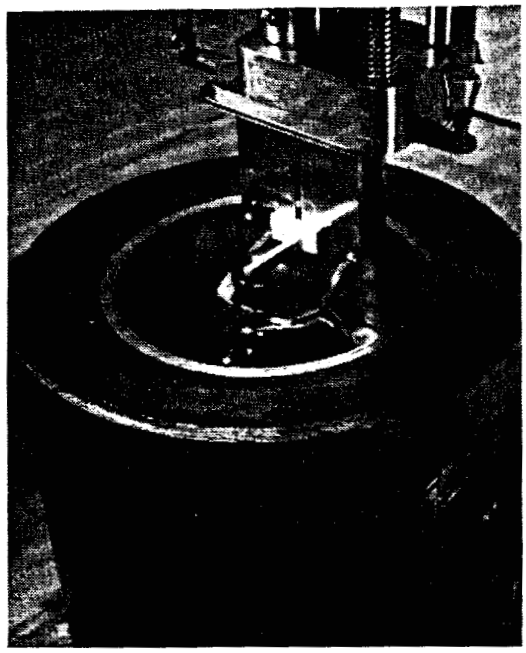
A gamma-emitting isotope preparation from the chemical processing area is received in the analytical building for storage. A heavy overhead conveyor (or monorail hoist) lifts the lead pig from the delivery truck and swings it in toward the storage barricade. The operators keep away and operate the conveyor by remote control since some gamma rays leak through the heavy lead container. Each worker in the isotopes area wears a film badge (visible on man at left) and two pocket meters (fountain pen-like devices on man at right) to keep a record of the total radiation received during the day's work.



The operator guides the suspended lead pig (see arrow) toward the storage barricade at right. Behind this 2-foot-thick concrete wall are the storage compartments for radioisotope preparations from which portions are withdrawn for shipment. The lead pig will be swung over the barricade and lowered to rest just behind a square lead door. The second operator is bringing the remote control apparatus (storage tongs) down to the receiving end of the barricade.

5001018

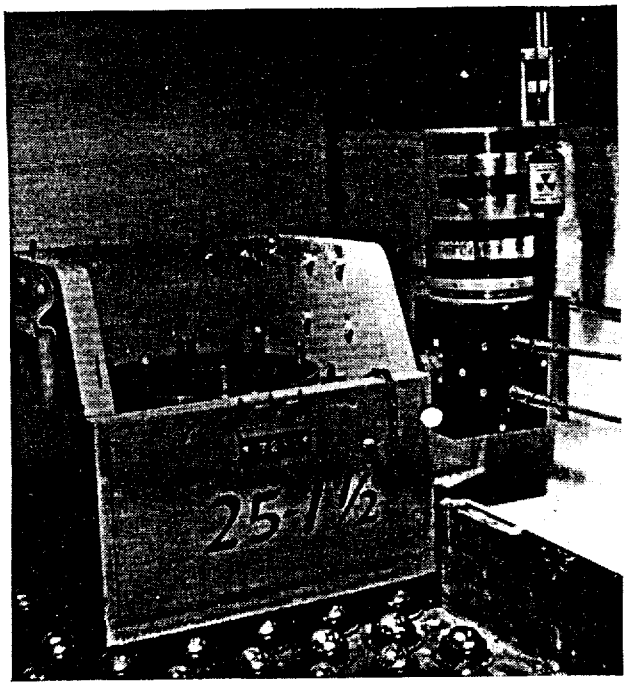
Lead door in the barricade has been opened, and the operator is lowering lead pig to rest behind the operations end of the barricade. The door will be closed before the pig is opened to remove the isotope preparation. This end of the barricade, behind which the operations of transferring radioisotopes are performed, is made of lead and can therefore be much thinner than the concrete portion of the barricade.



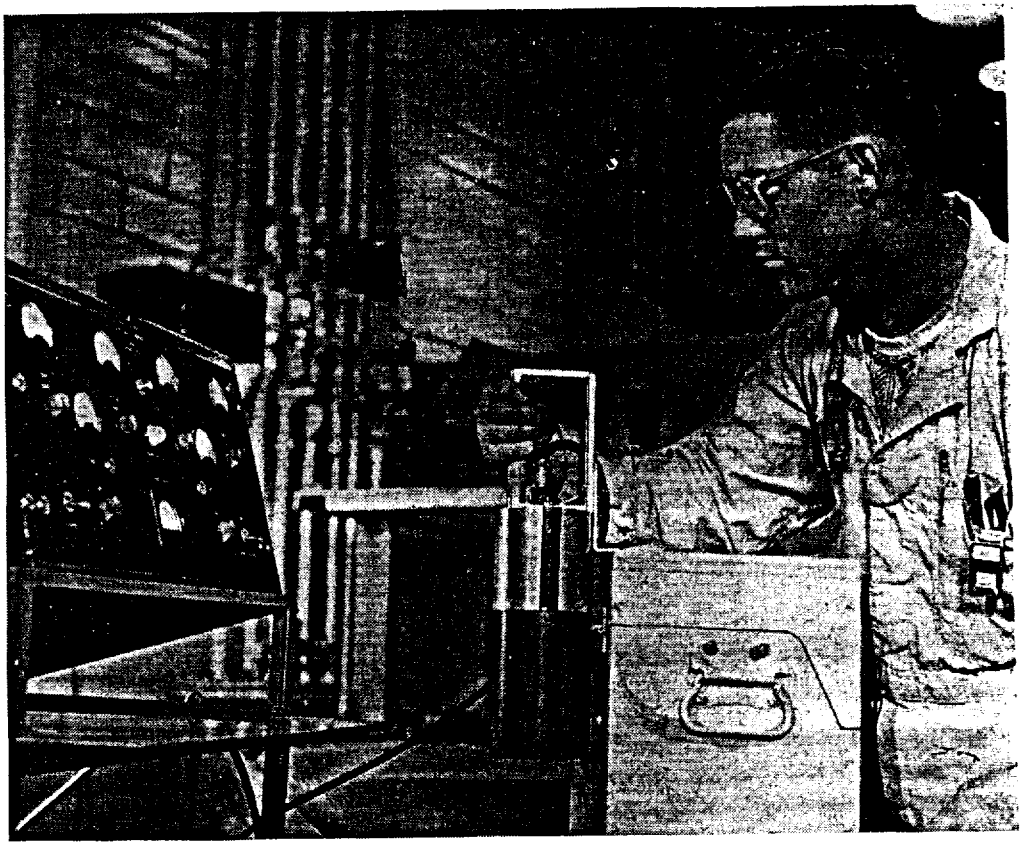
The lead pig is opened and the storage tongs on the remote control apparatus are grasping the neck of the isotope bottle. The operator on the other side of the barricade views this operation in an overhead mirror. He can thus see clearly, and manipulate the controls precisely, in complete safety from the radiation emitted by the "hot" radioisotope. Next, the storage bottle will be raised on the tongs and rolled along the barricade to the storage area.

The operator brings the storage tongs and the suspended isotope storage bottle over the slot already selected on a master storage chart. Each slot is identified by a system of coordinate marking by numbering and lettering the rows of slots. The numbers and letters are reversed so that they may be read more easily when viewed in the overhead mirror. The remote control storage tongs are finely balanced to permit precise and careful handling of the glass storage bottles.

500019



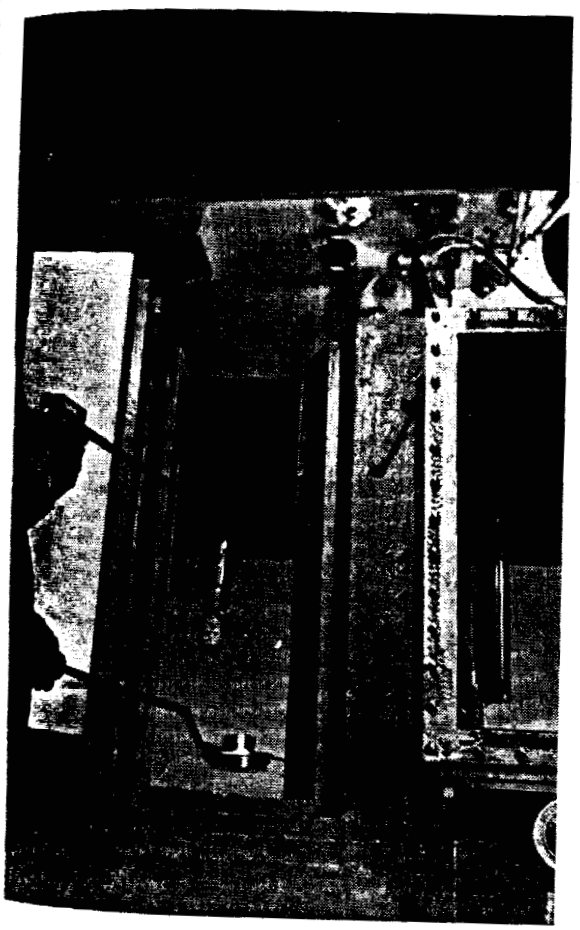
The shipping bottle, still suspended on the shipping tongs and still behind the barricade, is swung close to a radiation monitoring device. The operator reads and records the radiation level that shows on a dial in front of him outside the barricade. A shipping box stands ready with an uncovered lead pig in which may be seen a round receptacle for the shipping bottle. As the bottle is swung over and lowered into the receptacle, the operator observes this action in a mirror through a slit in the barricade wall.



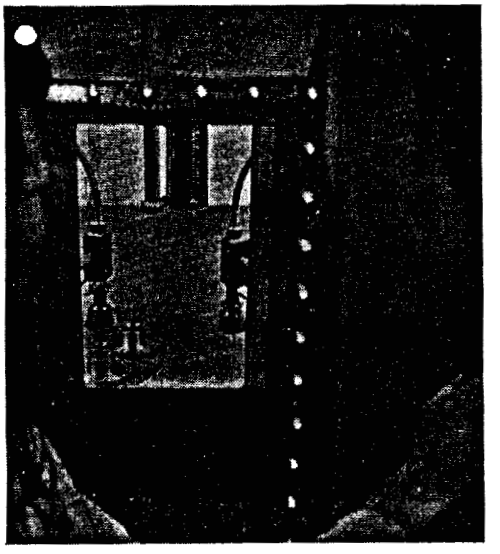
The sealed shipping box containing the isotope shipment is monitored on all sides as shown in this picture and, as a further precaution, smear samples are taken to determine if the box has any surface contamination. The film badge and the two pocket dosimeters, which are worn constantly when working with isotopes, are visible in the operator's pocket.

5001020

Before swinging the isotope storage bottle around the corner of the barricade to the transfer area, the operator opens a tall lead door in the barricade wall and rotates the remote-controlled pipettor out through the door to install a clean pipette. The clear-view window at the right of the operator is actually a thick space filled with high-density fluid that absorbs gamma radiations and allows the operator to view directly the procedure of transferring isotope material from storage bottle to shipping bottle. The round shipping table with small receptacles for the shipping bottles can be seen through the window. The clean pipette is next rotated back to a position behind the middle of the window. Every precaution is taken to maintain thorough laboratory cleanliness and to prevent mixing traces of one isotope preparation into another.

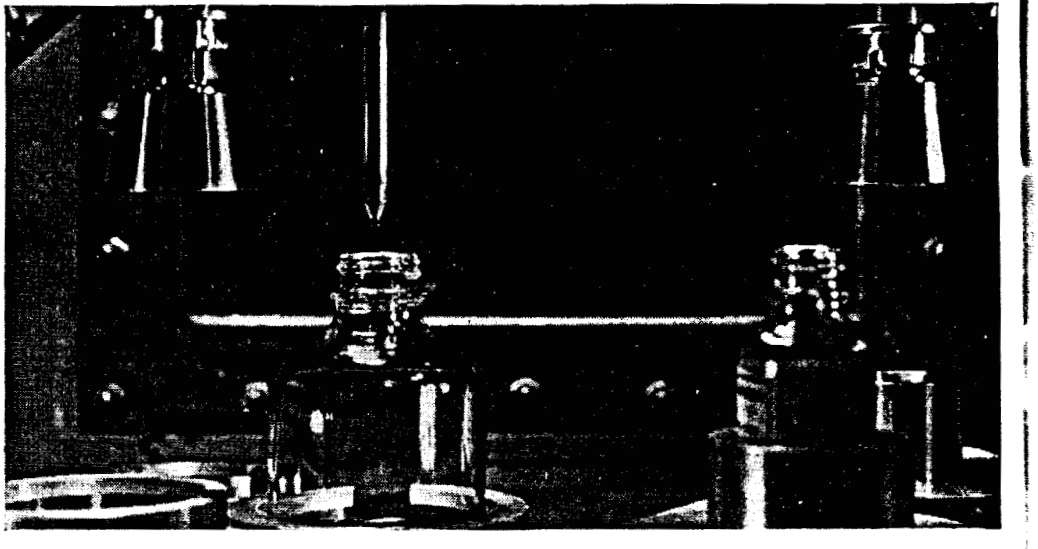


The operator uses hand tongs to place a receptacle and sterilized shipping bottle on the shipping table. The long overhead mirror gives a complete view of the operations area behind the barricade. The operator is quite safe with the door open during the operations shown in this and the preceding picture, because the "hot" storage bottle is still around the corner of the barricade some distance to the right. With the shipping bottle in place, the door is swung shut and the transfer operation can begin. The transfer operations can be viewed by the operator in two ways—in the overhead mirror and through the special thick viewing window. The operator thus has a complete view of the whole set-up as he swings the storage table around the corner of the barricade to a position adjacent to the shipping table and the pipette.



The shipping bottle has been rotated under the decapper, and the operator, using both hands and watching the operation through the thick window, manipulates the decapper. In this view, the decapper for the storage bottle and the pipette rack with its graduated volume scale can also be seen.

The storage table is swung around the corner of the barricade on the track that brings it to the proper location beside the shipping table and under the decapper. The storage table is set lower than the shipping table so that the tops of the storage and shipping bottles are aligned accurately at the same level.



In this view from behind the barricade, the pipette containing isotope material has just been withdrawn from the storage bottle. The operator will next rotate the pipette over a fixed arc that will bring the pipette exactly over the open mouth of the shipping bottle. During the pipetting, the bottle caps are held in the decappers which are swung to the sides away from the two bottles, giving the operator unobstructed view of the pipette throughout the process. The viewing window, opaque to radiation, is the black area in the background.

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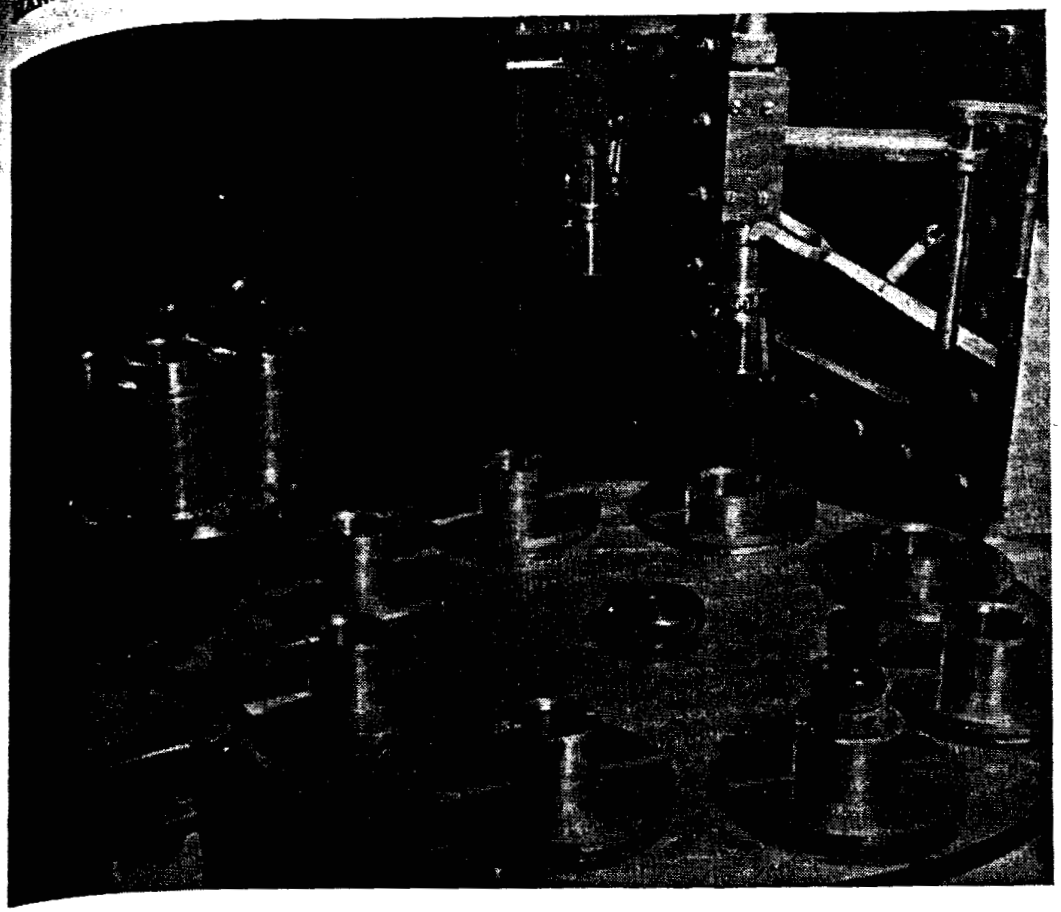
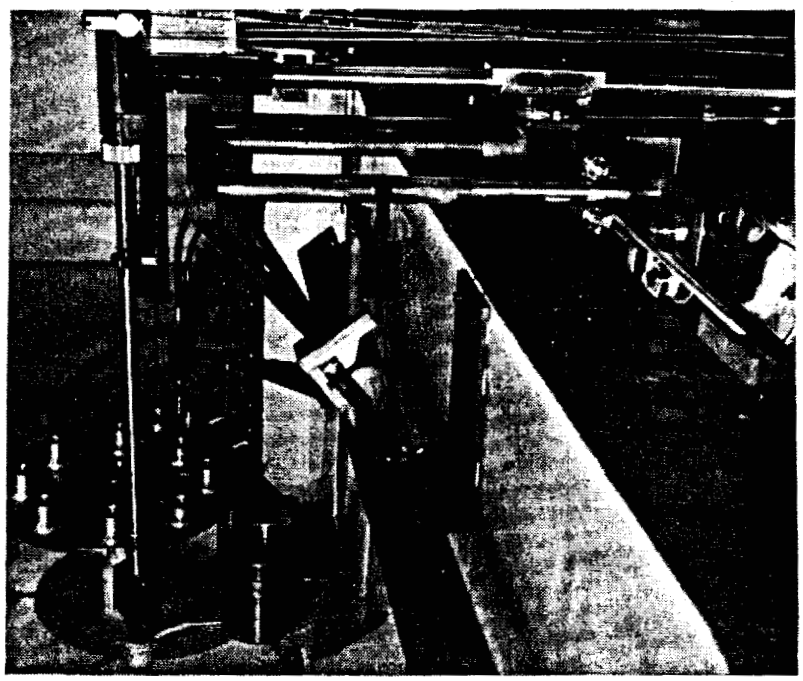


The isotope sample has been transferred to the small shipping bottle, which has been capped and rotated away from under the decapper. The storage bottle has also been capped and the storage table is being swung away from the shipping table on the semicircular track which can be seen extending around the barricade corner in the background. The storage bottle will next be returned to its slot in the storage bay, and the shipping bottle is ready for packing and shipping.



The operator watches in the overhead mirror as he picks up the shipping bottle from the shipping table and begins moving it toward the shipping end of the barricade where its radiation level will be measured and it will be packed for shipment. The vessel to the right of the isotope bottle is for rinsing the pipette.

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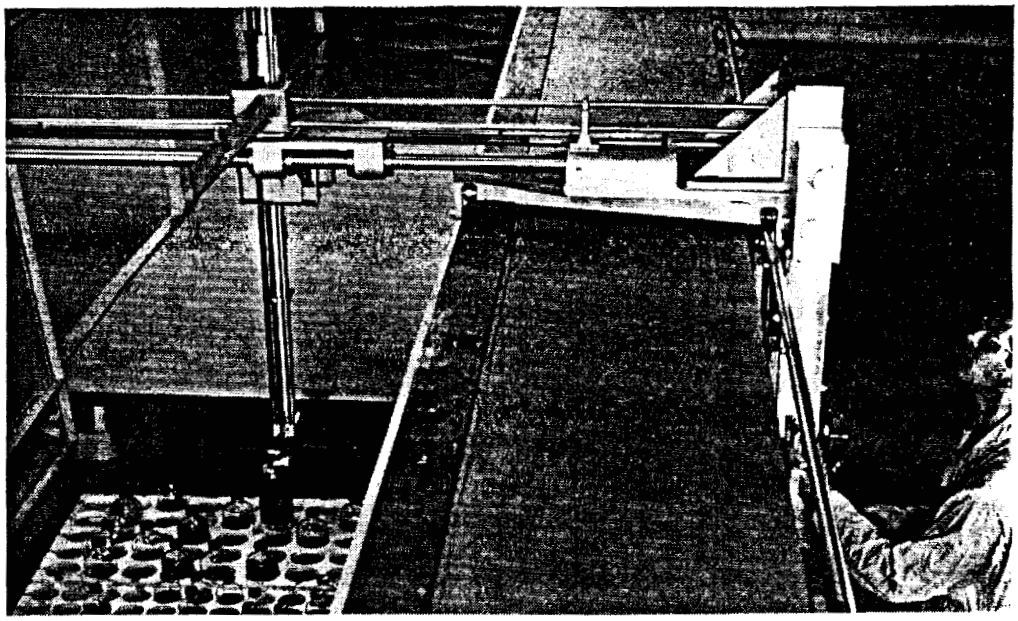
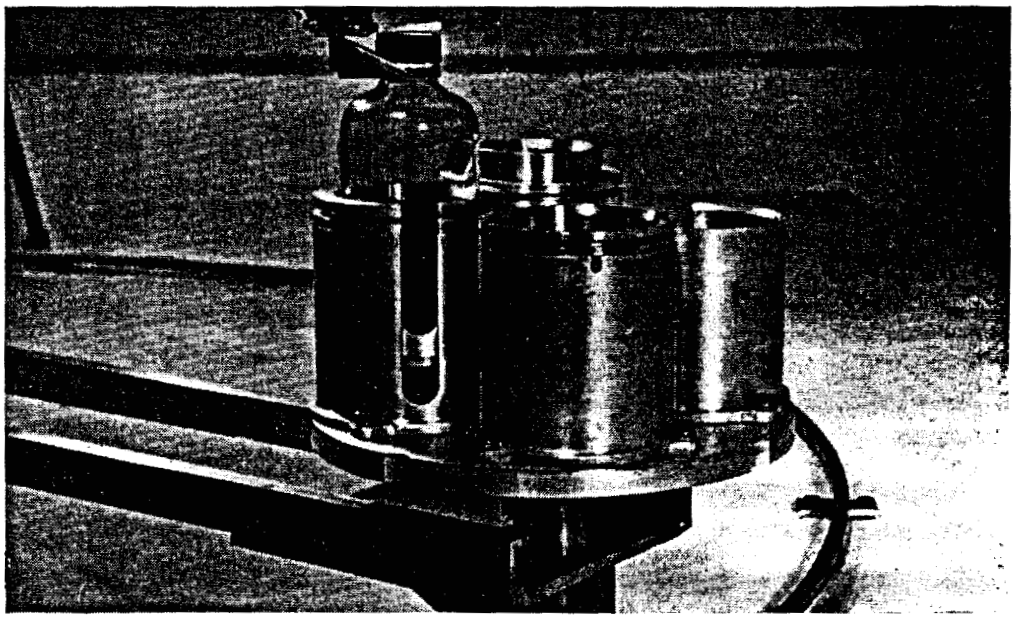


Preparation of an actual shipment begins when an operator picks up an isotope storage bottle from one of the "bays" behind the storage barrier. An aluminum dust shield covering the bay can be raised by a foot pedal; space for additional storage may be seen under the adjacent dust shield. The operator views the entire operation behind the barrier in a mirror above the remote control tongs. The storage bottle will be lifted above the dust shield level and swung to the operator's left toward the operations area of the barricade.



The storage bottle is deposited in a receptacle on a rotary storage table, which is mounted on a rack of which one end pivots at the inside corner of the barricade. The end of the rack supporting the table rolls on a semicircular track, so that the storage table can be swung around the barricade corner and close to another table containing the shipping bottle. In the position shown here, the corner of the barricade shields the operator while he prepares the shipping bottle.

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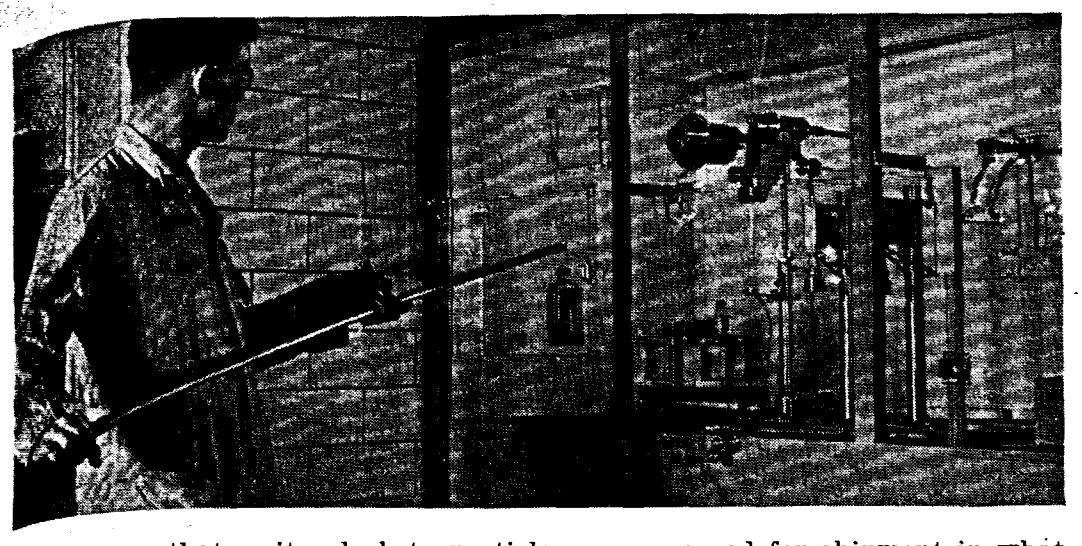
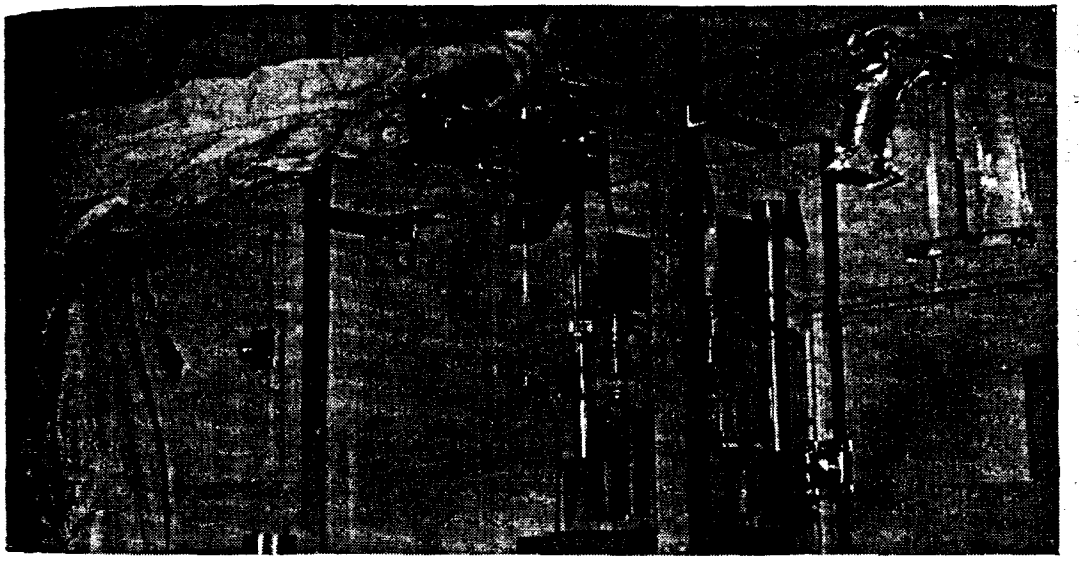
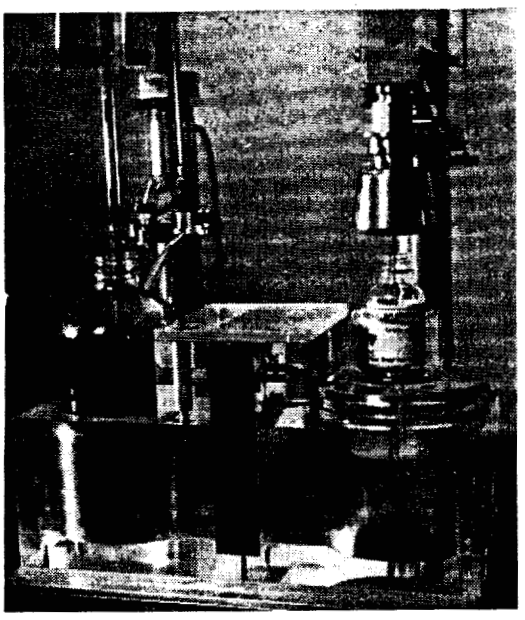
Shipping Beta-Emitting Isotopes



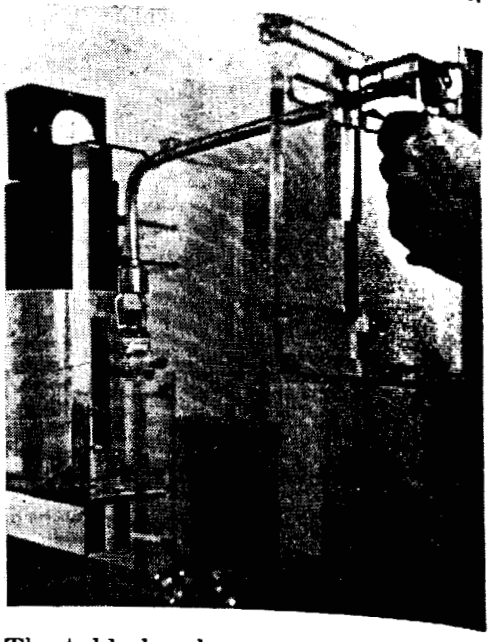
Radioisotopes that emit only beta particles are prepared for shipment in what is called a "low-level hood," shown here with a thick, transparent plastic shield. The operator has previously placed a shipping bottle in a receptacle on the table at the left end of the hood. He is carrying the isotope storage bottle in a thinly-shielded container at the end of a long rod and passing it through an open window. The storage bottle will be placed in a receptacle on the table. The hood is in three sections, and the table for the storage and shipping bottles may be rolled lengthwise from one section to another. The transfer operations take place in the center section where the remote-controlled pipette and decappers are located.



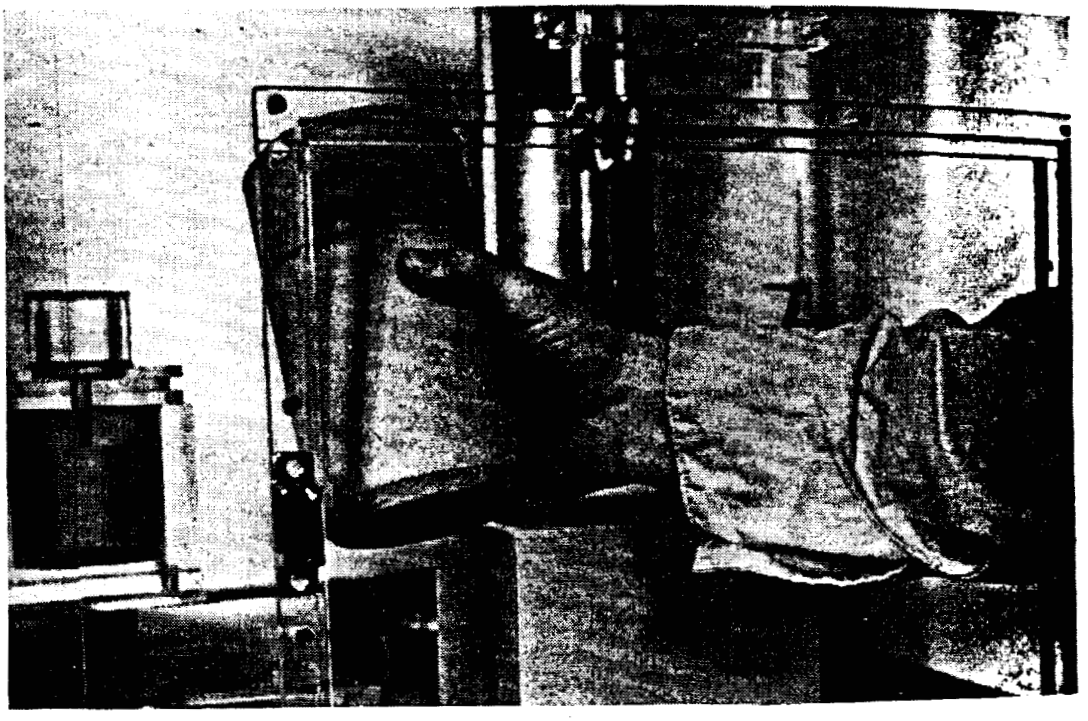
The table bearing the shipping and storage bottles has been rolled on a track to the center section of the hood and positioned accurately under the two decappers. The plastic window is now closed, and the operator has decapped the storage and shipping bottles. The transfer pipette may be seen to the left of the storage bottle. A plastic-handled manipulating rod is fastened in the shield in the right hand section of the hood.



Close-up of the pipetting operation. The pipette has been lowered into the storage bottle to draw up the sample for transfer to the shipping bottle. A small round metal drip tray beside the pipette will automatically swing under the pipette when the sample is drawn out of the storage bottle.



The table has been moved to the right hand section where the shipping bottle is picked up by the remote-handling tongs, swung over a plastic baffle and in front of a radiation counter that registers the radiation level. A concrete shipping container is just to the right of the bottle.



The operator has placed the cap on the shipping container and is just removing the container from the hood. The window can be opened safely and the container carried by hand, because the low-level radioisotope is thoroughly shielded by the relatively light container.

PROTECTION OF RADIOISOTOPE USERS

The users of radioisotopes, assisted by the AEC's service of consultation and advice on radiological protection, are doing a sound job of handling radioactive material without injury to themselves and without hazard to their environment. Most of the people who use radioisotopes in medical and research work are in private, university, and industrial laboratories, although much radioisotope work is also carried out in Government laboratories.

Two basic facts have contributed to the safety with which the isotopes have been used:

a) The users are experienced and highly trained in their own particular fields. Seventy percent of all radioisotope shipments have gone to medical and physiological laboratories, traditionally known for their high standards of safe handling techniques.

b) Shipments are made generally in relatively small quantities and 90 percent of all shipments contain only short-lived radioisotopes (with a half-life of less than 30 days) such as iodine 131, phosphorus 32, and sodium 24. Wide-scale, long-term radioactive contamination from these would be impossible since these radioisotopes decay to non-hazardous stable elements in a comparatively short time. Moreover, few of the radioisotopes require extreme precautions. According to the classification established by the National Committee on Radiation Protection, all radioisotopes are divided into three categories according to the degree of hazard they present: (1) slight hazard, (2) moderately dangerous, (3) very dangerous.[1] Only eight-tenths of one percent of the total radioisotope activity shipped from Oak Ridge falls into the third group.

In carrying out its statutory responsibilities relating to safe handling of radioisotopes,[2] and to assist users in protecting themselves and their environment, the Atomic Energy Commission and its contractors conduct a many-sided program that involves (*a*) assisting in setting and enforcing standards and limits upon distribution and use of radioactive materials, (*b*) setting and enforcing rigid standards which potential users are required to meet before their orders for radioisotopes can be filled, (*c*) training courses to teach the safe handling and use of radioisotopes, (*d*) an advisory field service (AEC) and the training program of the Oak Ridge Institute of Nuclear Studies (ORINS)

[1] "Safe Handling of Radioactive Isotopes," Handbook 42, U. S. National Bureau of Standards, 1949. Price, 15 cents.

[2] Atomic Energy Act of 1946, Sec. 5 (c) (2). . . . "The Commission shall not distribute any byproduct materials to any applicant, and shall recall any distributed materials from any applicant, who is not equipped to observe or who fails to observe such safety standards to protect health as may be established by the Commission. . . ."

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which promote safe handling and practical laboratory design for eliminating potential hazards.

Protection Through Standards and Controls

The following sections outline the progress made in establishing controls to assist in maintaining radiological safety, and in working with local governmental and private agencies in their efforts to set up and enforce safe practices in the use of radioisotopes.

Control by Allocation

In submitting requests for radioisotopes, applicants are required to describe the purpose for which they will be used and the facilities and equipment available for radiation measurement and health safety monitoring. The applications are reviewed by the AEC Isotopes Division at Oak Ridge and, if necessary, by one or both of the subcommittees of the Advisory Committee on Isotope Distribution (Appendix 2), the Subcommittee on General Applications or the Subcommittee on Human Applications. The applicant must agree to keep accurate records of receipt, storage, use, and disposal of all radioactive materials; to use the material only for the specific purpose authorized by the Commission; and not to make secondary distribution of the material without the prior written permission of the Isotopes Division.

Radioisotopes for use in medicine. Before radioisotopes are allocated for medical use on human beings, either for research or treatment, the Subcommittee on Human Applications requires that the physician who will use or directly supervise the use of the material, meet the following qualifications:

a) He must be accredited and in good standing with his local medical society.

b) He must be associated with a medical research institution, hospital, clinic, or other medical organization also in good standing with the local medical society and having adequate facilities for the clinical care of the patients and the assay, safe handling, and disposal of radioactive materials.

c) He must have had previous clinical experience with radiation and radioactive materials or be collaborating with an individual possessing such training and experience.

Each hospital is expected to appoint a local isotopes committee to evaluate all proposals for the therapeutic use of radioactive substances

within that institution, the committee to include: (*a*) a physician trained in internal medicine, (*b*) a physician trained in hematology, (*c*) an individual experienced in assay of radioactive materials and protection of personnel against radiation, and (*d*) a qualified physicist and a therapeutic radiologist available as consultants, if not on the staff.

Field and industrial use. The primary problems in outdoor studies and industrial use of radioisotopes are safety control and accountability. If a radioisotope is to be used under other than laboratory conditions, the proposed application must provide for long-term control of the radioactivity, taking into consideration the amount and type of radioactivity, and the likelihood that persons who could have no knowledge that radioactive material was present might be exposed to potentially dangerous radiation.

An application for a radioisotope to be used in a field study must generally be supported by the following information: (*a*) a detailed outline of experiments, (*b*) a map of the area showing topography, (*c*) a full description of the distribution of human and livestock population in and near the experimental areas, (*d*) a statement concerning the relationship of the experimental area to watersheds from which domestic water supplies are collected, (*e*) a description of the underground strata with respect to water movement and likelihood of fixation of radioactivity by mineral components, and (*f*) a statement regarding the degree of control which can and will be exercised over the experimental area.

Industrial applications for radioisotopes fall into three general groups: (*a*) use of radioactive material only as a source of ionizing radiation contained in a device such as a thickness or height gauge or a radiographic unit, (*b*) use of radioactivity in a process which does not carry radioactivity into any product sold to the public, and (*c*) use of radioactivity in which it might enter products sold to the public.

In the first two cases the factors to be considered are similar to those for laboratory use. If the radioactive source is well shielded, otherwise controlled, and the work is under the supervision of trained workers, the use is generally approved. Cases where radioactivity may enter into market products present additional health safety problems. The Commission has not encouraged such applications.

Training Courses for Radioisotope Users

The techniques developed by the Manhattan Engineer District, drawing upon the experience of prewar laboratory work with limited quantities of radioactive materials, permitted safe handling of radio-

5001029

active materials—mildly hazardous and extremely hazardous alike. But this experience was chiefly confined to Government-controlled facilities. When the first radioisotope shipments began, a great majority of private laboratories, research institutions, and hospitals had not had the opportunity to acquire these new techniques.

Radioisotope Techniques Course at ORINS

The Oak Ridge Institute of Nuclear Studies took an early interest in training off-project research workers in the techniques of handling radioisotopes. The 4-week Radioisotope Techniques Course now given repeatedly by the Special Training Division of ORINS is an outgrowth of concerted planning by ORINS, the Oak Ridge National Laboratory, and the Isotopes Division of the Oak Ridge Operations Office. With assistance from staff members of the Laboratory's Health Physics Division and of the Isotopes and Research and Medicine Divisions of the AEC Oak Ridge Operations Office, the first course was offered in June 1948.

Since then the course has been given 14 times to 458 research workers representing 324 laboratories in 42 States and nearly a dozen foreign countries. In many of the universities, hospitals, industries, research laboratories, and agricultural experiment stations, the ORINS course has provided the only formal training in radioisotope techniques. Completion of the course by a staff member of an institution is not essential to obtaining radioisotopes, but successful completion of the course generally satisfies the Commission's requirements that recipients be qualified to handle radioisotopes efficiently and safely.

The course has a single aim: To teach mature research workers how to use radioisotopes safely and efficiently. Knowledge of the participant's field is assumed; hence the entire 4 weeks is devoted to the use of radioisotopes. About 60 percent of the work is in the laboratory; the remainder is taken up with lectures, demonstrations, and nine seminars. One seminar is devoted to the principles and practices of radiation protection; another to the effects of radiation on cells; and a third to proper design of radiochemical laboratories. Members of the Special Training Division staff are available throughout the course as consultants and advisors on the particular radiation problems that each participant will face in his own laboratory.

Cancer Research Program

The Medical Division of the Oak Ridge Institute of Nuclear Studies is conducting a research program on the use of radioisotopes to treat cancer, with a companion objective of training medical workers of the

southeastern universities in radioisotope techniques. Sound radiation protection practices are stressed in all research and training activities.

The Oak Ridge clinical hospital unit, with its attached research and treatment facilities, is the first to be designed specifically for use of atomic energy products in medicine (see p. 172); other units are being organized elsewhere. Special problems involved here may become commonplace problems in hospitals if radioactive materials prove generally useful in treatment of disease. For instance, attending a single patient who had received radioisotope treatment rarely would subject physicians and nurses to a radiation overexposure, but the cumulative effect of attending several patients receiving radioisotopes therapy would increase the potential hazard. Disposal of radioactive wastes and gases, and the storage and handling of a variety of radioisotopes for clinical use, also present special health physics problems for hospitals.

Advisory Field Service

The Commission has a positive program of encouraging and developing health safety standards in the use of the radioisotopes available for distribution. The Advisory Field Service Branch of the AEC Isotopes Division, Oak Ridge Operations Office, has staff members trained in various scientific fields who serve as consultants to isotope users on health safety facilities and practices. Through visits to laboratories, they give on-the-spot advice concerning radiation protection, monitoring and measuring equipment, standards of radioactivity, laboratory design, remote handling equipment, and radioactive waste handling. Isotope users are referred to private consulting laboratories for more detailed advice on planning and conducting their research investigations.

Institutions with a large number of users are encouraged to set up local control committees to maintain liaison with the Isotopes Division on allocation policies and health safety practices. The Isotopes Division suggests that these local committees approve all isotope applications and supervise the health training and monitoring programs of their own institutions.

Laboratory Design

The Advisory Field Service Branch, as one of its principal functions, advises isotopes users on the proper design of laboratories for radioisotope investigations. This is a serious problem for an institution interested in radioisotopes research which must construct or remodel and equip a suitable laboratory. Depending on the type and amount of radioactive material to be used, the cost of special laboratory equip-

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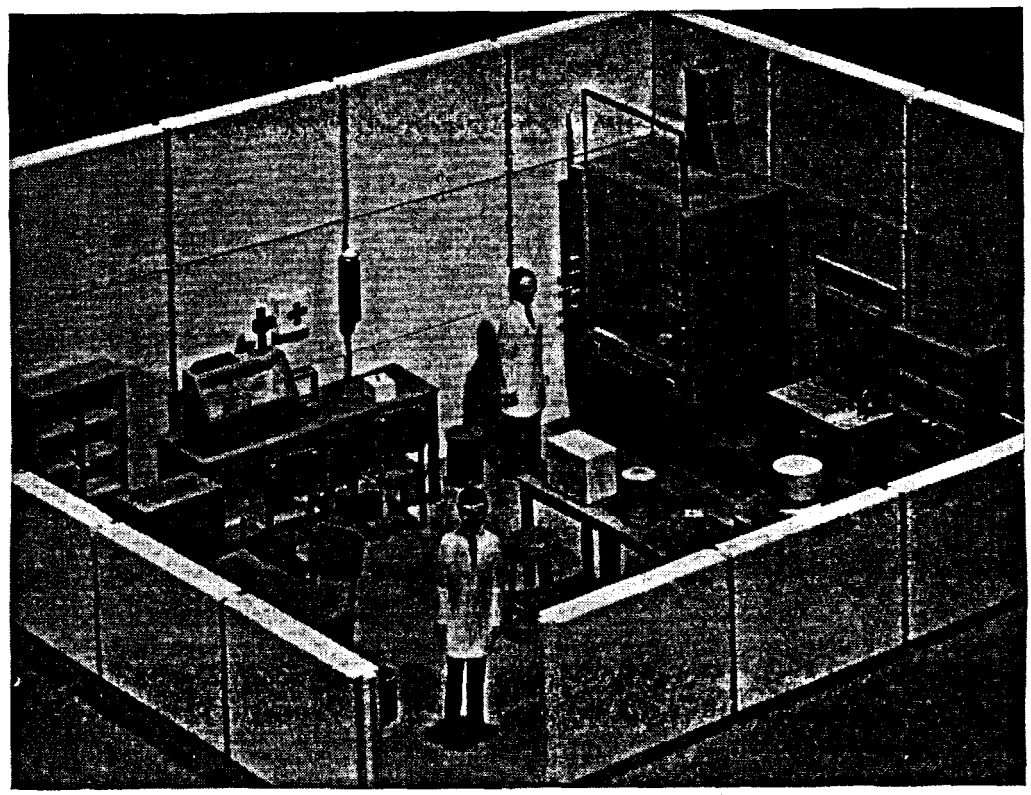

Two-man laboratory designed for millicurie levels of pure beta-emitting radioisotopes. The fume hood (right background) is for chemical manipulations which might cause formation of radioactive droplets, fumes, or dusts; any hazardous wastes are drawn up the hood chimney by an exhaust fan. Trays are used to retain any spilled materials. All controls are outside of the hood.

On the table in the left background is a large "gloved box" for handling radioactive powders or solids. The rubber gloves sealed into the front wall of the box protect the hands, and the viewing window shields the investigator.

The large white instrument on the center table is a "scaler," used to measure the radioactivity of laboratory samples, which are placed inside the cylindrical lead shield beside the scaler.

In actual construction, all tables, benches, and other laboratory furniture would be made of metal.

ment and facilities may range from about $3,000 for a two-man laboratory exclusively for low-energy, low-level (1 millicurie) beta emitters, to $20,000 or more for a laboratory capable of handling large amounts (500 millicuries) of gamma-emitting isotopes. The cost of constructing or remodeling the building to house a laboratory must be added.

The Advisory Field Service has devised flexible scale-model laboratories and equipment that can be altered to fit almost any combination of space limitations and range of radiation levels. With these, a prospective user can be assisted in adapting his laboratory space for the equipment and facilities needed in the particular radioisotope studies he has planned. The accompanying photographs show typical scale-model laboratories.

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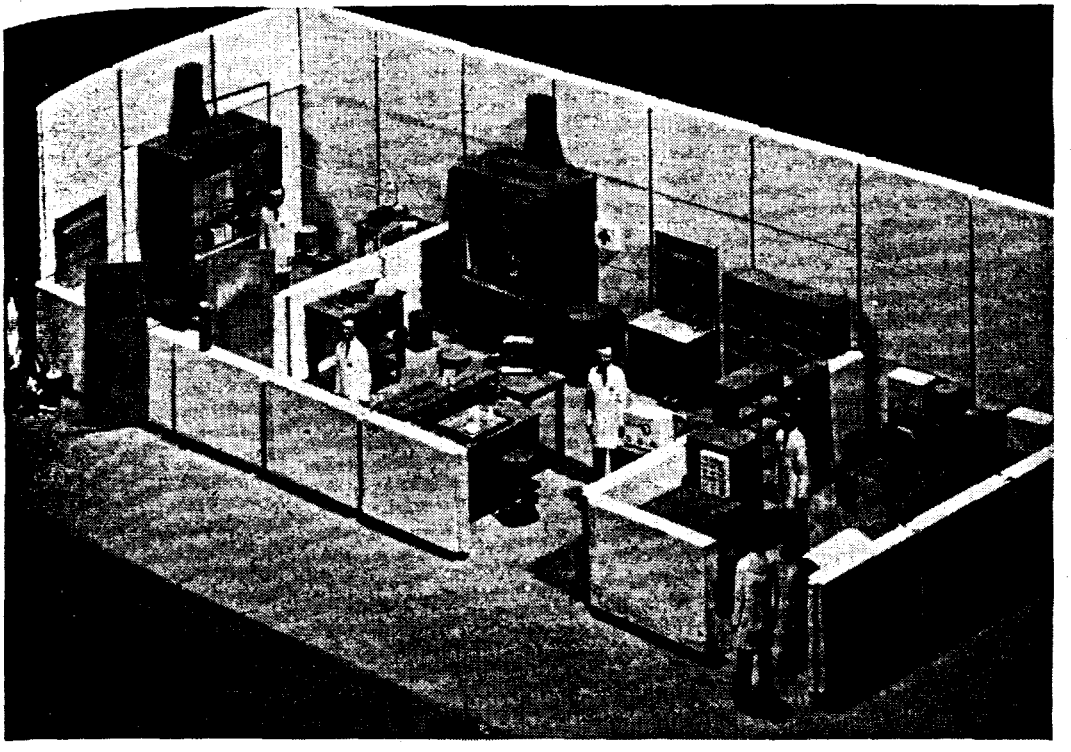
Other Services

In addition to consultation on laboratory design, the Advisory Field Service is available to isotope users for advice on all other problems involved in handling radioisotopes safely. Staff personnel answer individual requests for specific information, participate in seminar and lecture programs, and visit laboratories.

The Isotopes Division has prepared circulars on aspects of isotopes work, and participates in various training programs in isotope handling and health physics procedures. A series of technical training films on isotope utilization is being prepared by the U. S. Signal Corps for the Armed Forces Institute of Pathology with the technical assistance of the Isotopes Division.



This model three-room laboratory, designed to handle both beta- and gamma-emitting radioisotopes, has a high-level room on the left, a low-level room in the center, and a radiation counting room on the right. This arrangement prevents random radiations from the high-level laboratory from registering false "counts" on the counting room instruments and minimizes the possibility of spreading contamination. Shipping containers are received and amounts to be used are removed and processed in the high-level room.

The center room is designed for the lower levels of activity actually used in the experimental investigation. The large white instrument on the right side of the center room is used by each worker to examine his clothing and hands for stray radioactivity before he enters the counting room. Trays are used in the hoods and on the laboratory benches to catch any spilled materials. Lead bricks in the hoods and lead storage containers on the floor beside the hood protect investigators from the penetrating gamma radiations.

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Liaison activities with southern universities. Through the Oak Ridge Institute of Nuclear Studies southern universities participate in the Nation's atomic energy program, and 26 of the principal universities of the region sponsor the Institute (Appendix 3). Interchange of personnel promotes education in radiation protection.

Under the Research Participation Program, conducted jointly by the Institute and the Oak Ridge National Laboratory, more than 130 faculty members of southern universities have carried out research in Oak Ridge laboratories. Where their research deals with radioactive material, they learn radiation protection principles and practices and provide a nucleus of trained personnel throughout the South.

Through the Traveling Lecture Program, which the Institute and the Laboratory sponsor, about 50 scientists from Oak Ridge have given about 100 lectures at southern universities and conducted seminars, some of which dealt in part with radiation protection.

5001034

IV

CONTROL OF RADIATION IN RESEARCH AND DEVELOPMENT

In addition to producing fissionable materials, atomic weapons, and radioactive isotopes, the Commission sponsors and finances research in basic nuclear science, the production of useful power, medical diagnosis and treatment, the improvement of atomic weapons, the properties of engineering materials, the nature of obscure life processes, and other areas where atomic energy gives promise of advancing human knowledge and promoting the national security. These investigations and development projects are performed by the national and other AEC laboratories and under contracts with a long list of research agencies and industrial organizations in every part of the country.

Especially rigorous measures are necessary to control radiation in atomic energy research. The radiation dealt with is generally, though not always, less powerful than is encountered in the production of fissionable materials. But in contrast with the repetitious routine of manufacture, each new experiment creates a new combination of radiological problems.

In the laboratories scientists and technicians perform a wide range of physical, chemical, and biological experiments on all sorts of radioactive materials. Laboratory designers, engineers of remote control devices, and health physicists work together to control radiation hazards, and exposures are kept within stringent operating limits.

PROTECTION IN LABORATORIES

One main kind of potential hazard arises when the materials used in a study emit alpha or beta particles. In the typical illustration reported here, the Argonne National Laboratory's Radiobiology Experiment Station grows plants of economic or medicinal importance in an atmosphere containing measured quantities of radioactive carbon dioxide. Some of the irradiated plants—the opium poppy and digitalis foxglove are two of them—are used to make "tagged" drugs for tracing out how these agents do their work in living creatures.

Compounds of radioactive carbon emit low-energy beta particles which have little penetrating power but can do serious damage inside the human body. Thus, the safety problem is to keep the radioactive

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carbon dioxide out of the greenhouse where men are working. It was solved by putting the plants in a miniature greenhouse inside the larger greenhouse and hermetically sealing all joints. Water, fertilizer, and carbon dioxide are piped in without breaking the seal. So long as no gas escapes, the glass walls of the chamber stop the beta particles.

Dilution as a Safeguard

Before being piped in, the radioactive carbon dioxide is mixed with stable carbon dioxide, a component of ordinary air. The mixing employs two principles atomic energy research workers use constantly. First, it keeps the amount of the dangerous agent as small as is consistent with the needs of the experiment. And second, this "isotopic dilution" with a stable compound works against reconcentration of the radioactive material in living organisms. Some parts of the human body concentrate certain elements carried by air or water or in food. When a radioactive isotope is mixed with a stable and equally assimilable isotope of the same element, the amount of radioactive material the body can extract is approximately in proportion to the dilution.

If a pane in the Argonne plant-growing chamber were accidentally shattered, the researchers could withdraw from the greenhouse without harm. They might get heavier exposures, however, if a small leak went undetected for some time. Accordingly, they have set up an ionization chamber type of radiation detector near the growth chamber. If gas leaks out and causes radiocarbon to reach one-half the permissible concentration in the greenhouse air, a monitor instrument rings an alarm and starts a large exhaust fan that rapidly draws fresh air through the building. The detector is so sensitive that one breath of tobacco smoke blown into its "nostrils" causes the bell to ring and the fan to run for several minutes. Smoke is not radioactive but combustion, like radiation, produces free ions in air, though ordinarily in much smaller quantities.

Control of Radioactive Dust

At the conclusion of the growing operation, the plants are harvested, dried, and ground up. The grinding produces radioactive plant dust, which is confined by doing the job in the *dry box* illustrated opposite. A fan draws air through the box and keeps dust from escaping. The exhaust air passes out through a baffled chamber packed tight with fiber glass that filters out the dust. To do a job inside this box, the operator puts on long rubber gloves and inserts his hands through rubber sleeves cemented to the front.

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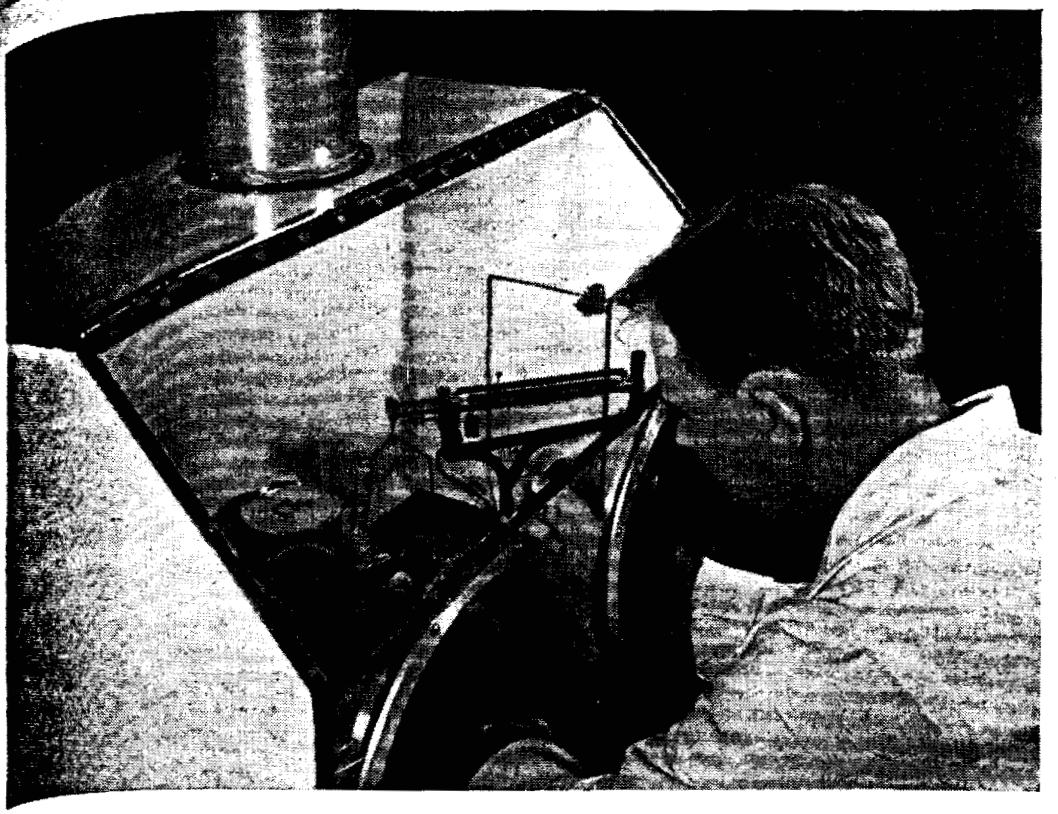
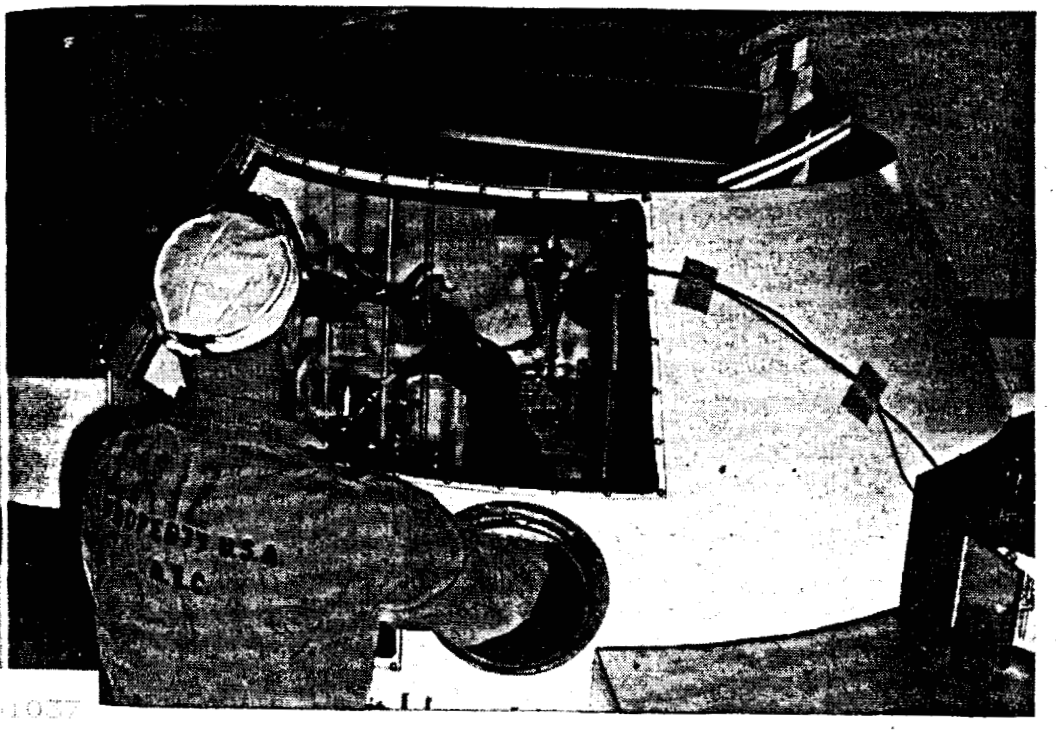


Then materials emit only weak particle radiation, experimenters handle them efficiently and safely with rubber gloves inside ventilated cabinets called dry boxes. Air suction through the boxes keeps radioactive dust and vapor from escaping into the room. In the upper picture, at Argonne National Laboratory, the cylinder on top of the box contains baffles packed with glass wool to filter contamination out of the ventilating air before it is discharged outdoors. The lower picture shows a more complicated dry box at Los Alamos Scientific Laboratory, in which the entire hood rotates to enable the operator to reach any part of the interior.



Vegetable waste containing radioactive carbon is disposed of at the Argonne greenhouse by being burned with several times its weight of coal. The end result of this isotopic dilution is the release into the atmosphere of carbon dioxide in which the concentration of radioactive carbon is actually lower than that already present in the atmosphere.

Since materials emitting alpha or beta particles can spread contamination in air and water and on solid matter, their control resembles the methods a bacteriological laboratory uses to deal with dangerous bacteria and viruses—chiefly good "housekeeping" of a thoroughness like that in a surgical operating room.

Choice of Building Materials

Radioactive dusts and vapors which collect in nooks and crannies and in the pores of materials are hard to clean out. Accordingly, atomic laboratories sometimes use such features of good hospital design as rounded joints between floors and walls, impervious wall surfaces, and pipes and electric lines in galleries or under the floor.

No known material completely repels pore contamination but stainless steel is highly resistant, cleans easily, and stands up well under cleaning and process chemicals. It is used extensively to line hoods and dry boxes.

Some interior walls are coated with plastics, which can be stripped off to remove contamination. Many flooring materials have been tested at Oak Ridge and elsewhere. Concrete is highly vulnerable to contamination but is widely used because of heavy floor loads. Concrete is kept painted to seal its pores. Where traffic is lighter, strippable surfaces such as rubber or plastic sheeting or waxed tile are used.

Advantages of Masonry

Reinforced concrete and heavy masonry buildings are preferred to wood. They are more resistant to fires that might set radioactive materials free in the atmosphere. They take up less contamination than wood, and serve as an additional shield against penetrating rays.

Laboratories built and equipped in the last year or two have benefited from experience gained in 10 years of intensive nuclear research. A laboratory nearing completion at Brookhaven has most of its working area arranged in two long banks of comparatively small rooms for individual experiments. An access corridor stretches along the outer side of each bank, and the two banks share an inner corridor for moving apparatus and radioactive materials. Pneumatic tubes will carry irradiated samples from the Brookhaven reactor to the work

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rooms. Stainless steel and other contamination-resistant materials protect surfaces and fixtures.

Various laboratories at Oak Ridge and Los Alamos are in temporary wooden structures erected during the war. Argonne is partly housed in Quonset buildings. Brookhaven is using many wooden barracks inherited from the Army. The persons working in such buildings make up for lack of advanced design by extra caution in their work and by rigorous housekeeping and monitoring.

Protection Against Gamma Rays

The amount of shielding used against gamma radiation depends on the intensity of the radioactive source and the energy of the rays. "Tracer" or microcurie amounts, equivalent to a few millionths of a gram of radium, are handled safely with ordinary laboratory apparatus and ventilation. The experimenters avoid unnecessary handling of the container and use short tongs and probes to keep the hands a little distance from the work. Where tracer-scale operations are prolonged enough to build up a significant radiation exposure, a light shield is set up.

The need for regular use of shields arises when the radioactive material amounts to millicuries, equivalent to a few thousandths of a gram of radium. Exposure of the whole body is avoided. The operator may erect a course or two of lead bricks at the front of a hood or bench to shade most of his body from the rays. Or he may protect his entire body (depending on the length of exposure and amount of radiation) by using instruments that curve around or over a head-high barrier and a mirror above the bench to view his work.

As Gamma Intensity Rises

As the amount of radioactivity moves up toward the curie level, or at a lower level in prolonged work, the laboratories provide permanent shields with special apparatus for manipulating and viewing the work. Such a set-up is usually shielded at the sides and rear as well as the front, and is called a *cave*. Thickness of the walls ranges up to several feet of concrete.

Up to a few curies of radioactive material, no shielded roof is needed. Above that point, a completely enclosed cave with a massive roof becomes necessary because of "sky shine,"—secondary radiation from air molecules caused by the gamma rays radiated upward from the source. These structures are sometimes called hot cells, especially in radioactive chemistry work, but in general continue to be called caves.

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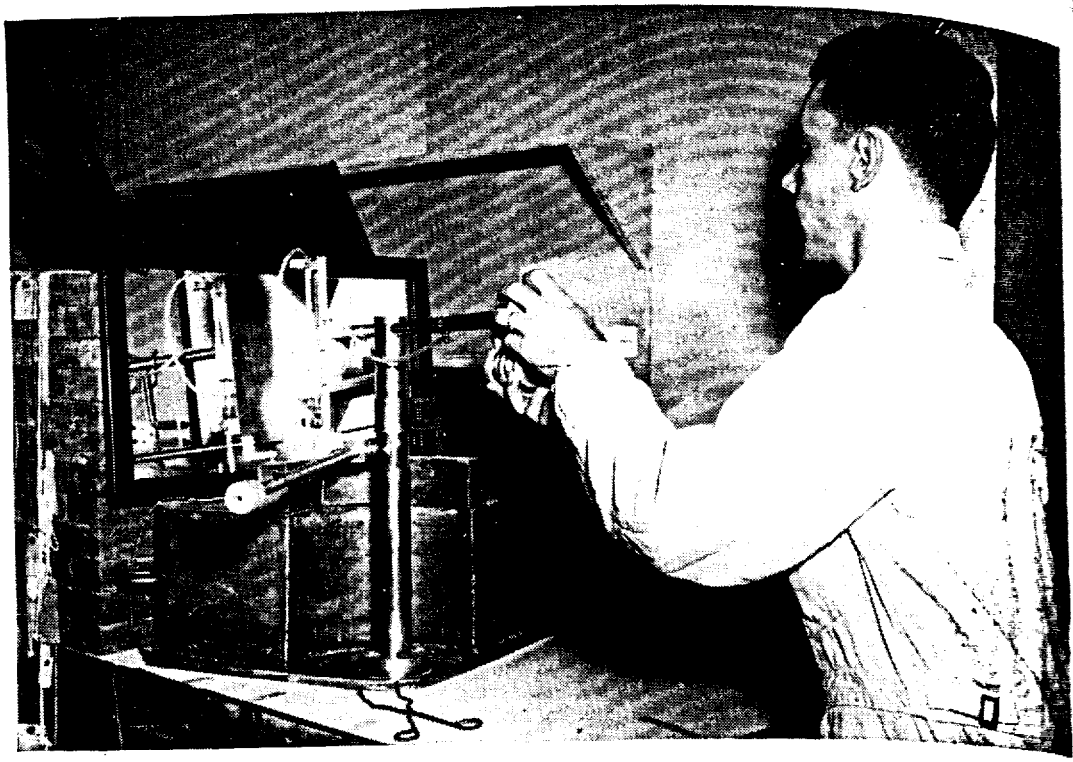
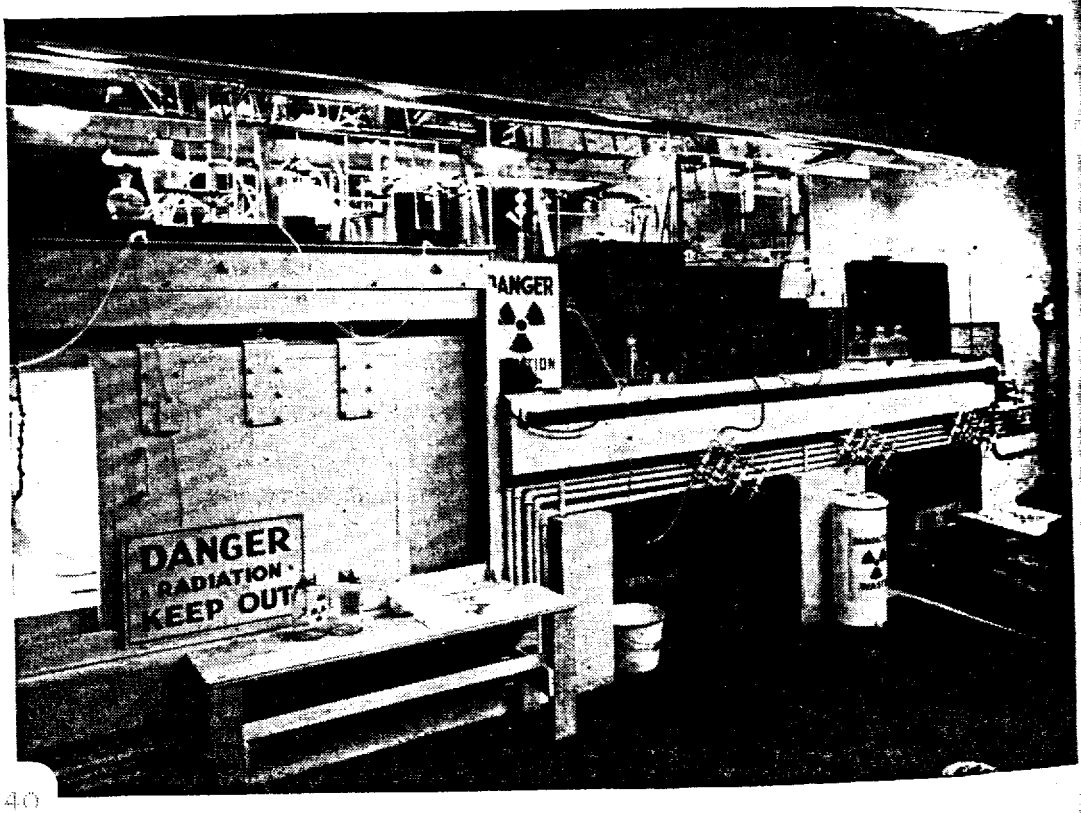


Equipment like this is used for laboratory procedures on "semi-hot" materials. In the upper picture, a chemist at Oak Ridge National Laboratory measures out portions of a radioactive solution, shading himself from radiation with a lead block and viewing the job in a mirror. A laboratory at Brookhaven National Laboratory, shown in the lower view, has various features that contribute to safety, including a wall of lead bricks, mirrors along the back wall, safes to store radioactive specimens, pipes neatly arrayed where they are easily reached for cleaning, and a tile floor that is readily replaced if it becomes contaminated.



Closing Cell or Cave Openings

Some designers use concrete on all sides of caves and cells, some steel-sheathed concrete, cast iron, aluminum, or lead. The entire front of a cell in Brookhaven's new hot laboratory is a pair of massive metal doors reaching from floor to roof and sliding on tracks to meet at the center. The butt end of one door is shaped like the stepped edge of a vault door and the other has a matching stepped edge. When the doors are rolled together, this joint is almost as radiation-tight as an unbroken wall. The same principle is used in the portholes that let electric cables into the back of a radiochemical cave at Argonne.

A Typical "Hot Cave"

A cave in the metallurgy laboratory at Argonne, pictured on page 86, illustrates several points of safety technique in working with very "hot" materials. The walls are of concrete 3 feet thick and the roof is of steel. By means of a device called the Argonne Master-Slave Manipulator (see p. 87), the operator moves samples and adjusts apparatus inside the cave with considerable ease. His eyes have a clear view of the work through a large shielding glass window directly in front of him.

Setting Up an Experiment

In a recent series of operations, this cave was used for physical tests on uranium specimens that had been irradiated in a reactor. These specimens were not only intense gamma-radiators; they also contained plutonium. A typical operation was carried out in this fashion:

The seven-ton concrete door that forms one end of the cave was rolled out on railroad tracks. After checking the interior with detection instruments to make sure that previous jobs had left no dangerous contamination, the operators set up their apparatus. In laying out the equipment, they took care to leave no crevices or blind spots from which it might be impossible for the master-slave manipulator to recover a dropped specimen.

They enclosed part of the apparatus in a clear plastic case, in effect making a dry box inside the cave. Where movable parts passed through ports into this enclosure, rubber bellows were used to prevent the escape of dust. This precaution became particularly important in a subsequent job of sawing plutonium-bearing uranium.

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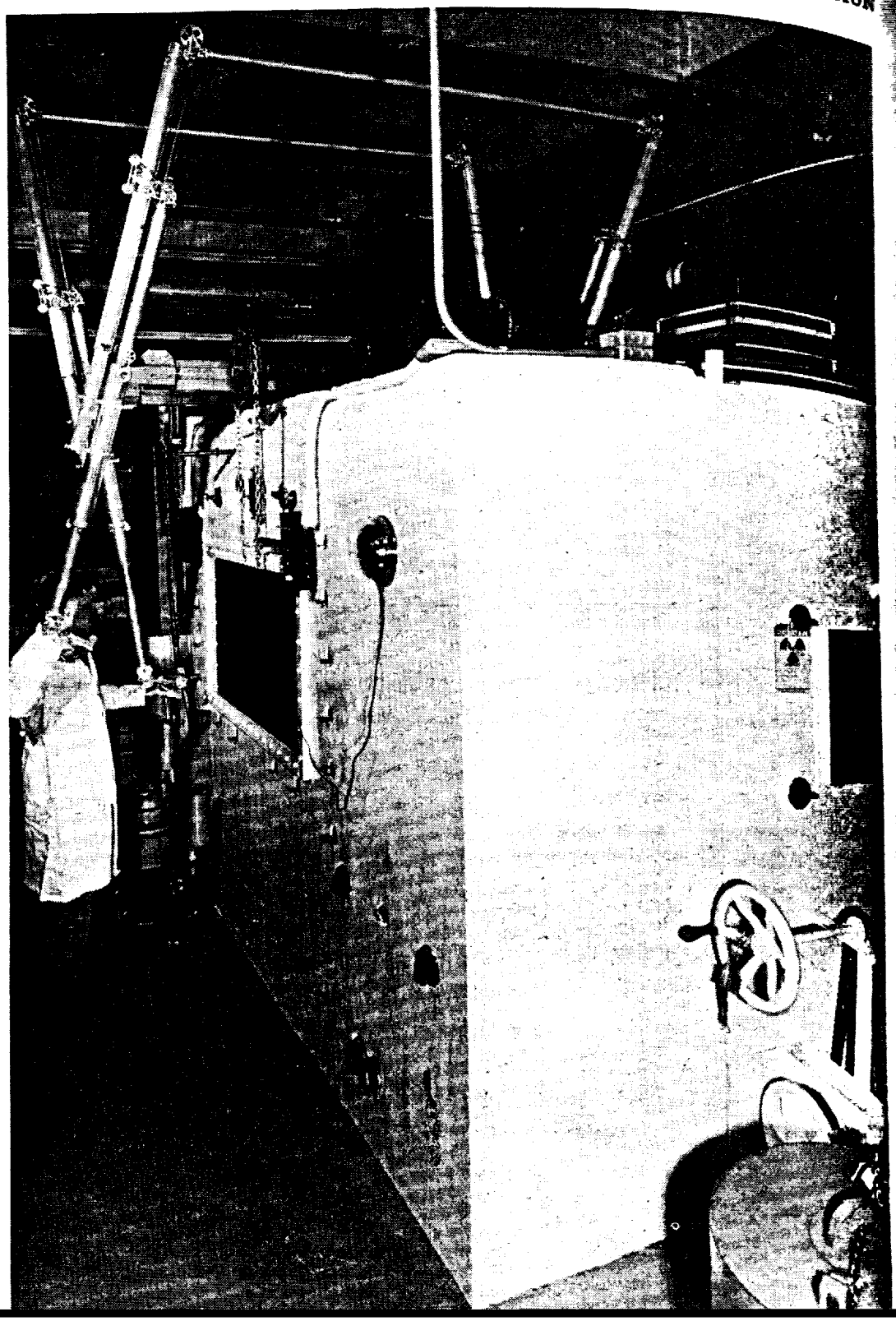

"Dry Run" Tests Plans

To make sure that the set-up would operate as anticipated, the operators first made a "dry run," a complete dress rehearsal with a dummy specimen. These preliminaries satisfactorily completed, they rolled in a heavy lead pot in which the uranium pieces had been encased from the time they came out of the reactor, lifted it to working level with a chain hoist, set up a shelf to catch any dropped specimen, retired from the cave, and rolled the door closed.

Taking over at this point, the man at the master-slave manipulators removed the lid from the pot, picked up a mirror with one manipulator and a pair of tongs with the other, extracted the first specimen from the pot, and set to work.

Even the intricate jobs of weighing specimens on precise balances and testing their hardness were performed readily with the master-slave manipulator. The operator saw clearly what he was doing through a large window into the interior, which was lighted with sodium vapor lamps. He stood 5 or 6 feet from his work. When he needed to read an instrument more closely, he put on a pair of opera glasses which hooked over the ears like spectacles.

Operators of this equipment use the manipulators almost as casually as a typist uses a typewriter. Telling their assistants about some adjustment inside the cave, they point with the slave ends of the manipulators as naturally as with their fingers.

A single specimen in this series of determinations was equivalent to, and had all the potential deadliness of, 50 grams of radium. Outside the cave, however, the radiation was below the permissible limit.

Remote Control Engineering

Such an operation could have been performed only with the greatest difficulty—if at all—without the advanced art and engineering of remote control embodied in the master-slave manipulator and the seemingly simple glass window.

Master-Slave Manipulator

The master-slave manipulator was developed at Argonne to give remote control work a dexterity approaching the nimbleness of the human hand. With the device it is possible, for example, to pour from one narrow-mouthed vessel into another without lost motion and without spilling any of the contents. Such feats can be performed because the slave end of the machine faithfully follows the motion of the operator's hand on the master end in speed, direction, and distance.

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The slave hand duplicates the applied power also, so that the opera accurately feels what he is doing and has sureness of touch.

This highly dexterous manipulator duplicates all seven fundamen motions of the human hand: right-left, up-down, forward-back, ro tion about three axes of motion, and opening-closing the fingers. three lineal motions are transmitted from the operator's hand to slave hand through a ∩-shaped assembly of aluminum tubing pended open end down over the cave wall. The three rotary moti are accomplished by equipping both the operator's grips and the sl hands with wrist joints, which resemble the differential gears in automobile rear axle. The mechanical connection between master slave consists partly of tubes sliding and rotating inside the m frame; other motions are driven by pulleys and cables.

This machine draws all its power from the operator's muscles. attain full usefulness, it must give him only negligible mechanical sistance. Accordingly, it is counterbalanced in a free suspension friction drag has been reduced to a very low point. Each manipu tor contains 130 ball bearings.

"Sense of feel" is achieved by direct mechanical connections betw the master and slave ends. Each mechanical part of the slave duplicate of the corresponding part of the master. The resista met by the slave hand in closing on a test tube is thus matched by resistance felt in the master's finger-grips.

An Electrically Driven Manipulator

An electrically driven manipulator has been developed at Argo to perform less complex tasks. It is called a *rectilinear* manipula because—unlike the master-slave—it makes a series of straight-l motions instead of the direct motions of the human hand.

The operator of this machine stands before a battery of keys switches that actuate a steel hand inside the cave. The hand c nects through a wrist joint to a vertical arm with a geared tr by which it is driven up and down in a support head. The head, turn, is moved by gears along a horizontal cross-member. And fina the ends of the cross-member travel along a pair of geared horizon tracks that support the whole machine.

Apart from the wrist joint, the machine resembles a small overh traveler crane capable of moving in all three dimensions of sp The controls are pushed to the right to accomplish a movement to right, and so on. The rectilinear manipulator can perform prec work but lacks the special dexterity of the master-slave.

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"Seeing" in Remote Control

It is almost as important to remove the unnaturalness from remote viewing of operations as it is to remove this handicap from remote handling. For some purposes, simple mirrors, or systems of mirrors and lenses arranged into periscopes, give a satisfactory view of shielded operations. Mirrors generally show objects from an unnatural point of view, however, or reflect only a narrow field, and are unsatisfactory for many laboratory procedures.

The most nearly natural view into shielded enclosures is through windows. Thickness for thickness, lime glass is a slightly better radiation shield than concrete. But glass available in the past colored under radiation bombardment and became opaque, so a search for noncoloring transparent materials was launched when the first periscopes were built for the atomic energy program in 1943. This led to the discovery that some pure plastics resist coloration between 500 and 1000 times as well as optical glass.

Preventing glass coloration. Continuing the search for shield windows, researchers at Argonne began with the known fact that a small amount of cerium in glass makes it more resistant to coloration by ultraviolet and X-rays. In cooperation with the glass industry, various metallic oxides were added to batches of glass, which were then subjected to intense gamma rays. Cerium oxide gave particularly promising results, and several cerium-containing windows were built into permanent shielded enclosures.

Argonne also investigated the denser lead glass originally developed for X-ray use, and flint glass which is used for lenses. The denser glasses cut down radiation better, and have higher indexes of refraction. Glass has the optical effect of "bringing things closer" visually, and the effect increases with the refractive index.

Commercial lead glass has a natural color that limits vision beyond a thickness of a few inches. In cooperation with a glass manufacturer, Argonne researchers are working on a heavy, nearly colorless lead glass which also will be stable against radiation. Preliminary studies have started on 7-foot-thick windows for the concrete shield of a cyclotron, which would have to stop neutrons as well as gamma rays.

At the usual working distance between operator and radioactive source, 1 to 3 feet of glass permits safe handling of from 0.3 to 300 curies of material emitting gamma rays of very high energies. With "softer" gammas, 3 feet of glass is a safe shield for 1000 curies. The photograph on page 90 was taken through 3 feet of laminated glass.

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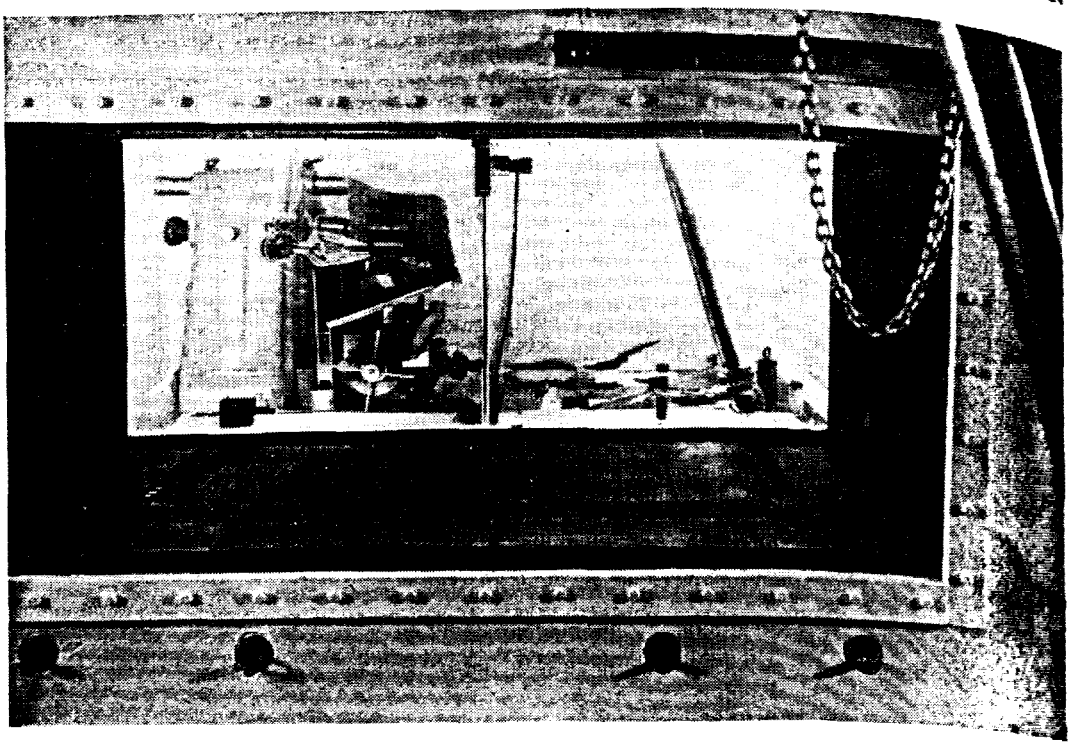

This view of a milling machine inside a metallurgy cave at Argonne was made through 3 feet of laminated plate glass. Commercial glass is an effective shield but it colors rapidly under radiation and becomes useless for viewing purposes. Argonne overcame this difficulty by developing a special glass that is many times more resistant to coloration.

Seeing through liquid windows. Liquid-filled glass windows are also in successful use at Argonne. A nearly saturated solution of zinc bromide is a good liquid absorber of gamma rays. Such a window is better than laminated glass in optical quality, and costs less. The liquid becomes cloudy under radiation and occasional filtering is necessary.

An experiment 1,000 feet away. A solid shield usually affords enough protection, but in a few operations great distance provides an added safeguard. One such operation at Los Alamos involves the use of quantities of fissionable material large enough to start a spontaneous reaction. Explosions are scarcely possible in these critical mass experiments but the materials may emit intense radiation if rapid fission should start. These experiments are performed with electric manipulators operated one-fifth of a mile away. The operator watches this job with wire-carried television.

In the interest of greater dexterity in such ultra-remote controls, the Argonne engineers are working on a long-distance master-slave

manipulator in which electrically powered servomechanisms [1] replace the mechanical linkages. Tests on a preliminary model have established that the sense of feel can be transmitted back from the slave hands to the hands of the operator.

Three-dimensional television. Television is a necessary adjunct to such extreme-range remote control tools but it has a drawback. Ordinary television reproduces width and height clearly but gives poor perception of depth. Accordingly, Argonne engineers have developed a practical system of *stereoscopic television*, employing the optical principle embodied in such familiar instruments as binoculars and the stereoscope.

In the Argonne stereo-TV system, the camera has twin lenses set approximately eyes-width apart, which pick up slightly different images on the screen. The single picture consisting of two images is then handled through the camera in conventional fashion, transmitted by coaxial cable and reconstructed in the receiver.

The original model receiver projected the images side by side on a single picture tube as illustrated on page 92. Ninety-degree-opposed polarizing filters were mounted on the halves of the tube face and the two images were viewed through spectacles polarized in the same 90-degree pattern and fitted with prisms. An improved system developed a little later uses twin receivers with picture tubes pointing together at right angles. The electronic impulses for both images flow into each receiver but the controls are set to project only the right-eye image on one tube, only the left-eye image on the other. The two picture tubes are equipped with polarizing filters, and a half-silvered mirror bisects the right angle between them.

The half-silvered mirror, a familiar device among researchers in optics, transmits half the light falling on it and reflects the other half. Consequently, a person looking at the mirror sees the reflected image from one tube superimposed on the transmitted image from the other. With the naked eyes, the resultant single picture is flat and blurred. With properly polarized spectacles, the blurring disappears and the result is a clear picture in which differences of depth are vivid.

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[1] A servomechanism in general is a combination of elements in which the output or a system, or some function of the output, is fed back for comparison with the input, and the difference between these quantities is used in controlling power. As applied here, a servomechanism is a mechanical, electrical, or hydraulic device which causes remote operation to take place in correspondence to signals applied to the controls. Servomechanisms were used extensively during the war in the apparatus that automatically aimed ship or airplane guns after such data as distance, direction, speed of the target, and wind velocity were fed into a computer.

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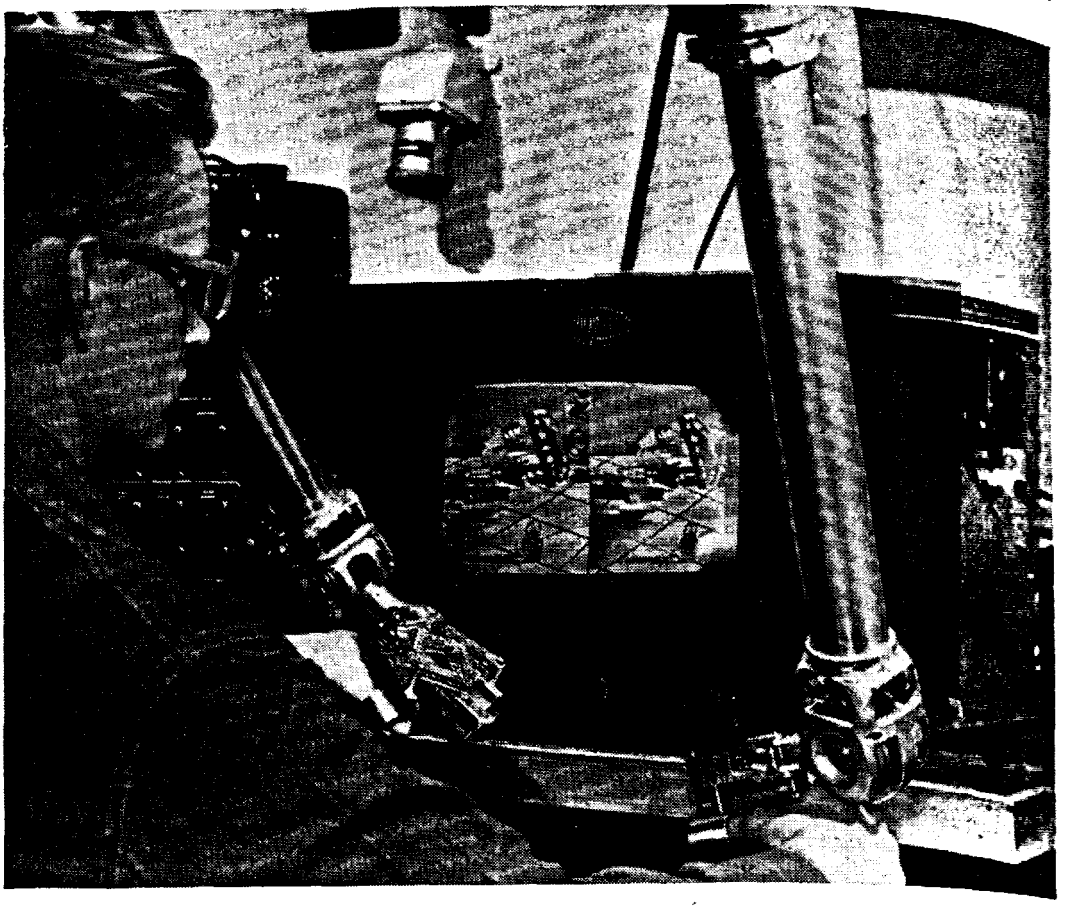


Television is used to view experiments from extreme distances. To restore the accurate depth perception lost in ordinary TV, Argonne engineers developed a system of stereoscopic or "two-eyed" television. With his special spectacles, the operator sees a single picture with natural perspective, and easily performs the delicate operation of pouring from one small vessel into another with his master-slave manipulators. To accompany this advance in ultra-remote optics, Argonne is currently working on an electrically connected master-slave for distant work.

Other Remote Control Development

Remote controls, like process equipment and laboratory apparatus, have largely been developed locally to meet the particular needs of various atomic energy centers. Part of the pattern of remote controls at Hanford has been reported in Chapter II. The method of packaging Oak Ridge isotopes behind a shield is given in pictures in Chapter III. The Radiation Laboratory at Berkeley, California, has a program-wide reputation for its advanced work in the design of dry boxes. The installations carrying out research and development exchange techniques and design data through reports and consultation.

PARTICLE ACCELERATOR WORK

The highest-energy radiation generated anywhere in the atomic energy program is produced in the *particle accelerators*—the cyclo-

trons and other "atom-smashers." The control of particle beams from these powerful research tools creates special problems of shielding. The accelerators speed alpha and beta particles to energies many times higher than their natural values, and they also use positively charged nuclei of hydrogen isotopes—protons, deuterons, and tritons. Even at relatively low energies (for an accelerator) of 2 and 3 million electron volts, a proton beam almost instantly turns a quartz crystal white hot and erodes it. Alpha particles are harmless to the skin at ordinary intensities and natural energies of 3 to 5 Mev, but when a student at a laboratory outside the AEC program moved his hand through a beam of 32 Mev alpha particles from an accelerator, he suffered a severe burn that took weeks to heal.

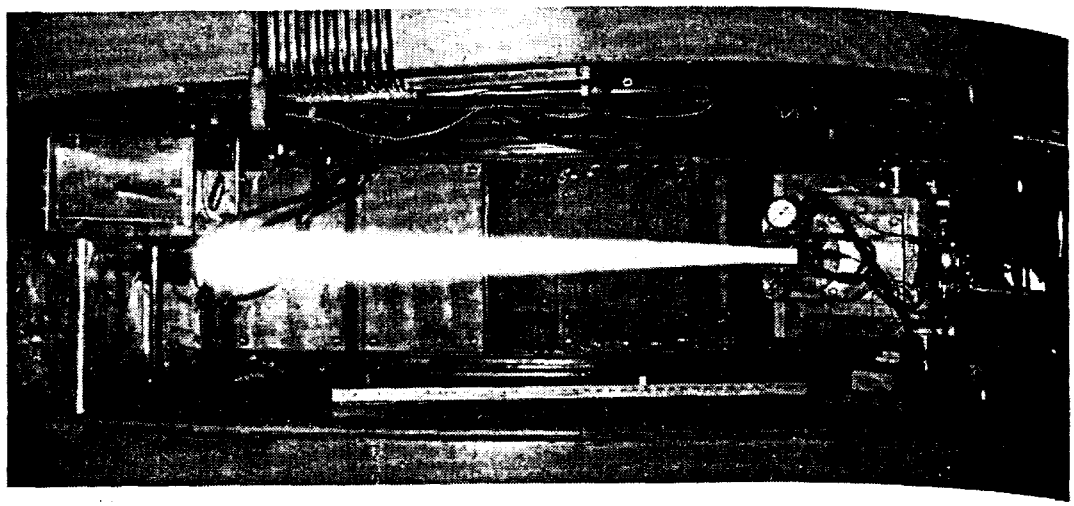
As explorers of unknown forces inside the atom, workers with accelerators pioneer a great deal of fundamental knowledge. Scientists frequently change the use of their accelerators—bombard various targets with several different types of particles, reverse the beams, or bend them in magnetic fields and test diffraction patterns. The problem of radiation safety is complicated because of frequent changes in experimental set-ups and because nuclear particles accelerated to atom-smashing energies have enormous power of penetration.

The Radiation Laboratory at Berkeley, California, is building a proton-synchrotron or Bevatron to accelerate protons to 7 billion electron volts. In the similar but smaller Cosmotron at Brookhaven, protons will build up energies of 2.5 billion electron volts by flying around a circular track 2½ million times and reaching a speed over 170,000 miles in one second—approaching the speed of light.

Accelerator Shielding Problems

The radiation field around a cyclotron varies with experimental conditions of beam direction and target position, and therefore demands occasional readjustments of the shielding. Recently it was found, for example, after a change in the deflector system of the Berkeley 184-inch cyclotron, that a large number of circulating protons hit the deflector apparatus in such a way as to throw a strong beam of high-energy neutrons directly at the control room. The shield on this

even within a half-inch of the beam. A small, biologically unimportant increase in ionization is produced by air-scattering. When the neutron beam impinges on a scatterer, however, 200 to 300 neutrons per square centimeter per second are measured at a radius of 10 feet. The operating limit is 60 neutrons per square centimeter per second, so the operators supervise such experiments from a distance.



A deuteron beam emerges from the target chamber of a 60-inch cyclotron with an energy of 60 million electron-volts, which carries it 5 feet through the air. This picture from the University of California Radiation Laboratory suggests the peculiar radiation safety problems involved in work with particle accelerators.

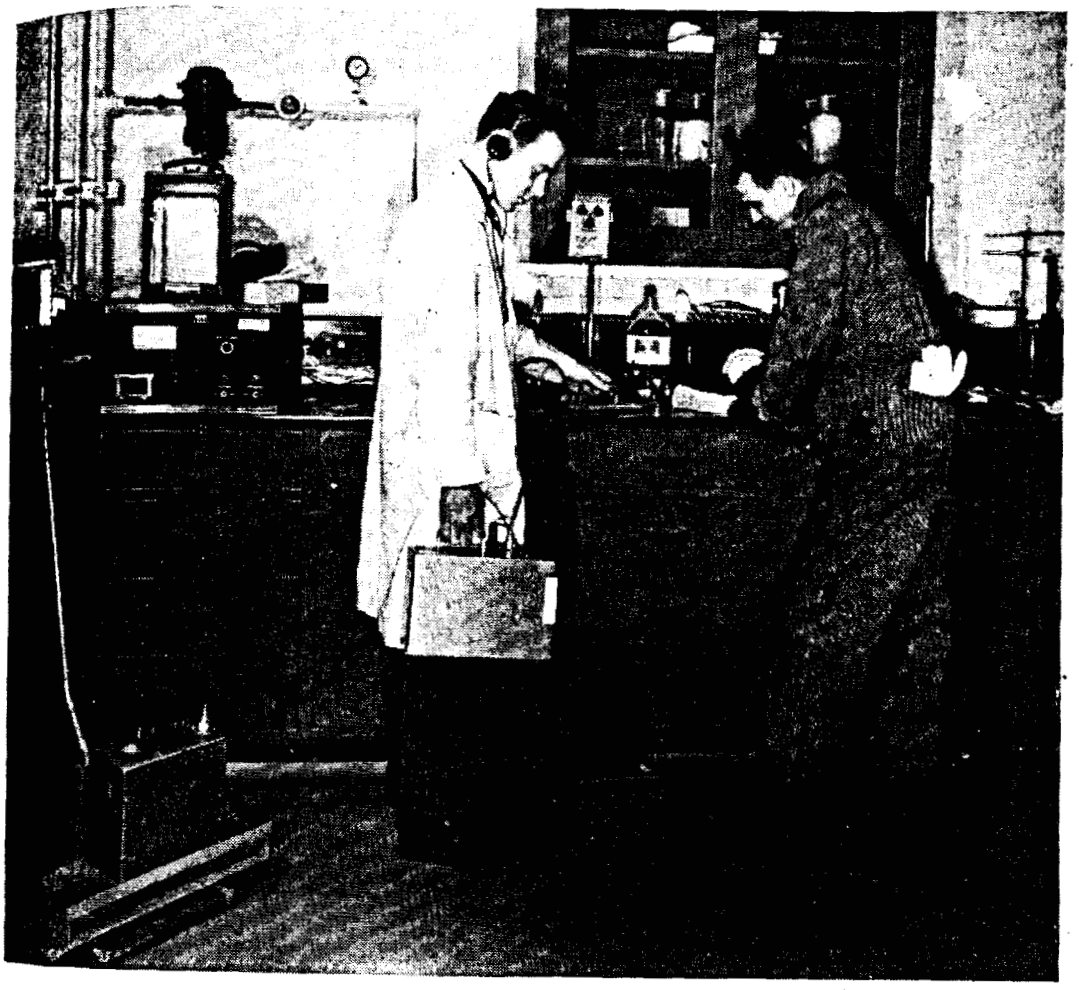
Shielding for 7 Billion Volts

The shielding of the 7-billion-volt Bevatron presents an interesting and novel problem since mesons will constitute an important component of the radiation. Shielding requirements are difficult to estimate since the nuclear reactions of mesons are not well known. Special biological hazards will most likely result from the fact that negative mesons can be captured by nuclei of atoms in the body, shattering them and producing "stars" [2] whose fragments cause very high ionization. Hence the exposure factor by which the ionization must be multiplied to obtain the biological effect may be very large. These mesons decay with a half-life of about one hundred-millionth of a second, however, so only very fast-moving, high-energy ones will be able to pass through the shield. The problem of "star" formation must also be considered in dealing with high-energy protons and neutrons. Work on the biological effects of high-energy particles from the 184-inch cyclotron indicates, however, that the destructiveness may not in fact be greater than could be expected solely on the basis of ionization in tissue.

[2] So named because the nucleus shatters with such force that its fragments make a star-like pattern when this phenomenon of radiation is recorded on photographic film.

Because of these many special radiation problems, designers place massive shields completely around accelerators wherever it is possible to do so without impairing the usefulness of the instrument. The 184-inch cyclotron at Berkeley is shielded by movable 10-foot concrete blocks. The cyclotron nearing completion at Brookhaven is enclosed in heavy concrete walls with various interior baffles and shields. When the machine is running, the operators will withdraw behind massive steel-encased concrete doors that rise up out of the floor. Beams drawn out of this cyclotron for experiments will pass through a narrow slit in a concrete wall several feet thick and terminate on the far side of the experiment chamber in a concrete wall built into a hillside.

The Van de Graaff electrostatic generator at Argonne, a lower-energy accelerator, operating now in a Quonset hut, is surrounded with concrete bricks laid up into a wall 3 feet thick and higher than



A health physics surveyor at Argonne checks a bench top for radioactive contamination and a decontamination man prepares to remove the "hot" spots with acid. Three detectors of alpha particles are shown: the portable instrument in the surveyor's hands, a floor counter on wheels, and a registering air monitor at the left end of the bench.

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a man's head, on which radiation detection instruments are placed.

Areas around these machines need continuous and unusually detailed radiation measurements. Accelerator experiments in general, and especially those which break new ground, are conducted by senior scientists or under their close direction. Despite the severe latent hazards, the combination of shielding, monitoring, and know-how is giving this pioneering branch of nuclear science good radiation safety records.

CONTROLLING REACTOR RADIATION

In contrast with the accelerators, which produce limited amounts of extremely high-energy radiation, nuclear reactors produce great amounts of radiation at lower energies.

The hazard of the greater quantity remains only potential, however. Laboratory instruments though they are, research reactors are built to perform over and over a limited range of tasks. Accordingly, they have permanent, built-in radiation protection of a massiveness that approaches the scale of the Hanford production works (see chapter II).

Reactors are automatically controlled during operation. In the reactor under construction at Brookhaven, electrically driven control rods have devices to shut down the reactor even in the event of power failure. "Scram" controls for emergency shutdown also are provided.

Problems of control vary with reactor design. The Oak Ridge and Brookhaven reactors are cooled with air. The production piles at Hanford are cooled by flowing water. One reactor at Argonne has a closed-cycle cooling system, in which the heat is removed by circulation of heavy water through the reactor and then through coils in a tank of ordinary water. One of the research reactors at Los Alamos also has closed-cycle cooling. The original Stagg Field pile, rebuilt at Argonne, operates at so low a level that it needs no cooling beyond the heat radiation from its surface. Each design requires different detailed engineering of controls, but a carefully planned system of multiple automatic, manual, and emergency safeguards is common to all.

Radiation From Open Ports

The potential hazards of reactors were reported in Chapter II. The only additional hazard in a research reactor comes from ports opened during operation to let out neutron beams for experiment.

At the Brookhaven reactor, it is planned to take neutron beams out of the top of the pile. The top shield is made in removable sections

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which interlock into one another. When sections of the shield are removed, the radiation safety problem will resemble that of cyclotron operations, except that the beam will have lower energies and greater intensity. Such work will be directly supervised by scientists and each approach to the open sections will be accompanied by a surveyor who will test radiation levels with monitoring instruments.

In an experiment at Oak Ridge, in which neutrons emerged from a side port, lead brick was walled along the path of the beam and a massive neutron-absorbing basin, shaped like a hollow cube with one wall removed to check diffracting neutrons, was used as an end-stop.

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ENVIRONMENTAL SAFEGUARDS

The Commission endeavors to safeguard areas surrounding atomic energy installations under the same mandate that directs it to protect workers in the program.[1] This task of protecting the general public from injury and property damage is accomplished partly by extension of the same careful techniques that achieve the safety record within AEC plants and laboratories, and partly by special measures.

Permissible levels of radiation released from routine operations into the environment were set extremely low—at or below the levels of background radiation under many natural conditions. Rigid operating procedures were established to meet these standards. Continuous surveys in the neighborhood of plants and laboratories check on performance and watch for accidental or unforeseeable releases of radiation. Research goes on constantly to anticipate potential hazards and to discover how present precautions and operating procedures may be improved. Systems are being developed to deal with emergencies that might threaten the environment (see pages 41, 135).

Routine control of the environment is largely a matter of managing waste materials—gases, liquids and solids—which are generated by atomic energy installations as they are by nearly all heavy metallurgical or chemical industries. The unique problem of the AEC is that the wastes from its operations are radioactive—often persistently so. Radioactive carbon, for example, continues to emit beta particles whether it is incorporated in a carbohydrate molecule in a plant, in carbon dioxide in the air, or in the human body—whether it is gaseous, solid, or liquid. Regardless of temperature, pressure, or any known condition, a quantity of radiocarbon loses only half its radioactivity in 5,900 years and continues to decay at this same slow rate. Half-lives vary from element to element, ranging from less than one second to tens of thousands of years. But only time diminishes the radioactivity of any of them.

Broadly speaking, there are two methods of controlling radioactive wastes: (*a*) *concentration and storage*, reducing the radioactive material to small bulk so that it may be safely stored or economically contained (cast in concrete, for example, and sunk in the ocean depths); (*b*) *dilution and dispersal*, mixing the material with

[1] Atomic Energy Act; the pertinent extracts are quoted on page 8.

so much nonradioactive material (air, water, or a stable isotope of the same material) that it will be harmlessly dispersed. There are numerous promising lines of attack in each of these general approaches; and the AEC, in its own laboratories and through research and industrial contractors, is investigating them. The AEC reported recently on the problems and the program of research and development undertaken to solve them.[2] Accomplishments and new developments not previously reported are given here, together with a brief summary of the basic techniques.[3]

KEEPING WATCH OVER RADIATION

Raw and Feed Materials

Extensive atmospheric pollution surveys around the plants that process feed materials, operated by a number of contractors in various places throughout the East, indicate that they are not contaminating their surroundings to such a degree as to constitute hazards.

The problem of solid and liquid waste disposal is to keep uranium and radium from contaminating water supplies and adjacent land. Regular analyses are made of neighboring soil and water. With a minor exception, the surveys have disclosed no surface stream which contained more than its natural content of radioactive elements. At one plant, uranium did accumulate for a time in river mud near a sewer outlet. Waste treatment equipment was installed, and a subsequent survey showed that the accumulation had ceased.

The U. S. Geological Survey in a cooperative program with AEC has studied the possibility of ground water contamination at one isolated storage area. Soil analyses there showed that very small amounts of radioactive materials had carried short distances outside the site, but they were blocked off from streams and became so diluted that they are no longer detectable.

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[2] "Handling Radioactive Wastes in the Atomic Energy Program," Superintendent of Documents, October 1949, Washington 25, D. C.; 15 cents.

[3] All Commission plants and laboratories do research on waste handling. An extensive research program in this field was recommended by an Advisory Committee on Liquid Process Waste Disposal and Reclamation in 1948. Research on treating the atomic energy program's liquid and dry wastes has been carried on by a number of institutions and commercial firms: (1) For ventilation of plants, filtration and treatment of airborne effluents, and meteorological researches; Air Reduction Sales Company, Arthur D. Little, Inc., Union Carbide and Carbon Corporation, Owens-Corning Fiberglas Company, American Air Filter Company, Harvard School of Public Health, U. S. Army Chemical Corps, U. S. Weather Bureau, University of Rochester, Mine Safety Appliance Company, University of Washington, University of Illinois. The advice and recommendations of the Stack Gas Problem Working Group, named in June 1948, have been instrumental in starting various studies, now under way, on more efficient methods of ventilation and of filtering gaseous radioactive wastes. (2) For concentration and disposal of liquid and solid wastes: American Smelting and Refining Company, General Electric Company, Massachusetts Institute of Technology, New York University, North Carolina State College, Tennessee Valley Authority, University of California, U. S. Department of Agriculture, U. S. Public Health Service, Washington State College.

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Plans have been developed to take care of such emergencies as fires, including detailed operating arrangements with local fire departments and health authorities. New feed materials plants, being planned or under construction, will further improve control.

Hanford Safeguards

Over the last 5 years, the operators of Hanford have greatly reduced the amount of radiation released into the environment, particularly the radioactive content of plant stack gases. It is the responsibility of the AEC to know—and know with accuracy—that the Hanford operations are not adversely affecting the welfare of the region.

The General Electric Company, as operating contractor at Hanford during the last 3 years, has been strengthening an environmental program that has three major aspects: *first*, area monitoring to discover as precisely as possible where radioactive materials discharged from the plants are going; *second*, research to discover as precisely as possible the composition of the radioactive wastes and their effects on plant and animal life; and *third*, installing facilities to reduce or eliminate the release of radioactivity to nature. Since the war years, the number of personnel devoted to protecting the Hanford environment has increased four-fold.

Seven site surveyors are continuously in the field measuring radioactivity and collecting samples of air, water, earth, vegetation, and animal life from the Hanford region. Equipped with mobile laboratories, they travel scheduled routes, some covering points a hundred miles away. Each month they travel 10,000 miles or more and make more than 5,000 measurements. A typical month's record shows 600 samples of river and well water; 4,000 air samples and readings; 500 samples of vegetation, soil, and mud; and 15 surveys of special areas with portable instruments. At site survey headquarters, maps show the month-by-month distribution of radiomaterials in the air, water, and earth around the Hanford reservation and also record natural background and other radioactivity at scores of selected points outside the reservation.

Samples are routed into a central control laboratory for analysis in quantities that have increased rapidly over the past 3 years. All water samples are evaporated to allow accurate readings on beta and alpha activity that they contain. In 1946, the amount of water thus evaporated amounted to about 230 gallons; in 1950 it will be about 4,800 gallons. Other determinations have been multiplying at the same rate.

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At Los Alamos

Planning is well established and constantly revised to meet radiological problems that might arise at Los Alamos. After 7 years of experience the environmental conditions brought about by operations at Los Alamos are well known, and only routine precautionary measures are necessary.

Protection at Research Laboratories

In a large measure, the methods of safeguarding the environs of an atomic research laboratory are the same as those at a production-scale plant. No research laboratory produces the amount of "hot" byproducts that Hanford does, but the laboratories handle a much greater variety. And since Argonne, Oak Ridge, Brookhaven, and Knolls Atomic Power Laboratory are in more populous regions where cooperating university and industrial scientists can reach them easily, there is particular reason to resolve on the safe side any possible doubts about environmental hazards. Elaborate safeguards against environmental contamination are in force at each laboratory.

Oak Ridge Operations

At Oak Ridge, operated by a division of Union Carbide and Carbon Corporation, an air-cooled reactor is in operation. The U. S. Weather Bureau conducts thorough meteorological surveys under a cooperative agreement with the AEC. The work involves detailed measurement of wind flow and temperature in the broken ridge country surrounding the plants, including the behavior of the upper atmosphere. Turbulence and gustiness, primary atmospheric factors in dispersing stack gases, are measured by a special technique employing highly sensitive wind instruments, small free balloons, and chemical smoke pots.

The Oak Ridge Laboratory's network of radiation monitoring stations first demonstrated its usefulness by detecting rises in radiation caused by occasional localized failures inside the reactor. Since then, reactor improvements have virtually eliminated this hazard and efficient filters have been installed. Area radiation monitoring continues as a primary environmental safeguard for Oak Ridge's chemical separation plant and as an added check on its reactor.

Organized research into methods of economical and safe handling of radioactive waste at Oak Ridge is assisted by the U. S. Public Health Service and TVA sanitary engineers, and by a geological survey staff from the U. S. Geological Survey and the University of Tennessee, as well as by the Weather Bureau.

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Safeguards at Argonne

At Argonne National Laboratory, the two reactors release no radioactivity through coolants. In one of them no coolant is used; in the other heavy water is recirculated in a closed system. This eliminates the radioactive stack gas problem as far as the reactors are concerned and ameliorates the liquid disposal problem at that institution. Since Argonne carries on other research with highly radioactive materials, however, the Laboratory carries out survey work to keep check on the environment. A meteorological survey is in limited operation. The Laboratory is also making a careful study of natural radiation background.

Here, as at other atomic energy centers, tests are conducted to make sure that plant, fish, and animal life downstream from the Laboratory are not reconcentrating extremely dilute radioactive wastes to any dangerous extent.

Laboratory Wastes at Knolls

Radioactive wastes at the Knolls Atomic Power Laboratory, operated by the General Electric Company, consist primarily of solutions and some contaminated solid articles such as clothing, equipment, and filters.

The solutions are concentrated in a specially designed evaporator, and reduced to solids in drum driers. Small flatcars, operated by remote control, carry the solids away in shielded metal containers for storage underground.

Clothing worn in hot laboratories, used air filters, and other combustible radioactive solids are burned in an incinerator designed to remove contaminating particles from the gases of combustion. The ashes are buried.

As at other AEC installations, the ventilating air of Knolls hot laboratories is filtered before it is discharged through a tall stack.

Constant monitoring is maintained within the Laboratory and through the neighboring countryside. Weather conditions are observed to time the release of airborne materials with favorable meteorological conditions.

Reactor Safeguard Committee

With the advancement of nuclear knowledge and operating experience, the postwar atomic energy enterprise has continued to design and build nuclear reactors, some of which depart greatly from the older piles in purpose, principle, design, and power. The AEC had

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to determine what special hazards these reactors would present or make more acute, and to work out the special features of design that would limit hazards most effectively.

The Commission, in one of its first official acts, sought counsel from its General Advisory Committee and, accepting its recommendation, created a Reactor Safeguard Committee in 1947 to give advice on safety features of nuclear reactors. The Reactor Safeguard Committee originally made its own field investigations, but during 1949 the Committee was relieved of some of the heavy duties incident to this work. Now the reactor designers themselves submit detailed reports which the Committee evaluates. Under both procedures, the Committee's technical advice on plant design, operation, and location has been invaluable. Advice from this body played an important part in determining the special environmental safeguards that surround the atomic research laboratories and in choosing the site for the Reactor Testing Station, established last year in southeastern Idaho.

Choice of a Reactor Testing Site

As reactor technology advanced, it became desirable to build new types of reactors. The AEC determined that such reactors should be tested on a large reservation of public land—preferably of submarginal value for farming and ranching and not suitable for future agricultural, mining, or other development—whose very extent would serve to guard the population of the surrounding area against potential hazard. The geology of the site was of importance; the earthquake risk had to be small.

With the assistance of the Reactor Safeguard Committee, the Department of Defense, the Geological Survey, the Bureau of Reclamation, the Weather Bureau, and private consulting engineers, the AEC searched for a site "removed from large population concentrations and from vital industrial and other strategic areas" with hydrological, topographical, and geological features to permit adequate control of radioactive wastes even under emergency conditions. Extreme climates which affect operation or restrict design of reactors were to be avoided.

The choice went to the Naval Proving Ground at Arco, Idaho.

Safeguards at Arco

Operations at Arco, which are now directly under the AEC, will be planned in advance and in the light of the detailed knowledge of

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reactor technology that has produced the record of radiation safety for the older reactors.

The Reactor Testing Station is setting up a program of environmental studies and area monitoring similar to those at the other atomic energy installations. The Weather Bureau has had technicians on the site almost from the first. Meteorological stations are being set up to guide operations of reactors and associated plants. The Geological Survey is engaged in test-drilling and other explorations to provide knowledge about surface and ground water and soils and geological strata.

With the cooperation of the Civil Aeronautics Administration, automatic stations to register cosmic rays and other natural background radiation have been set up at the Pocatello, Idaho Falls, and DuBois airports, all at some distance from the Arco site. A fourth station is located at the site. In addition, a contract has been signed with Idaho State College for a study of plant and animal life, soils, water, and air of the Snake River Plains area.

In the beginning, this work will determine the levels of natural radiation and radioactivity in the region. As reactors are built and go into operation, this environmental work will disclose even slight increases of radioactivity in the area, thereby enabling the Testing Station to eliminate sources of potential hazard that might arise.

These general precautions—choice of site, precise design, monitoring, and research—are supplemented by many special operating techniques, devices, and systems of waste handling which are reported in the following sections.

CONTAMINATED SOLIDS

Solid materials that have become contaminated with excessive radioactivity must be decontaminated or safely disposed of. All the plants must dispose of contaminated equipment and materials—machinery, structural pieces, laboratory wastes, clothing that is beyond economical recovery, wiping rags. Such solid wastes are stored or buried in guarded areas on Government property.

During the early days of the Los Alamos project, it was necessary to designate areas or "dumps" where radioactive waste materials could be placed. Since Los Alamos at that time was regarded as a short-term operation, it was believed that disposal of radioactive materials would not prove troublesome. With the continuation and increase of activity at Los Alamos, however, waste handling has become a more important problem.

Because of the long life and biological peculiarities of some of these waste materials, safeguards were established to protect both project

5001060

personnel and nearby residents. Dumps are well guarded. Frequent tests are made of surrounding watersheds and wells to make sure that the water is not being contaminated. Frequent air samples are taken to make sure that unsafe concentrations of radioactive particles do not occur.

An experimental incinerator for burning combustible radioactive wastes, developed by Air Reduction Sales Company for the AEC, has been built at Knolls Atomic Power Laboratory near Schenectady, N. Y. Another incinerator has been built at Mound Laboratory near Dayton, Ohio. An AEC project at the University of Illinois is making headway with basic research to glean more information about particle sizes, their distribution in stack gases, and their other significant properties. AEC has contracted with Harvard University to do applied research on air cleaning. An improved air filter has been developed for AEC by A. D. Little, Inc.; information about it has recently been distributed to prospective manufacturers through the technical and trade press.

HANDLING LIQUID WASTES

Liquid wastes from atomic energy installations may carry considerable radioactive solid material, as in the wastes from chemical separation plants or laboratories, or may carry small amounts of radioactive salts in solution like the cooling waters from the Hanford reactors.

Water Wastes at Hanford

The cooling water of the Hanford piles is held for a number of hours in retention basins until much of the short-lived activity has decayed; then it is returned to the Columbia River. At the time of this release, about 95 percent of the remaining radioactivity comes from short-lived isotopes. The final small amount comes from radiophosphorus (P 32, half-life 14.3 days) and trace amounts of longer-lived isotopes of iron and calcium. These materials are so diluted and, for the most part, undergo such rapid radioactive decay in the first few miles of their trip down the river that they present no difficulty. Although the cooling water amounts to many thousands of gallons a minute, it constitutes a very small fraction of the river's total flow.

Because the minute amount of radiophosphorus and other elements may be taken up and concentrated by algae and similar aquatic organisms, Hanford carries on a number of studies in this field. Sampling of the extremely pure water of the Columbia River began early in 1945. This program has been steadily developed and analytical methods improved so that the site survey group now collects water

samples weekly from 11 points on the Columbia, 5 on the Yakima, and also, less frequently, from points as far down as the mouth of the river.

No harmful effects from the pile discharge have been found. Radioactivity in the water nowhere exceeds permissible limits set by AEC. It comes closest to the limits at the retention basin outlets. From there on the concentration of radioactivity is rapidly reduced downstream by dispersion of the material throughout the river and by dilution from tributaries such as the Yakima and the Snake Rivers, and the radioactivity is reduced by the additional time for decay of the radioisotopes.

Surveys of River Life

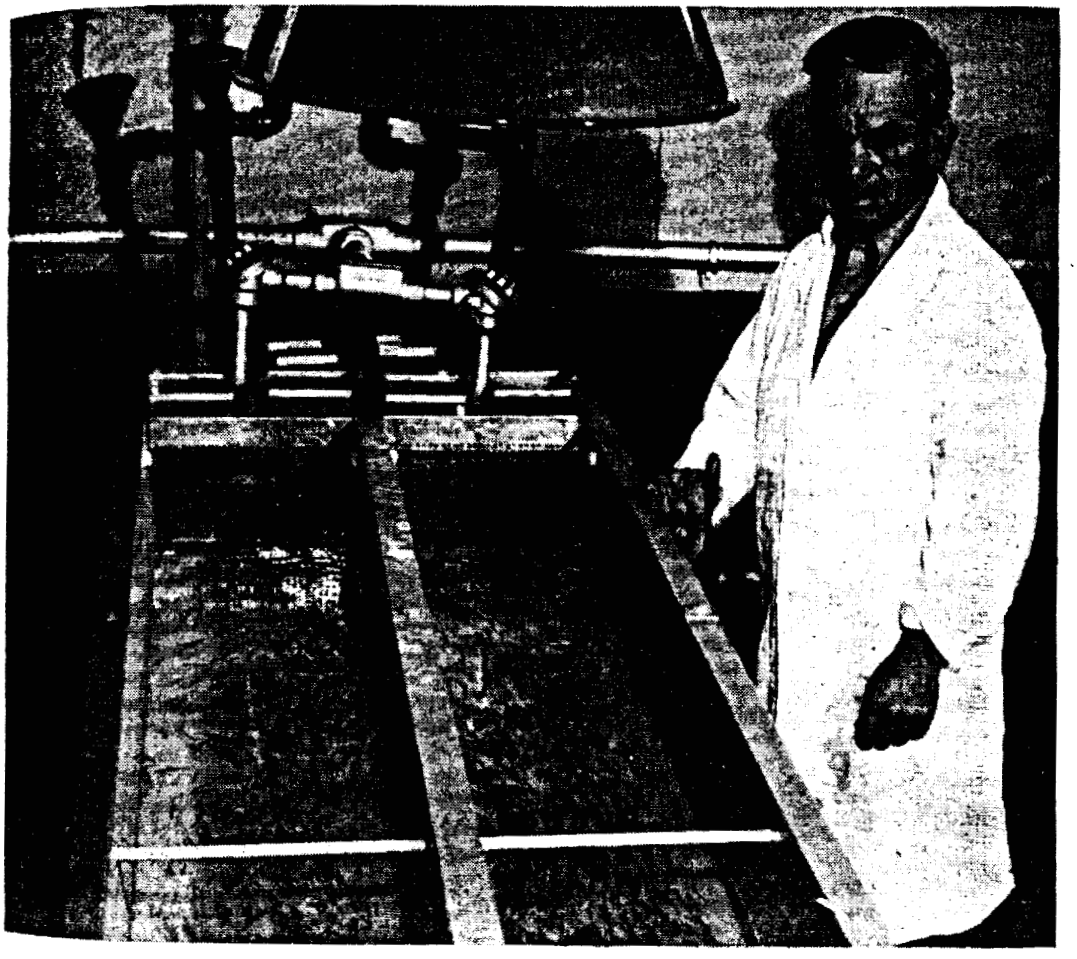
From evidence now at hand there is no reason to believe that the operation of the Hanford piles will have any harmful effect on the natural balance of plant and animal life in the river. It is essential that the Commission be sure that the situation remains safe, however, particularly since the river regimen will be greatly altered by water backed up when McNary Dam is completed.

Studies during the current season are far more extensive than anything done before. Plankton can accumulate phosphorus (stable and radioactive isotopes alike) in concentrations 200,000 times that of the surrounding water, algae as much as 50,000, and fish over 100,000. Phosphorus can be transmitted and concentrated through biological chains: for example, from water into algae, from algae into insect larvae, from either algae or larvae into young carp, and from carp into trout. The trout can also pick up phosphorus from insect larvae or adult insects. Other chains can include such creatures as snails, lobsters, and, of course, salmon. The Chinook salmon is the fish of chief interest because of its economic importance; it represents a 10-million-dollar yearly business in the Northwest.

Hanford, therefore, has developed a program of extensive study of the Columbia River which involves, besides the site surveys, aquatic biology, botany, and zoology. A proposed Columbia River survey, being planned by the AEC and the U. S. Public Health Service, will obtain information on the effect that McNary Dam will have on the hydrological, physical, chemical, and biological characteristics of the river as they relate to Hanford operation and waste disposal. This 2-year study will be financed by the Public Health Service.

Aquatic biology. In a small laboratory on the bank of the Columbia near one of the pile areas, aquatic biologists are growing Chinook salmon and trout in a long row of test troughs (see photograph).

Columbia River marine life is studied systematically as a safeguard against radioactive contamination from the Hanford plants. In the upper picture two men are collecting plankton for analysis in the laboratory and a third is measuring the current. The lower view shows part of a research project to test the effects of artifically high concentrations of irradiated reactor cooling water on fish.



There are other fish in tanks outdoors. The water in which the fish live is a mixture of Columbia River and pile cooling water.

Down the row of tanks the concentration of pile water in the river water ranges from one percent, which is higher than is actually found in the river, up to 10 percent. Bad effects do not begin to appear until the tanks where pile water is at least five percent—more than five times the amount actually found anywhere in the river. At this level, growth is slowed and mortality rises. When the pile water is as much as 10 percent, the ill effects are very definite.

In the short run, the radioactive content is less harmful than the chemicals mixed with the water before it passes through the reactors. In the long run, the radioisotopes are likely to prove more important than the chemicals because they may accumulate in the fish and have genetic effects. Tests for genetic effects will be long and laborious. A group at the University of Washington, Seattle, under contract with the Commission, is carrying on studies in this field (see Appendix 6).

River studies. Tests up to now have not shown any cumulative effect that is important to man as a consumer. A man would have to eat 100 pounds of these fish at a sitting, or as much as 10 pounds a day, day in and day out, to get any appreciable dose of radioactivity.

The aquatic biologists are studying silt and all living organisms from the river. Few of the fish studied have contained radioactive material in amounts approaching the permissible dose set for human beings. Several invertebrate organisms slightly exceed this level, but only when specimens are taken near the cooling water outlets.

Estimates of the abundance of organisms do not show any gross disturbances to aquatic populations from either radioactivity or toxic chemicals.

Study of irrigation waters. Because the Columbia River is so extensively used for irrigation, Hanford investigates whether or not the radiomaterials added to the water could affect crops. Hanford botanists established an experimental field station in which two plots of approximately equal size support orchards and grow crops that are important in the Columbia Valley: alfalfa, beans, sweet corn, potatoes, oats, carrots, peaches, apricots, cherries, plums, and apples. One plot is irrigated with water from a well, the other with river water that contains water discharged from the operating piles.

Results obtained during the 1949 growing season showed no difference between the yields of the two plots, and no significant increase in radioactivity. The experiment is being expanded during the current season.

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Columbia River Advisory Group. In July 1949, the AEC Manager of Operations at Hanford took the initiative in establishing the Columbia River Advisory Group to assist the Commission and the General Electric Company in a long-range program to prevent water pollution and promote public health. The members, in addition to Hanford officials, are representatives of the U. S. Public Health Service, the Department of Health and the Fish and Pollution Control Commission of the State of Washington, and the Oregon State Board of Health.

One of the difficulties in carrying out this program of environmental protection at Hanford has been that, although the AEC needs the cooperation of interested officials in the Northwest, the requirements of protecting atomic energy security have hindered exchange of information. The members of the Columbia River Group have been cleared to receive information which cannot for security reasons be released to the general public.

Wastes From Chemical Separations

The radioactive materials discharged into the water at Hanford are trivial in comparison with the great quantities of highly active process wastes from the chemical separation plants where plutonium is extracted. This great bulk of material could never conceivably be handled by dilution; it must be segregated.

The liquid and solid process wastes run off through underground pipes, and most radioactive material is retained in underground tanks. Test borings are made to detect any leakage.

Tanks for the total volume of plant waste would be needless as well as unnecessarily expensive, and the least active material is run into underground cribs which effectively concentrate the active components within small areas. Conditions of soil and geology permit this method of disposal at Hanford, and close study indicates that it could be continued safely until research and development on the concentration of radioactive wastes eliminate the necessity for this practice. The water table in the vicinity of the chemical separations plants is 300 feet or more below the surface of the ground and roofed by a layer of clay, which forms an effective barrier between the percolating liquids and ground water. Nearer the surface are soils that are remarkably efficient in retaining plutonium and other fission products. Therefore a crib into which waste material is run becomes a sort of tank without walls, where a very large proportion of the active material is retained.

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Movements of underground water. Before geological conditions at Hanford were thoroughly understood, some separations plant wastes were run off into deep dry wells and they contaminated underground water in limited areas. Samples from the many wells bored by the geologists to follow the course of this material show that its slow flow toward the river has been stopped. Even if the movements of these materials had not been controlled, the U. S. Geological Survey estimates they would take 20 years to reach the river and their entry would be so gradual that no significant hazard would ensue. The Geological Survey has rendered invaluable service in all these Hanford water and waste handling studies.

The propensity of desert plants for sending roots far underground and bringing up deep-lying material is being considered as a means for monitoring the movement of the radioactive wastes in the soil.

Los Alamos Liquid Wastes

Los Alamos maintains studies of liquid waste disposal problems in cooperation with the AEC Division of Engineering, U. S. Public Health Service, and U. S. Geological Survey. The program covers the physical and chemical characteristics of the wastes to be treated, methods of rendering them innocuous, and the effects of wastes upon surface and subsurface environment.

Experiments have shown the feasibility of adapting commonly used water, sewage, and industrial waste treatment processes as a means of reducing the residual radioactivity in liquid wastes to a harmless level. Laboratory-scale studies during recent months have indicated that a chemical process may be adequate to remove radioactive and other harmful chemicals from plutonium wastes. The plutonium remaining after this treatment was of the order of 600 millionths of one millionth of a curie per milliliter of fluid. A pilot plant should be in operation this summer.

Laundry wastes. Liquid wastes from the contaminated clothing laundry contain radioactive materials and various complexing agents in addition to the soaps and synthetic detergents regularly used by commercial laundries. The chemical process mentioned above is not dependable for removing radioactivity from laundry wastes, but investigations disclosed that plutonium could be removed by a filtering and biological process in common use to treat wastes from commercial laundries, dairies, packing houses, and breweries. This process may leave substantially less radioactivity than the chemical method. An experimental pilot plant is testing the process before a full-scale plant is designed.

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Oak Ridge Liquid Wastes

A portion of the liquid wastes released at Oak Ridge ultimately reaches the Clinch River. The waste system involves holdup and radioactive cooling in tanks, then passage into a settling basin, holdup again behind a dam in White Oak Creek, and finally discharge in greatly diluted form into the Clinch River, with radiation monitoring at several points along the line and in the river itself. With the cooperation of the Tennessee Valley Authority, which operates Norris Dam a few miles upstream, sufficient water for extreme dilution is assured at all times. The people in charge of Oak Ridge waste disposal have a double incentive to play safe inasmuch as the water supply for the gaseous diffusion plant is taken from the Clinch below the point at which the diluted liquid wastes from Oak Ridge National Laboratory enter it.

Control by concentration. The problem of concentrating waste material is high on the priority list of AEC research programs. The first plants to concentrate liquid wastes by evaporation went into operation this year at Oak Ridge and Knolls. While doing a day-by-day processing job, these plants also provide pilot data for future designs. Also this year, the AEC has approved construction of a crystallization and distillation pilot plant at Knolls and authorized Oak Ridge to expand its development program in waste processing.

Plans for Brookhaven's Liquid Wastes

The Brookhaven sewage disposal system is typical of precautions taken with radioactive wastes at national laboratories. The method is to reduce the amount of wastes, then to monitor discharges to assure their harmlessness.

Reducing the volume of wastes starts in the laboratory, where research workers set aside "hot" wastes in labeled bottles and limit the amount of radioactive material they pour down the drains. Water from the sinks passes first into holdup tanks, where automatic equipment collects a continuous sample. If tests show long-lived radioactivity above a prescribed limit, the contents of the holdup tank is pumped into tanks for permanent storage. When the samples fall within the set limits, the water is released from the basin into the sewer system. Brookhaven waste water is tested twice more before it flows into uncontrolled drainage: at a pool where sewage is subjected to a standard bacterial treatment which precipitates out some of the radioactive contamination, and at sand filter beds which catch still another fraction of the contamination. The water is then chlorinated, given a final radiation monitoring, and released into a stream.

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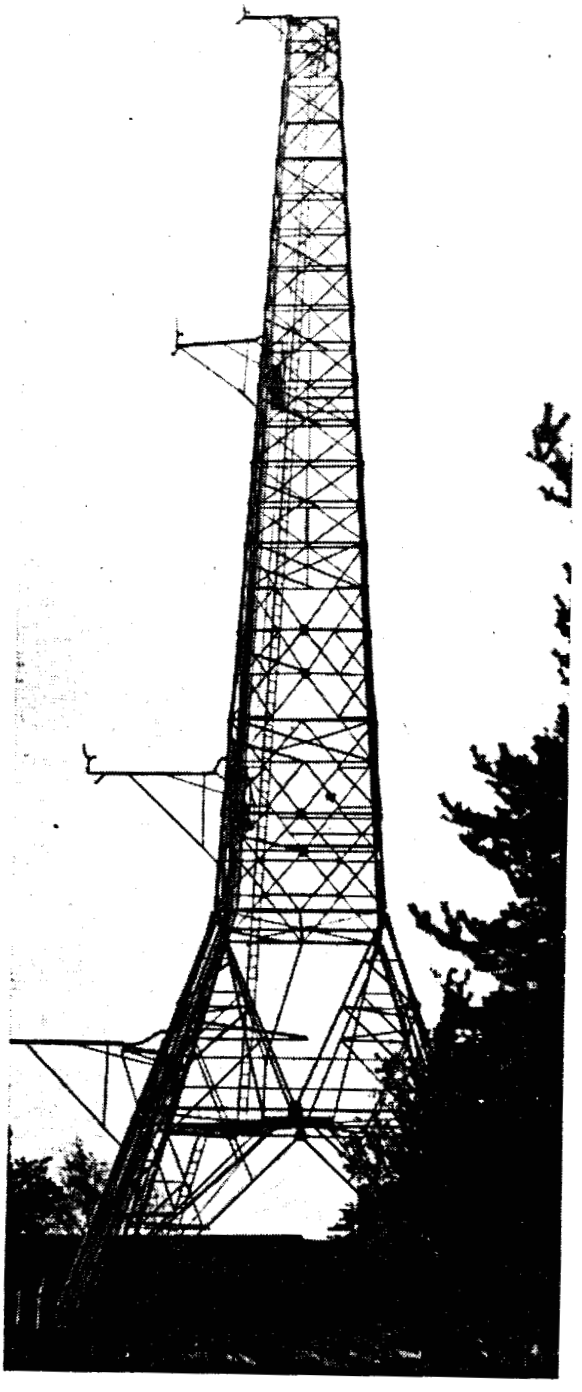

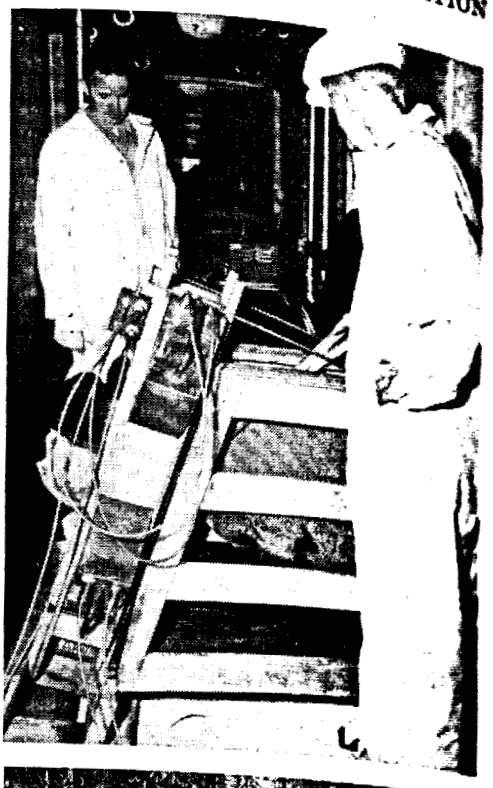

Diverse means are used to protect the neighborhoods of atomic energy installations. In a study the University of Washington is performing to contribute to the control of Hanford stack gases, meteorologists use the tower at the left to determine changes of wind speed and direction in relation to the vertical temperature gradient. At the upper right, Hanford biologists are determining the radioiodine content of a sheep's thyroid with Geiger counters clamped about its neck. Oak Ridge surveyors at the lower right are taking mud and water samples from the White Oak Lake system, in which waste water is held up until checked for dangerous contamination.

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As an additional safeguard, Brookhaven conducts continuing studies of the geology and water table underlying central Long Island. A cooperative program was set up more than 2 years ago in which the AEC provides funds and the Water Resources Branch of the Geological Survey supplies scientific direction and technical personnel. Survey teams drilled five 200-foot covered wells and two 1,600-foot wells to bed rock, analyzed many samples of surface and underground water for chemical content and natural radioactivity, and studied the direction and speed of ground water flow and the ability of the geological formations under the Laboratory to absorb radioactive materials.

It appears that ground water under the Laboratory moves only a few feet a day so that routine water tests would show up any significant changes in radiation caused by Brookhaven's conservative release of waste materials. In the event of an accidental spillage of greater amounts of radiation, the very slow migration of ground waters would provide the time for corrective measures before surrounding areas were at all affected.

One of the ideas Brookhaven scientists have considered for dealing with such eventualities is the possibility of pumping contaminated water from shallow "scavenger" wells into very deep special wells. This would be effective because the subsurface water lies in layers separated from the surface by highly impervious strata of clay. Domestic water supplies are taken only from the uppermost stratum.

CONTROLLING GASEOUS WASTES

Gaseous wastes that contain radioactivity are generated in large quantities at two atomic energy installations—Hanford, where gaseous fission products are released in the chemical separation process, and Oak Ridge, where the nuclear reactor is cooled by air. Brookhaven's reactor also will be cooled by air. Possible contamination of the air presents a lesser problem at a few other installations such as Los Alamos, where plutonium is handled, and certain feed materials plants, reported on earlier.

Control of Hanford Gaseous Wastes

Radioactive iodine 131, emitted by the chemical separations plant stacks, is the principal constituent of concern in the disposal of gaseous wastes at Hanford. The stack gases also sometimes carry radioactive particles, chiefly fission products that have collected on dust or other material, which may travel considerable distances in the air. Hanford has made substantial progress on three fronts in dealing with iodine 131 gas and radioactive particles: (*a*) reduction of the quantities emitted from the stacks; (*b*) reliable determination of

AEC 1069

the areas affected and the degree of contamination; and (*c*) establishment of research projects to determine precisely the effects these materials have on plants and animals within the affected areas.

Reduction of Radioactivity in Stack Gases

The importance of radioiodine is that it could fall to the ground, become concentrated in plants and be eaten by grazing animals. The quantity of I 131 reaching the ground near the separations plant stacks has been reduced by a factor of 4,000—from a concentration of 40 microcuries (40 millionths of one curie) per kilogram of vegetable material in 1945 to 0.01 microcurie in 1949. This latter concentration, it is believed, would be safe even if it existed outside the Hanford reservation—which it does not. The drastic reduction has been achieved in two ways: by longer "aging" of the pile slugs to allow decay of the radioiodine before they are dissolved, and by scheduling the chemical operations in accordance with meteorological conditions.

To provide meteorological data for Hanford, there is a tall tower with instruments to gauge air movement and temperature at intervals of 50 feet. The observer at this central station has this information before him on a row of dials. By correlating it with data from outlying substations, he gets a detailed picture of air movement. When weather conditions would cause materials from the stacks to be deposited on the ground in excess amounts, he notifies the chemical plant and operations are suspended.

To assist in meteorological control, the University of Washington is making a detailed study under AEC contract of the relationship between temperatures at various heights above the ground and the vertical movement of air. The Air Reduction Sales Company recently completed research and development on equipment for extracting radioiodine from process gases. Further studies on a full-plant scale are now under way at Hanford.

Radioactive particles. Radiation monitors in the Hanford reservation first detected the existence of radioactive particles on the ground near the separations plant stacks late in 1947. For several months thereafter, all workers in the area wore masks. Since then the quantities of these particles have been very sharply reduced by the redesign of plant ventilating equipment, by scrubbing (washing) and by filtering the gases. Further research is under way, not only at Hanford but at Oak Ridge and also under contract with a number of commercial concerns (Appendix 6).

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Advisory group on stack gases. In June 1948, an Advisory Stack Gas Problem Working Group was appointed, the membership of which includes experts in industrial health and ventilating problems. This group has instigated numerous studies, and it will assist in evaluating results and recommending action.

Area Monitoring for Stack Gases

In addition to the routine and continuous collection of samples over a wide area, the Hanford monitoring groups have undertaken a number of special studies related to the stack gas problem, examining native rabbits and other native animals, notably sheep, and exposing and checking on laboratory animals. Two of 32 native rabbits examined showed above-limit concentrations of radioiodine; other animals did not.

The extensive monitoring program has demonstrated conclusively that the Hanford stack gases are not causing significant contamination outside the immediate vicinity of the plants. Beta and gamma activity from radioiodine is virtually indistinguishable from natural background radiation outside a radius of 5 to 10 miles from the stacks, a distance well within the reservation. The number of particles that travels any considerable distance was found to be so small as to be negligible from the public health standpoint. Workers within the plant areas receive regular thyroid checks, and none has been found with activity even approaching permissible limits.

Research on Biological Effects of Radioiodine

In spite of the reassuring results obtained from environmental monitoring, the Commission needs to know what the consequences would be if radioiodine, for example, were to fall steadily over a period of time within the range of grazing animals. It is possible that no harm would come from many times the amount of contamination now allowed. But this possibility cannot be assessed without a great deal more knowledge.

For this reason, the Hanford zoology group has undertaken a number of studies, the most ambitious of which is a continuing experiment with sheep, the common grazing animal of the region. New facilities completed in 1949 permit a full-scale experiment extending over several generations. The sheep are fed radioiodine regularly in doses considerably larger than they could get by grazing in the contaminated areas. The sheep barn has been designed and equipped so that every effect of this treatment can be closely studied. Such a research proj-

5001071

ect, although programmatic in its primary purpose, may well add to man's basic knowledge concerning mammal metabolism and the function of iodine in the body.

Radioactive Gases from Reactors

Methods of controlling radioactive gases from air-cooled nuclear reactors were worked out at Oak Ridge during the war and have been further improved through the years. The problems at Oak Ridge, which has the only air-cooled reactor in operation, and at Brookhaven, where one is under construction, are similar. At Oak Ridge radiation in the environment has been held to the level of natural background radiation in places nearby.

Radioactive Argon Gas

One natural constitutent of the air used to cool a reactor, the inert gas argon that comprises about one percent of the atmosphere, presents a problem of radiation control. A part of this gas becomes radioactive in passing through a reactor.

If the cooling air carried particles or dusts, some of this material, too, might become radioactive. To avoid this, the air is filtered both before and after it passes through the reactor. Thus the main problem is controlling radioactive argon.

This gas will be highly diluted before it leaves the reactor. Rapid further dilution is accomplished by discharging the cooling air from a high stack with the pressure of the blowers, plus the natural draft of heated air, to shoot the emerging gases even higher.

Radioargon (half-life, 110 minutes) rapidly undergoes radioactive decay into a stable element. The combination of radioactive decay with dilution is expected to eliminate the potential hazard of the outlet gases at Brookhaven as it has for seven years at Oak Ridge.

Adjusting Operations to the Weather—Micrometeorology

If weather conditions threatened to cause a poorly dispersed flow of reactor gases over one spot long enough to raise the radiation exposure above the permissible weekly limit at ground level, the reactor would be shut down. To provide the detailed technical information that such a plan of control requires, Brookhaven, like Oak Ridge and Hanford, maintains a novel project in micrometeorology—the intensive study of weather conditions within unusually small areas. This involves measuring temperature and wind differences between

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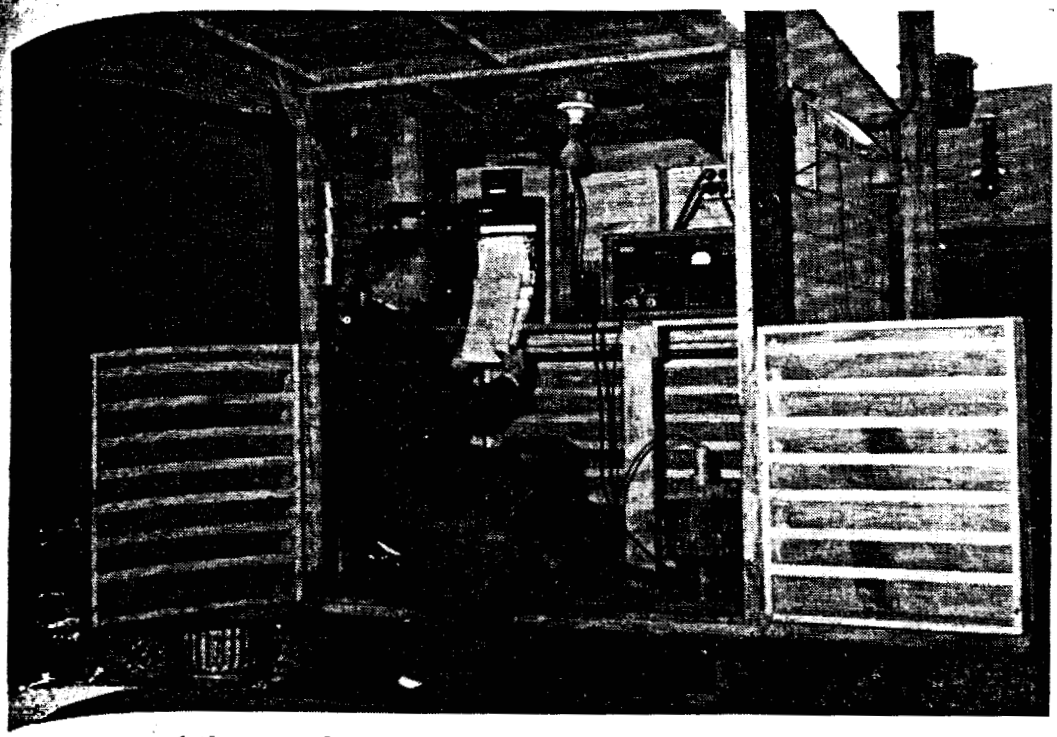
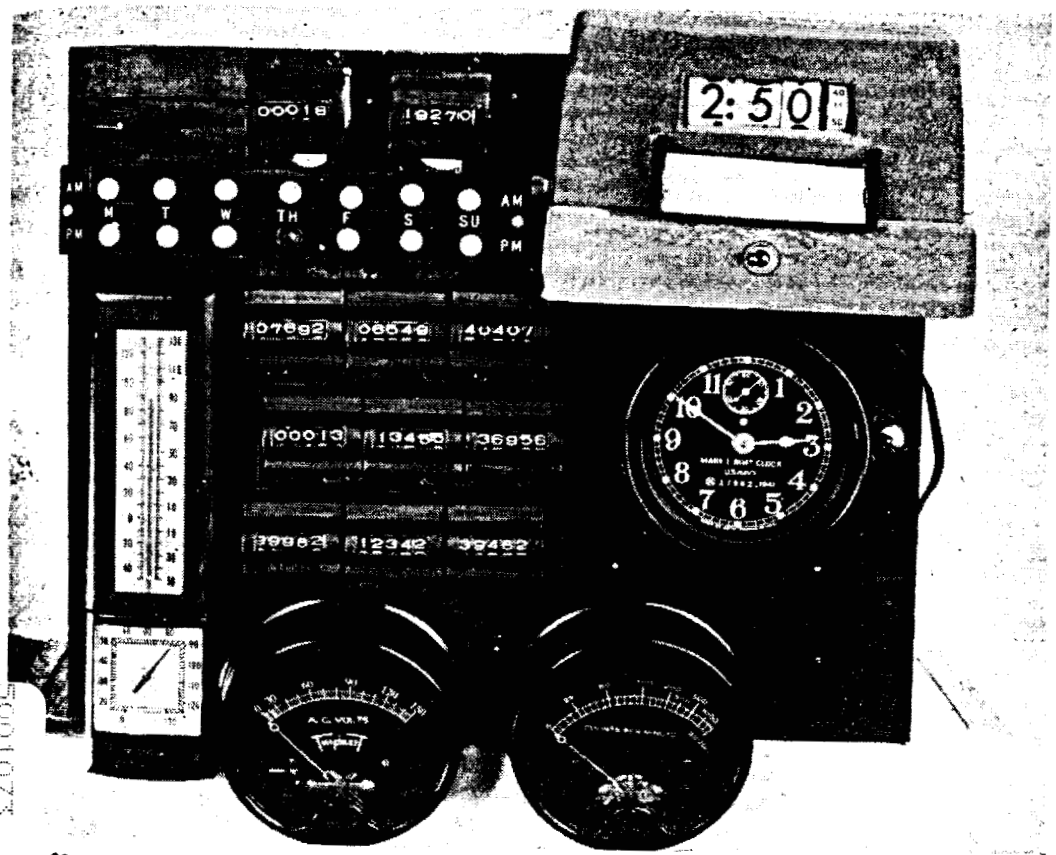


Constant tests of the outside air are standard operating procedure on and near atomic energy reservations. The upper view shows an air monitoring station at Oak Ridge. The lower is the assembly of registers actuated by radiation counters located in each of the 16 Brookhaven monitoring stations. The panel is automatically photographed each 6 minutes on a film strip that is collected and developed weekly. Any difference between the electric and the mechanical clocks indicates an interruption of the power supply and helps to correct the readings accordingly.



ground level and reactor stack level, and determining how conditions vary between plots only a few hundred feet apart on the ground.

Brookhaven has a weather tower similar to that at Hanford. Reactor meteorologists undertake to find out at all times what is happening to the invisible cloud of air coming out of the stack—how high it is above the ground and how fast it is rising or falling, the direction and speed it is moving, and the rate at which it is being diluted in the atmosphere. The meteorologists' estimates of resulting radioactivity will be checked with actual radiation measurements from a network of monitoring stations so as to give prompt warning when the reactor should be shut down. Meteorological observations and forecasts at Brookhaven have been under way about 2 years and reports are exchanged daily with the reactor operators to establish the routine.

The U. S. Weather Bureau has detailed a liaison officer to observe and to cooperate in research connected with the Brookhaven project.

Monitoring the Air

Sixteen radiation monitoring stations have also been in operation for some time at Brookhaven to make continuous records of radiation levels in the air for some miles around. Six stations are on the laboratory site, four are arranged in the cardinal compass directions between 2 and 4 miles from the reactor stack, and the other six form an outer ring between 6 and 9 miles out. There is also a mobile station that can be moved to any location which develops special interest.

Geiger tubes and ionization chambers on the roof of each station actuate equipment inside the building. All meters and radiation indicating registers are brought together on a central panel and, in some stations, meteorological meters are included. Each station also has a dust sampler for radioactive materials.

In the station, a battery of lights comes on every 6 minutes and an automatic motion picture camera photographs the instrument panel, providing a continuous radiation record. Additional instruments run from storage batteries maintain a continuous record even during a power failure. Each station requires a visit only once a week to check and service the apparatus.

This routine radiation monitoring program has collected enough measurements to determine the intensity of natural background radiation in the neighborhood. When the reactor goes in operation, it will check on meteorological observations, as described above, to provide one more planned safeguard for Brookhaven's neighbors.

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VI

CONTROL OF HAZARDS AT WEAPONS TESTS

The explosion of atomic weapons in testing operations releases large amounts of all types of ionizing radiation. For the task force conducting the tests, hazards occur at two different times:

a) During the explosion. In the test explosion of six weapons on three different occasions (including the first test at Alamogordo, New Mexico), there has never been an injury or overexposure.

b) In research and examination after the explosion. There has been a single isolated accident, which occurred when AEC contractor personnel suffered burns to their hands from handling beta-contaminated material.

Weapons tests are conducted by a joint task force composed of AEC staff and the three armed services. Much of the civilian crew is drawn from the Los Alamos Scientific Laboratory. Exclusive responsibility for radiological safety during a test rests in the commander of the task force conducting the test. Potential hazards vary with the way in which the weapons are tested. Of the two fired at Bikini (Operation Crossroads), one was an air burst of a bomb dropped from an airplane and one was detonated under water. The three fired at the AEC testing ground (Operation Sandstone), whose headquarters are on Eniwetok atoll in the western Pacific, were tower explosions as was the first at Alamogordo. This report on control of radiation hazards in weapons tests is drawn from the record on Operation Sandstone as typical of satisfactory organization and method of operation for radiological safety.

Operating limits for radiation exposure as fixed for the weapons tests paralleled those in use in the atomic energy program in 1948: one-tenth of one roentgen a day. In special cases, exposure might be allowed up to 3 roentgens in one day, provided the exposure was approved by the top radiological officers and that the person so exposed was then allowed no further radiation exposure for 30 days. No exposure in excess of this amount was allowed except at the express permission of the task force commander. The maximum single exposure of 3 roentgens is considered harmless.

In one case, remote control apparatus arranged to recover samples

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from near the tower on which the weapon was exploded failed to operate. Since it was important, in order to make radiation effect measurements, to recover the samples quickly, an emergency exposure was allowed. Men working in relays recovered the samples in a jeep. A radiological monitor went with each team and warned when the operating limit was being approached. Exposures did not exceed the authorized limit. No evidence of biological injury was demonstrated in any case as a result of whole-body exposure to gamma radiation.

Radiological Safety Group

As in protection against all potential radiation hazards, prime dependence was placed upon thorough planning, organization, training, and discipline. A Radiological Safety Group, code-named RadSafe, was established to advise the commander on radiation problems, to furnish monitors, assure adequate supplies of properly working detection instruments and other equipment, to determine tolerance levels throughout operations, supervise decontamination procedures when necessary, prepare operational plans, to keep records of exposures of personnel and to conduct certain assigned surveys.

The preparations of RadSafe began months before Operation Sandstone with selection of a hand-picked group of officers and technicians. They prepared the program of the group, selected and assembled equipment including nearly 1,000 detection instruments costing more than $100,000, some 10,000 radiation film badges and smaller numbers of dosimeters. Before leaving the United States, every person expected to enter contaminated areas received a complete physical examination including chest X-ray, blood count, and urinalysis, and the records of these examinations were turned over to the radiological safety group.

Regulations required that a radiological safety monitor accompany each survey party that landed after the explosion of weapons, be present in each pilot-operated plane, on each ship, at air bases, and at troop installations. Nine subgroups were organized including an air monitor unit, staff unit, operations unit, laboratory unit, radiological records unit, technical measurements unit, test site monitor unit, advisory unit, and rear echelon unit.

When the task force assembled, RadSafe launched immediately into training programs. Daily classes were held,[1] covering all phases

[1] Lectures to RadSafe group during the trip to Eniwetok included: First week, general nature of operations, phenomenology of weapons explosions, task force organization, radiological safety plan, instrumentation, types of instruments, calibration of instruments, travel of radioactive clouds, evacuation and reentry of test area, operations, air operations, instructions to monitors, security; second week, instruction on operations, scientific operations, electronics, including electricity, vacuum tubes and details of survey instruments, communications, medical aspects, measuring beta activity, gamma radiation, protective devices, gas masks and hoods, and safety precautions.

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of the operation. Each instrument was calibrated at least five times during the trip, using radium sources standardized by the National Bureau of Standards. A card system was set up to keep a detailed record of all radiation exposures, day by day, so that the status of any individual could be quickly determined at any time. A daily operation schedule was planned for the employment of the monitor as required in each test. For the use of unit commanders, a series of instructions was prepared on matters pertaining to radiological safety.

Controls Established in Advance

The RadSafe group set up a system to prevent the spread of contamination by parties returning from the island. Decontamination units were established on the radiological safety ship and at each installation where personnel came in contact with radioactive material. Every individual who had worked with such material was processed through these stations. Equipment, film badges, dosimeters, and monitor reports were turned in there, and contaminated clothing was segregated.

Special detection instruments were installed on ship and ashore to monitor the "fallout" of air-borne radioactive material following the tests. Detailed plans were made for evacuating the area if fallout became too severe, but it did not become necessary to use them.

Monitors were assigned to planes to keep check on exposures throughout flights after the weapon explosion. If exposure threatened to exceed a rate that would produce one-tenth of one roentgen a day, the monitor's responsibility was to warn the pilot to turn toward a safer area. These planes and crews, and the drone planes (remotely controlled by radio) were monitored at outlying air strips and, if necessary, decontaminated before being allowed to return to base.

Each radiological safety party was designated by a code number and schedules drawn to indicate time of movement, specific mission, names of monitors, and type of transportation used. Each group maintained radio communication with RadSafe headquarters.

A full-dress rehearsal was held for the weapons test, including evacuation, withdrawal of ships, and re-entry into the assumed contaminated area. Monitors assigned to the various scientific parties familiarized themselves with the expected problems that would arise in each operation. They inspected all stations or installations involved in their missions and briefed the personnel assigned.

Precautions during the explosion itself consisted primarily of removing all personnel from the test island and nearby islands and stationing all ships at least 10 miles away. The downwind area was

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carefully charted and all ships were prohibited from entering this zone in which fallout might occur.

Certain personnel were provided with dark glasses for protection of the eyes against the initial flash of light at the time of detonation. This was necessary to prevent the temporary blindness which occurs if the naked eyes are exposed to any intense light source. The rehearsal disclosed that this would prevent airplane pilots from reading their instruments during a few important seconds. During the explosion itself, therefore, pilots were permitted to have small clear slits in their dark glasses. Everyone not equipped with dark glasses was ordered to turn his back several seconds before the explosion.

Monitoring operations by planes and small boats started immediately after the explosion. Radioed reports of radioactivity in the water were recorded on a chart which permitted the drawing of key lines indicating levels of radioactive intensities. All land areas where inspection parties were bound were monitored by RadSafe crews before any unit landed.

Other RadSafe men monitored the entire island and posted radiation level signs in each part of its area so that work teams knew how to plan their duties in each area without exceeding the allowable exposure. Areas which had excessive radioactivity were outlined and marked by warning signs. Resurveys were made at intervals to measure the decay of radioactivity.

Monitors took posts at each landing point to brief landing parties as to exposures that could be expected at various places, and to make sure they had all proper equipment. Equipment included film badges, dosimeters, and special clothing as required. Gas masks were worn only in the initial survey of the crater after the first of the series of tests. If a unit monitor warned his group that operating limits had been reached, the group withdrew, turned over film badges and dosimeters to the monitor and disposed of shoe covers and gloves before debarking. Thorough washing of hands was required before eating, drinking or smoking in a contaminated area.

Immediately after each of the three weapons tests, remote control tanks controlled by helicopters were sent into the bomb crater to gather a sample of earth for analysis. On each occasion, one tank bogged down in the soft soil and another was sent in to do the job. After 5 days, radioactivity in the soil had declined so greatly that work teams were able to recover the stalled tank without exposing themselves beyond Operation Sandstone's exposure limit.

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VII

THE AEC PROGRAM FOR RADIATION CONTROL

The present program of radiation control in the Nation's atomic energy enterprise began with a small group of radiological experts in the early days of the Metallurgical Laboratory at the University of Chicago in 1942. At that time, it included 10 men. In 1950, the radiation control program affects nearly every aspect of work at all atomic energy plants and laboratories and, besides direct control operations which now employ about 800, includes (*a*) broad schedules of research on radiation effects and control, and on detection instruments, (*b*) a variety of training courses and fellowships, and (*c*) considerable assistance and participation by other Government agencies.

Much of this work, and the devices, techniques, and knowledge developed through radiation protection operations, contributes directly toward fulfilling the Commission's responsibility to assist the National Security Resources Board in its planning for civil defense. This contribution, the programs which assist radiation work, the history of radiation control in the atomic energy program, and the way in which the present program is administered are reported in this chapter.

HEALTH PHYSICS HISTORY

The development of health physics as a separate profession started at the University of Chicago during construction of the first nuclear reactor. There, the small group of radiologists and radiological physicists undertook to determine, and to solve, some of the basic problems of protecting workers and the public from the new and powerful sources of radiation that would be created. The work of these early specialists established the tradition of radiation safety that the atomic energy program has maintained ever since.

Early History

Over the half century between the discovery of natural radioactivity and X-rays, and the inception of the atomic energy program, radiation took a severe toll of life and health. In the first year, 1896,

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several scientists injured themselves with radiation. By 1914, when X-rays and radium were already extensively used in medicine and in industry, the dangers of radiation were known to scientists, but they were not generally understood except among professional radiologists.

In the 1920s, although radiation burns were common and scientists had died from the deeper-seated effects of radiation exposure, the toll continued to increase. People who drank radium-bearing waters, marketed as a cure-all, suffered anemia, bone diseases, and death. Painters of illuminated watch and instrument dials, pointing their brushes with their lips, swallowed minute quantities of radioactive materials and afterward died.

From 1921–22 on, scientific societies in Great Britain and the United States published radiation protection measures, which they constantly revised in the light of new experience. In this country, the National Committee on Radiation Protection was formed in 1928 under the sponsorship of the National Bureau of Standards. By 1942, when the U. S. atomic energy project took form, there were internationally accepted limits of exposure for gamma and X-ray radiation and for quantities of radium deposited in the body. But even at that time, the record of safety in industries, hospitals, laboratories, and doctors' offices where radiation was used was by no means consistent. Doctors and technicians accepted a certain amount of radiation injury as a hazard of their profession. Scientists and technicians in laboratories generally applied their own protection standards.

Wartime Beginning at Metallurgical Laboratory

The founders of the health physics program in the atomic energy project at Chicago realized that they would have to establish entirely new standards of radiation hazard control if the nuclear chain reaction became a reality and a national atomic energy enterprise was undertaken. Types of radiation and radioactive materials that previously had been known only in the scientific laboratory—or like plutonium never known at all—would have to be handled on an industrial scale. Some of the problems and protection procedures could be worked out in advance; others necessarily depended on increasing experience.

Protection at the first nuclear reactor under the West Stands of Stagg Field on the University of Chicago campus could be relatively minor—its power level was low. Planning for future operations, for piles thousands of times more powerful, for workers much less familiar with radiation hazards and their control, would be a bigger job.

The 10 health physicists at Chicago were kept busy establishing the maximum exposures to various kinds of radiation that workers might

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tolerate without harm; developing new instruments to detect radiation or adapting old ones; checking designs for shielding; constructing remote control equipment; studying procedures for handling industrial amounts of radioactive materials; and making essential radiation measurements.

At Chicago, instruments to measure the amount of radiation a person received were made available to all those who would be subject to radiation exposure, but their use was not compulsory. People wore dosimeters somewhat on a voluntary basis; and each scientist made whatever area survey measurements he considered necessary.

Health Physics at Oak Ridge

In the summer of 1943, five of the Chicago health physicists transferred to the Manhattan Engineer District's new Clinton Laboratories at Oak Ridge, where a more powerful nuclear reactor was being built. It began operation on November 4, 1943, and during the next few days the small health physics group worked night and day surveying the sides of the reactor, making an inch-by-inch survey to check radiation leaks.

Because the health physics group was small, and in line with the practices at the University of Chicago, precautions were left largely to individual scientists, and it was not at first considered necessary for the health physicists to make routine surveys in various working areas. Several accidental overexposures, detected before they could cause injury, caused a revision in these early procedures.

On one occasion, a worker pulled from the reactor some copper wire on which she had fastened samples for irradiation, and carried this highly radioactive wire in her bare hands toward the counter room. Her overexposure was short and did not result in injury, but longer exposure could have been serious.

On another occasion, some scientists on an inspection tour entered a restricted area at the west side of the reactor. At that time, a large experimental opening in the reactor was shielded by a metal tank normally filled with water to absorb the radiations, but without a conspicuous indicator to show whether or not the tank was filled. On this occasion the tank was empty while the reactor was operating at a low level. The scientists walked unknowingly into the beam of radiation.

When health physicists that night read the scientists' pocket meters and film badges, they discovered that during the few seconds the visitors were in the reactor beam they had received a gamma ray and neutron exposure of about 20 roentgens. It was good fortune that they did not spend several minutes in the path of the beam and receive an injurious exposure.

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Tightening of precautions. Procedures were immediately revised. Additional personnel began making routine surveys of all working areas and monitoring all operations closely. Barricades were erected to prevent people from entering zones of high-level radiation. Supervisors did not permit jobs to start until a survey indicated what precautions should be taken. Everyone working in radiation areas was required to wear monitoring meters, which were read after each shift. Any significant exposure was investigated.

Through classes of instruction, all laboratory personnel were taught to observe certain general principles and to follow radiation protection rules. Health physicists were made available for consultation on radiation problems. The surveyors spent most of their time reading meters that indicated radiation fields in various areas; measuring surface contamination of desks, floors, and equipment; and making frequent samplings of the air.

Another task of health physicists was to check possible contamination which the workers themselves might have picked up. Extreme precautions were taken to avoid the spread of contamination—into the air where it might be inhaled, or to cigarettes, water, and food from which it might be taken into the body. Many chemical operations had to be performed differently because of the radiation hazard, behind lead shields and with the use of remote-control equipment. Under the new system, the health physics surveyor was always at hand to oversee precautions against radiation damage.

This work, and that of keeping a continuous check of the levels of radioactivity of the air and water in a neighborhood, started in 1943 at Oak Ridge. A research group was set up to study the properties and effects of radiations. Better and more reliable instruments were developed. A training program was instituted for the engineers—about 35 in all—who were to initiate the health physics program at the Hanford works. About September 1944, a reactor at Hanford, Washington, began operation and many people transferred there—and carried with them the lessons learned at Oak Ridge.

HEALTH PHYSICS UNDER AEC

Health physics problems today extend far beyond the limits of Atomic Energy Commission operations. Radioisotopes are being used in many laboratories throughout the world. The Commission's health physicists supply information on handling radioactive materials, on using equipment to measure the radiation exposure, on monitoring safe levels of exposure, and on training health physicists.

One of the first acts of the Commission, after taking charge in January 1947, was to appoint a Medical Board of Review to survey the

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program. Upon the Board's recommendation, the Commission established a Division of Biology and Medicine to conduct a Nation-wide program of research and to administer radiation protection, and appointed a permanent Advisory Committee on Biology and Medicine.

Health Physics Administration

Responsibility for the AEC health physics program is assigned to the Division of Biology and Medicine in Washington, but practically all health physics work is carried out by contractor employees in the Commission's plants and laboratories.

The Division of Biology and Medicine, through the Biophysics Branch, keeps closely informed of all major operating problems in radiation protection; maintains close liaison with the National Committee on Radiation Protection which recommends the permissible levels of radiation exposure; coordinates the development of new research knowledge and its transmittal among the operating contractors; and advises the operating divisions and Managers of Operations Offices on radiation protection problems.

In carrying out its responsibilities, the Division of Biology and Medicine works closely with the Divisions of Research, Production, Reactor Development, and Military Application which administer the program operations involving radioactive materials. In addition, for certain phases of environmental protection, responsibility rests with the sanitary engineering and chemical engineering groups in the Division of Reactor Development.

All major AEC contracts, administered through its Operations Offices (Oak Ridge, Hanford, Chicago, Santa Fe, New York, Idaho, Schenectady, and Raw Materials, Washington, D. C.) carry clauses that require the contractor to take adequate precautions for the health of his employees. The Operations Offices have the direct responsibility for seeing that the terms of the contracts are carried out.

Range of Health Physics Interests

The scope of the Commission's responsibilities in health physics is indicated by the following range of activities assigned to Biology and Medicine's Biophysics Branch:

Permissible limits for external radiation. The setting of permissible levels of exposure, and research projects to determine: (*a*) limits for whole-body radiation, particularly gamma rays and neutrons; (*b*) limits of individual organs (including reproductive mechanisms) for gamma rays and neutrons; (*c*) limits of external organs (skin and eyes) for all radiation.

Permissible limits for internal emitters. Determining pathological and genetic effects of radiations from the various isotopes; concentration of isotopes in

the various organs of the body; permissible concentrations of radioactive isotopes in food, air, water, and the general environment. This activity includes research projects.

Instrumentation and procedures for limiting human exposures. Devised through: (*a*) instrument development research for measuring all kinds of radiations from all sources and in various carriers (see Chapter VIII); (*b*) methods for monitoring personnel exposures, site and building contaminations, and waste effluents; (*c*) studies to determine how the physical and biological environment of AEC activity centers affect the dispersal and reconcentration of wastes in that region, and to assure the adequacy of radioactive waste handling systems; (*d*) instrument stockpile for emergency and civilian defense.

Waste handling techniques. Devised through specific research.

Research contracts. University and research institute contracts administered to stimulate fundamental research in biophysics.

Training and education activities. Support of the research and service functions through post-doctoral research fellowships and pre-doctoral fellowships in biophysics; graduate fellowships in radiological physics; individually designed lecture courses to inform interested groups of the health-protection activities.

Health Physics Organizations

These broad responsibilities and activities are carried out through the Commission's contractor-operated laboratories and production plants—the Health Physics Division at Oak Ridge National Laboratory, the Radiological Physics Division at Argonne National Laboratory, the Health Instrument Divisions at Hanford, and the Radiologic Safety Group at Los Alamos Scientific Laboratory, for example. In one case, the health physics staff is combined with the medical staff; in all instances, medical and health physics staffs maintain close liaison. Other functions require close cooperation between health physics and scientific, engineering, and construction personnel.

No two health physics organizations in AEC installations are exactly alike. Each has developed to meet the special problems at its own installation; each is the particular contractor's instrument for fulfilling his responsibility of safeguarding his employees and the people who reside in the area.

Health Physics Personnel

At present the health physics activities in the various AEC laboratories and installations employ over 300 professionally trained persons. Most of the senior personnel are physicists; others are chemists, engineers, meteorologists, laboratory assistants and technicians. The health physics surveyors are college graduates in physics or engineering with theoretical and applied training in health physics.

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The numbers of health physics personnel at various installations vary with the size of the installation and the extent of the radiation hazards. The accompanying table shows the distribution of health physics employees. Of the 828 employee total (as of February 20, 1950) 333 are professionally trained. The remaining 495 include a wide variety of technicians and supporting staff. Only 20 of the total personnel in the health physics program are direct AEC employees.

Office	*Professional (includes monitors)*	*Others*	*Total*
New York Operations Office	23	21	44
Oak Ridge Operations Office	96	159	255
Hanford Operations Office	100	153	253
Santa Fe Operations Office	27	86	113
Chicago Operations Office	47	67	114
Schenectady Operations Office	38	8	46
Washington, D. C., Headquarters	2	1	3
Totals	333	495	828

Types of Radiation Protection Work

Other chapters of this report have indicated the wide range of techniques and devices used to confine and control radiation sources. Health physicists and engineers assist in, or are responsible for, six major categories of this work:[1]

Radiation protection design. Advice and consultation in the design of plants, processing facilities, experimental set-ups, and special equipment so that workers are automatically protected from radiation by shielding and distance from sources of radiation.

The research program in connection with protection at reactor and production plants owes much to the advice and assistance of the Reactor Safeguard Committee (Chapter V). New projects may well arise from the recommendations of the advisory committees on chemical processing plants and on the engineering and planning of the Reactor Testing Station in Idaho. Some of the contractors involved are: Allis Chalmers Company; Associated Universities, Inc., operators of Brookhaven National Laboratory; Fairchild Engine and Airplane Corp.; General Electric Company, operating contractors at Hanford and the Knolls Atomic Power Laboratory at Schenectady, N. Y.; Hydrocarbon Research, Inc., New York; Massachusetts Institute of Technology; North American Aviation Company; Nuclear Development Associates; Powder Weld Process Company; Naval

[1] A comprehensive report on research in radiation effects was made in the AEC's Sixth Semiannual Report, July 1949.

Radiological Defense Laboratory, San Francisco; Union Carbide and Carbon Corp., operating contractor at Oak Ridge; Westinghouse Electric Corp.; University of Chicago, contract operator of Argonne National Laboratory; University of California, Berkeley, contract operator of Los Alamos Scientific Laboratory and of the Radiation Laboratory at Berkeley.

The safe design of laboratory equipment—such as hot cells, caves, and remote control devices—are vitally necessary at Argonne, Brookhaven, Oak Ridge, and Los Alamos, and all have well-developed programs for providing it (see Chapter IV). Some of the contractors who have assisted are: Associated Universities, Inc.; Corning Glass Works, New York; General Electric Company; Kellex Corp.; Massachusetts Institute of Technology; Monsanto Chemical Company; Union Carbide and Carbon Corp.; University of California, Berkeley; University of Chicago.

Specification of protective clothing and procedures. Setting up regulations for the use of protective clothing and masks, prohibiting practices that could cause personnel contamination, such as pipetting radioactive solutions by mouth, smoking in certain areas, and wearing contaminated clothing beyond entrances to "clean" areas, establishing rules for frequent washing of hands with certain soaps and solutions (see Chapters II, III, IV).

Personnel monitoring. Requiring workers in areas where radiation exposure is possible to wear film badges and pocket meters; specifying use of portable and stationary radiation instruments to measure any contamination on hands, feet, and other parts of the body; reading, interpreting, and recording the exposures of all persons, and carrying out corrective measures as necessary; periodic sampling of body fluids and wastes to check on internal radiation exposure.

Radiation survey of areas, surfaces, spaces, atmosphere, and liquid discharges from all operations. Conducting regular surveys with portable detection instruments; maintaining and reading regularly stationary instruments in operating areas of plants, in waste discharge lines, in strategic locations for environmental monitoring.

Radiation detection instruments. Procuring, maintaining, and supervising the use of all types of instruments for detecting and measuring radiations; conducting research and development work on new instruments; keeping all instruments calibrated against standard sources so that readings will be valid. The various operating units of the Commission, although they have taken the lead in developing new and better instruments and have provided designs, prototypes, and ideas, have been assisted by commercial instrument makers in the development of this equipment (see Appendix 8).

Training in health physics principles and procedures. Training health physics workers; conducting orientation programs for all employees on the nature and effects of radiation and on safe practices in controlling radiation exposure; assisting in the training of off-project users of radioactive materials and of persons interested in civil defense organizations.

HEALTH PHYSICS TRAINING

The Atomic Energy Commission sponsors and finances three general types of training courses in health physics. Men and women are trained through (*a*) on-the-job courses, (*b*) university courses at predoctoral and postdoctoral levels, and (*c*) courses for users of radioisotopes in industry, laboratories, and hospitals (see Chapter III). In addition, the AEC sponsors a number of courses, like those in support of the civil defense program, and those for members of the armed services, which contribute to the maintenance of radiological safety.

AEC In-Service Training

The Hanford Health Instrument Divisions conduct in-service training programs, as described below, and similar courses are given at Oak Ridge and at Los Alamos. For the first Hanford course, which began in January 1947, senior health physicists compiled a series of lectures [2] to serve as a training manual for surveyors for Hanford's many plants. Besides the lectures, this formal 3-month course included assigned reading, a laboratory course in fundamental radiation measurements and orientation, observations in calibration of radiation detection instruments, survey methods in laboratories and operating buildings, and the use of survey instruments.

Lectures and subsequent panel discussions provide the basic information needed by young college graduates entering this new field. Practical application and extension of this knowledge is provided through field tours and laboratory experiments on such subjects as counter tests, absorption of beta and gamma radiation in shielding materials, effect of distance on measurements, and measurement of decay of natural radioactivity.

After this formal training, the trainees work with experienced radiation surveyors in production areas and laboratories. Under this guidance, they become familiar with processes, servicing require-

[2] Typical lecture subjects were: "Fundamental Concepts of Nuclear Physics," "Properties of the Elementary Particles," "Ionization in Gases," "G. M. (Geiger-Mueller) Counters and Other Particle Detectors," "Radioactivity," "Effects of Radiation on the Body," "Radiation Dosimetry," "Tolerance Doses," and "Protection Methods."

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ments, and hazard control practices and can gradually assume greater responsibility in the protection program. This process takes approximately one year.

About 60 young graduates have participated in this program and an additional 30 to 40 people from other lines of work at Hanford attended varying portions of the program.

University Training Programs

In 1947, the AEC project at the University of Rochester, Rochester, N. Y., obtained approval to conduct an educational program dealing with the biophysical, pharmacological, toxicological, biological, and medical aspects of atomic energy. The University integrated the courses with other undergraduate and graduate programs. Additional instruction was offered, leading to a mastery of certain individual research or health protection techniques.

With this program established, the Commission set up, through the National Research Council, a fellowship program for giving college graduates with scientific backgrounds the necessary training to enable them to function efficiently in the tasks of radiological physics and radiation protection. The fellows underwent the investigation and security clearance necessary for employees of the AEC and its contractors, since they would have to work with classified material and in restricted projects. The first such group was trained during the academic year 1948–49: eight students at the University of Rochester with 2 months of field training at Brookhaven National Laboratory, and nine at the Oak Ridge National Laboratory, which had enlarged and revamped its own training program.

A second year's group, selected for their background in physics and mathematics or in engineering, is now being trained—10 at the University of Rochester and 12 at the Oak Ridge National Laboratory. Three others of this group, because of their superior qualifications, were offered an opportunity to take broader training in radiation biophysics, and as a consequence, two are studying at the University of Minnesota and one at California Institute of Technology.

As an extension of this idea, the Advisory Committee for Biology and Medicine recommended in September 1949, that the AEC establish approximately 20 fellowships for predoctoral training in biophysics. When the National Research Council of the National Academy of Sciences, which formerly administered all AEC fellowships, withdrew from the AEC predoctoral fellowship program, this phase of advanced health physics training was affected adversely. Administration of a national program of graduate fellowships in radio-

5001085

logical physics was then undertaken by the Oak Ridge Institute of Nuclear Studies, and arrangements were made with Vanderbilt University (Nashville, Tenn.) for its participation in the Oak Ridge part of the program. Graduate credit is offered for course work at two training centers (Rochester–Brookhaven, and Oak Ridge–Vanderbilt), and provision is made for selected fellows to take master's degrees on an extension of the fellowships.

The work at Rochester–Brookhaven and Oak Ridge–Vanderbilt is essentially the same, and consists of:

Modern physics. A general survey of the field of atomic physics, study of nuclei and nuclear processes, nuclear transformations, fission, methods of producing high energy particles, and counting techniques.

Radiation biology. Essentially a survey of the effects of ionizing radiations on living things and on the constituents of body fluids and cells.

Radiation measurements. Radiation instrumentation and monitoring, including fundamental electronics; measurement of alpha, beta and gamma radiation; air sampling and analysis techniques—a program designed to prepare the student for practical problems of radiation hazards in the laboratory and environment including general problems of soil and water contamination.

Industrial hygiene and toxicology. Basic principles of toxicology, specific materials constituting industrial hazards, characterization of toxic atmospheres, and the biological application of statistical methods.

Research. Selected problems assigned to qualified students.

Approximately 200 applications were made for 40 available fellowships, and the caliber of the applicants was exceptionally good. Fellows were selected by representatives from the University of Rochester, Vanderbilt University, ORNL, ORINS, and AEC, for training at the center of their choice during the academic year 1950–51.

Contributory Training

Other training which contributes indirectly to the maintenance of radiological safety is provided by the following AEC-sponsored courses:

Medical. For doctors after internship and residency, 6-month courses in the physical and medical aspects of radiation are given at four AEC regional training centers: Duke University, Rice Institute, University of Colorado, and Reed College. Approximately 50 AEC postdoctoral fellows and 50 armed forces medical officers have received this training.

Military medical. Officers of the above group obtain further training in 12 weeks of additional study at ORNL on isotope handling, area and personnel monitoring, instrument calibration, waste disposal and general field training. and selected biological subjects.

Military engineers and scientists. Groups of 20 to 25 officers from the Armed Services and U. S. Public Health Service are given 6 to 8 weeks of training at

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Oak Ridge National Laboratory during the summer in field training, monitoring, and general health physics techniques. This is a part of a 3-year course for training Radiological Defense Engineers, which is given at the Naval Academy Postgraduate School and at selected civilian universities, under the sponsorship of the Armed Forces Special Weapons Project.

Civilian defense. For medical men and teachers who will in turn train others in certain aspects of radiation protection.

General. Biophysics and radiology courses in the country's universities, although not pointed specifically toward radiation protection, provide students with the basic training of potential senior health physicists.

CONTRIBUTIONS TO CIVIL DEFENSE

The research work that promotes the health physics program, and some of the operating experience as well, contribute to the Nation's program of preparation for civil defense in a possible atomic war. The Commission's activities in civil defense were described in the Seventh Semiannual Report to the Congress. Additional information was presented to the Joint Committee on Atomic Energy in February and March 1950. The AEC's major responsibility lies in providing the National Security Resources Board, and other appropriate agencies and the public, with technical data concerning the biological effects of radiation and the effects of the atomic weapons. AEC also assists in such matters as development and procurement of radiation detection instruments, the organization of interim emergency radiation monitoring teams, and the training of people who will instruct others on atomic energy aspects of civil defense work.

Technical Information.

Reports issued under the Commission's technical information program include more than 400 concerning the effects of radiation and the treatment of harmful effects. Of special reports, "The Effects of Atomic Weapons," prepared under the direction of the Los Alamos Scientific Laboratory with the cooperation and assistance of other groups under the AEC and of the Department of Defense, is to be issued in August of this year; a bibliography and three interim reports [3] were prepared by the Department of Defense and the Commission during the last 6 months and transmitted to the National Security Resources Board; the report on handling of radioactive wastes already referred to will be useful, as will the declassified Handbook of Aerosols, issued in May 1950, which contains information

[3] "Medical Aspects of Atomic Weapons" and "Damage From Atomic Explosion and Design of Protective Structures," each available from Superintendent of Documents, Washington 25, D. C., 10 cents; and "Radiation Detection Instruments," unpublished.

5001070

needed by engineers and others charged with preventing atmospheric contamination by radioactivity (Superintendent of Documents, Washington 25, D. C., price 60 cents).

Instruments

Projects for the development of radiation detection instruments for civil defense are reported in Chapter VIII. The plan is to build up stockpiles of instruments that can be used in emergencies by persons who do not have expert knowledge.

Emergency Monitoring Teams

Pending establishment of civil defense organizations with definite assigned functions for radiological defense, the Commission, after consultation with the Department of Defense, acted in 1949 to establish

The captain of an emergency monitoring team at Hanford displays the contents of an emergency monitoring kit. From left, the main items are a white coat, an ionization chamber instrument (the "Juno"), radiation danger signs, white gloves and head covering, two pocket dosimeters, a film badge, a portable Geiger counter, rubber gloves, road maps, flashlight, shoe covers, and, just being taken from the aluminum case, an assault mask.

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emergency radiation monitoring teams in about 20 locations throughout the United States. Each team is to consist of about 12 men experienced in radiation detection work at atomic energy installations or at AEC contracting universities and institutions. They will be trained and drilled so that, if needed, they could make use of stockpiles of radiation detection instruments, either in case of a major accident at an atomic energy installation or in case of an emergency resulting from an attack with atomic weapons. At some places, the project is well under way (see photograph, p. 135). Teams are being established under five AEC Operations Offices as follows:

New York Operations Office. New York City; Brookhaven National Laboratory Upton, Long Island, N. Y.; Schenectady, N. Y.; Boston, Mass.; New Brunswick, N. J.

Oak Ridge Operations Office. Oak Ridge, Tenn.; Dayton, Ohio; Washington, D. C.

Chicago Operations Office. Argonne National Laboratory, Chicago, Ill.; Pittsburgh, Pa.; Ames, Iowa; Berkeley, Calif.

Santa Fe Operations Office. Los Alamos, N. Mex.; Albuquerque, N. Mex.

Hanford Operations Office. Richland, Wash.; Seattle, Wash.; Pullman, Wash.; Portland, Oreg.

Training

All training programs that support the Commission's health physics operations assist preparations for civil defense. Workers trained in radiation monitoring and similar activities could, if the need arose, form nuclei for regional organizations. In consultation with the National Security Resources Board, the AEC is conducting two series of training courses to provide teachers for local defense workers in radiological monitoring and in treating radiation injury.

Radiological training courses began in March and April at Brookhaven National Laboratory, at the Atomic Energy Project of the University of California, and at Oak Ridge National Laboratory, with a total of 48 participants. Beginning early in the summer, similar courses will be given at Reed College in Portland, Oreg., and at the Illinois Institute of Technology, Chicago, Ill.

During March, April, and May, one-week courses for medical personnel in various medical aspects of atomic warfare were held at seven locations, with a total of 144 participants: University of Rochester Atomic Energy Project, Johns Hopkins University School of Medicine, Argonne National Laboratory, Western Reserve University School of Medicine, University of Utah School of Medicine, University of California at Los Angeles Atomic Energy Project, and University of Alabama.

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ASSISTANCE FROM OTHER AGENCIES

The Commission's program of radiation safety is assisted by the advice, support, and active participation of a large number of Federal and State agencies. The Department of Defense has provided valuable help in many phases of the program; various branches of the Army have conducted research connected with instrument development and the treatment of radioactive wastes; the Office of Naval Research has been of invaluable assistance in administration of many projects in the research program. The National Bureau of Standards assists in numerous research and development projects and sponsors the National Committee on Radiation Protection. The U.S. Weather Bureau has conducted meteorological surveys at all major installations and also provided current weather data as a guide for operations at Hanford and elsewhere. Studies conducted by the U. S. Geological Survey have been helpful in safe handling of radioactive wastes at Hanford, Oak Ridge, Los Alamos, and elsewhere.

The U.S. Public Health Service has provided assistance in environmental protection around atomic energy installations. The U.S. Bureau of Mines has done research and development on the incineration of combustible radioactive wastes. The National Research Council has contributed invaluable advice and administrative service both in the fellowship program and in the survey of bomb effects in Japan. Scores of agencies of the various State governments where atomic energy installations are located have cooperated wholeheartedly in the work.

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VIII

DETECTION INSTRUMENTS FOR RADIATION PROTECTION

Since the human senses cannot detect nuclear radiations, the development and production of devices to detect the presence of radiations and to measure their intensity is an important element of radiation protection in the national atomic energy program. In the earliest work on X-rays, their effect on photographic films was the first means of detecting them. Progressively since then, instruments to detect and measure radiations have been developed in pace with new discoveries and wider use of radioactive materials.

During the war, radiation detection instruments for the Manhattan Engineer District were, for the most part, manufactured by laboratories on the project. For security reasons, only five industrial concerns had wartime contracts to make instruments. Looking towards peacetime operation, the Manhattan District in June 1946 established the Instrument Production Section of the Oak Ridge Research Division to help develop industrial production of instruments under contract with the Government. Procedures were set up with the Navy's Bureau of Ships to consolidate Navy and Manhattan District requirements. Additional arrangements were made by the Atomic Energy Commission to increase coordination with other Governmental agencies that require radiation detection instruments.

During the last half of 1946, approximately $325,000 in contracts were negotiated with private industry. Production of instruments gradually shifted to industry, the total procurement from various manufacturers during 1947 totalling approximately 1.5 million dollars. During fiscal 1948, more than 2.1 million dollars in instrument production contracts were negotiated and in 1949 this increased to 3 million dollars.

Beginning in 1948, the AEC prepared performance requirements for the various classes of radiation detection instruments as a guide to industries entering the field. By 1950, nearly 80 commercial firms were manufacturing radiation instruments and components (see Appendix 8). In July 1948, the centralized procurement system was discontinued, and each installation began contracting directly for manufacture of its instruments. The AEC shifted emphasis from straight procurement to developing sources for the relatively few

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types of instruments that were not available commercially, and to improving and extending the utility of the standard types. Small research and development contracts were given to industry, and consultants were chosen from the AEC and prime contractor organizations to provide technical guidance. As new instrument designs appeared on the market, samples were purchased and made available for appraisal throughout the AEC.

In October 1947, the Radiation Instruments Branch published the first issue of "Ra-Det," a restricted monthly periodical designed to assist exchange of information on radiation detection among the AEC installations and other Governmental agencies doing related work. In May 1949, a "Radiation Instruments Catalog," listing commercially available radiation instruments, was distributed throughout the AEC and made available to the general public through the Document Sales Agency in Oak Ridge. Two supplements have since been issued. A "Bibliography on Radiation Detection" was also published in July 1949 and is available for public purchase at Oak Ridge.

Beginning in 1948, nine conferences on selected fields of radiation detection instrumentation were held for technical personnel from the various AEC installations and from the military services. In addition, two conferences under the Technical Cooperation Program were sponsored for interchange of instrument information among key personnel from the United States, Canada, and Great Britain.

TODAY'S INSTRUMENTS

A wide variety of detection instruments is now available. The most important types and techniques of use are listed and briefly reported in the following paragraphs.

Photographic Methods

The principles of ordinary photography may be used to detect nuclear radiations. When exposed to radiation, the emulsion of a photographic film reacts in the same way as when struck by visible light. When the film is developed, the latent image is converted into a black, visible deposit of metallic silver, and the amount of radiation can be estimated from the degree of darkening of the film.

Properly used, films will detect any type of ionizing radiation. They are frequently used to measure gamma ray exposure, especially in personnel badge meters for permanent exposure records. Such radiation meters usually contain several dental-sized X-ray films in a thin-walled container which keeps out visible light (see photograph on p. 39).

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Scintillation Counters

When certain materials are struck by radiations they emit light. A familiar example is the screen used in making fluoroscopic (X-ray) examinations in medicine; another is the television screen. The visible light from the screen in these cases is made up of millions of tiny light flashes, or scintillations. This principle is widely used in the radiation detection instruments called *scintillation counters*, which employ a photomultiplier tube. In these devices, the tiny light flashes resulting from impact of radiations on a fluorescent material may be invisible to the naked eye. But when the light strikes a coated metal surface in the photomultiplier tube, electrons are dislodged. These electrons in turn strike another surface which gives off more electrons for each electron that hits it. By using from 9 to 16 of these metal surfaces in succession, the number of electrons released by each initial scintillation can be multiplied a million to a billion times. The electrical output of this so-called photomultiplier tube is sufficient to register in an electronic instrument.

Scintillation detection instruments are highly efficient and count very rapidly, so that they may be used for measuring intensely radioactive sources of gamma rays and beta particles. Scintillation counters also have been designed for detection of extremely low levels of alpha particles—of the order of one count every few minutes. Such counters are of particular value in environmental monitoring near plants processing uranium, plutonium, or other alpha-emitting materials. Scintillation counters are also being developed for neutron detection.

Ionization Chambers

Ionization chamber instruments to detect radiations are based on the principle of ionization in gases, that is, the formation of ion pairs as a charged particle passes near atoms in a gas. When an electrically charged nuclear particle, such as an alpha or beta particle or a proton, passes through a substance, it will occasionally come close enough to an atom to *ionize* it, hence the term *ionizing radiation.* In this process, one of the atom's electrons (which are negatively charged and moving in orbits about the nucleus) is separated as a negative ion from the rest of the atom. The atom, with one negative electron removed, is left with a net positive charge, and is called a positive ion. (The radiations that are electrically neutral—X-rays, gamma rays, and neutrons—react with matter and produce ionizing particles which can be detected in the same manner as alpha and beta particles.)

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Formation of ion pairs is the mechanism by which radiation damages living cells and tissues. This same process provides a means by which radiation can be detected and measured.

A simple design of ionization chamber is indicated in the accompanying diagram. There are two electrodes, one the outer chamber shell, the other a central rod. The electrodes are insulated from each other and given opposite electrical charges.

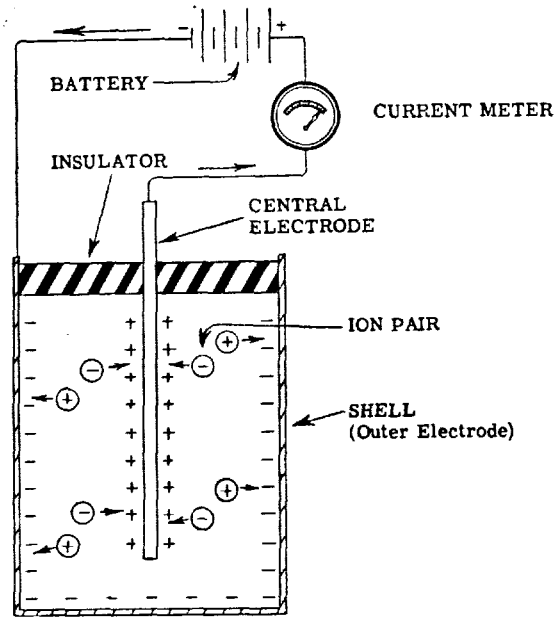

Diagram of ionization chamber registering flow of ionization current.

When ion pairs are formed by radiation passing through the gas in the chamber, the negative ions are attracted to the positive pole and the positive ions are attracted to the negative pole. This causes current to flow in the battery circuit and to register on a current meter, the rate of flow varying with the amount of ionization produced by radiations entering the chamber. The meter can be scaled to read directly in terms of the amount of radiation.

Ionization chambers respond directly to alpha particles, beta rays, and proton beams, since these electrically charged radiations ionize the gas inside the chamber. Gamma rays can also be detected because they react with the molecules in the chamber walls or in the chamber gas, causing secondary emission of electrons which produce ions that can be measured. And, with appropriate modifications, ionization chambers can detect either slow or fast neutrons.

The pocket dosimeter represents a group of personnel meters that are essentially modified electroscopes (see photograph, p. 32). In these, the ionization chamber electrodes are given a static charge, and the battery is then disconnected. A metal-coated quartz fiber at-

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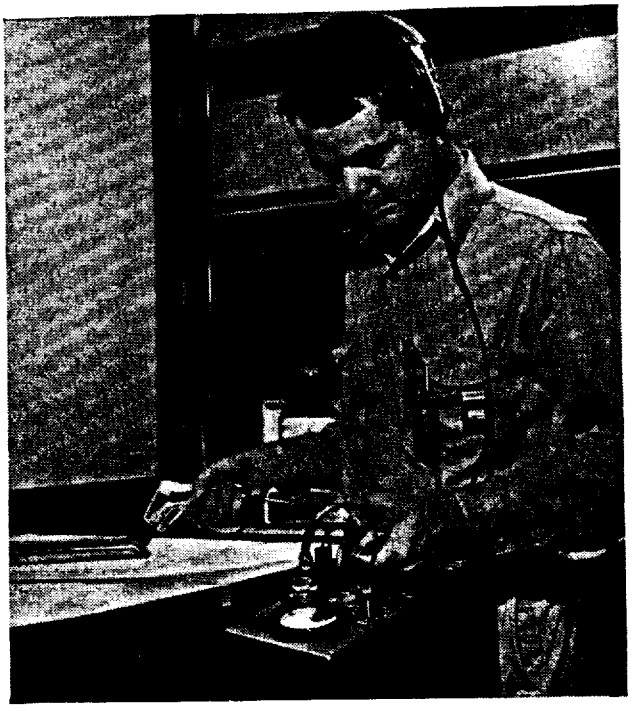
tached to an electrode will have the same charge as the electrode. Because like charges repel each other, the fiber will stand out away from the electrode a certain distance that depends on the stiffness of the fiber and the strength of the static electric charge. As ionizing radiations produce ion pairs in the chamber, the static charge is gradually lowered and the fiber collapses toward the electrode. The change in the position of the fiber indicates the total radiation that has entered the chamber from the time it was fully charged.

The pocket dosimeter has small microscope lenses for viewing the position of the fiber along a scale that is calibrated in terms of the amount of radiation the instrument has received.

Some ionization chamber instruments can distinguish one type of radiation from others on the basis of a difference in penetrating powers. This is done by means of filters which screen out all radiation below a given level of penetrating power.



Health physics surveyor at Oak Ridge National Laboratory using an air proportional counter (the "Pee-Wee") to detect and measure possible radioactive contamination on a laboratory table. Earphones and a dial on the instrument register the amplified ionization surges. The surveyor wears a rectangular film badge and two pocket dosimeters in addition to his identification badge.

Proportional Counting Chambers

The ordinary ionization chamber has a weak electrical field between the electrodes. This field may be made stronger, however, so that the negative ions (electrons) produced by radiation are attracted strongly toward the positive electrodes. The negative ions are thus accelerated more rapidly and gain enough energy to ionize additional molecules in passing. Furthermore, these secondary ions may also produce more ions, and so on. If an ion produced in an instrument by the primary radiation gives rise to 999 others, the amplification factor of the chamber is said to be 1000. Amplification factors nor-

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mally vary from 100 to 100,000. Over a wide range of amplifications, the pulse size is proportional to the energy of the original particle; hence the name—*proportional counters.*

Proportional counters are useful for counting alpha particles, particularly because they can distinguish alpha particles from betas and can count alphas in the presence of beta or gamma radiation. Some proportional counters have large windows for admitting radiation into the chamber with several parallel wires for electrodes. These are handy for measuring low-penetration alpha contamination on hands and clothing, in dust collected on filter paper, or on laboratory tables and other surfaces (see photograph, opposite).

Geiger Counters

When the amplification factor of an ionization chamber is increased beyond a certain point by increasing the electrical field between the electrodes, ion multiplication spreads so rapidly through the chamber that complete discharge takes place almost instantaneously. An ionization chamber used in this way is called a *Geiger counter.* In this instrument, the size of the electrical pulse registered is no longer proportional to the number of electrons which initiate it. A single beta particle can trigger the discharge.

Geiger counters, therefore, may be arranged to count any radiation that produces at least one ion pair inside the sensitive volume of the chamber, or tube as it is generally called. After each count the counter tube is immediately recharged by a high voltage supply connected to the electrodes.

Beta rays which penetrate the walls of the tube will be counted with nearly 100 percent efficiency. However, the efficiency of this instrument for registering gamma and X-rays is low, usually less than one percent; the reason for this is that the tube will count only those gamma and X-rays that cause ionizing electrons to be emitted by atoms in the tube.

Geiger counter pulses are essentially constant in size so that there is no method of discriminating between pulses induced by gamma rays and those caused by neutrons. For this reason, proportional counters are better detectors of neutrons.

Since Geiger counters are lightweight, portable, and quite sensitive, they are highly useful for survey work (see photograph, p. 135).

Calorimetric Detectors

When radiation reacts with a substance containing chlorine, carbon tetrachloride and water or chloroform and water, for example, hydro-

chloric acid is formed. This in turn will cause a color change in certain dyes; and the amount of color change depends on the amount of radiation received. Such colorimetric detectors are largely in the experimental stage, but eventually the principle may be used to design a low-cost, simple dosimeter for personnel monitoring.

Specialized Instruments for Medical Use

Small-volume ionization chambers inserted into body cavities have been used to measure internal X-ray dosages. These instruments are similar in principle to the pocket chambers described above.

A recent development in scintillation counting techniques at the Atomic Energy Project, University of California at Los Angeles, has provided a valuable tool for internal dosage measurements. One such instrument, *the tissue radiation fluorimeter*, uses a small internally light-reflecting "light pipe" inserted through a hypodermic needle. A small amount of fluorescent material is mounted in the tip. The scintillations or light flashes caused by alpha, beta, gamma, or X-rays are piped through the needle and counted in the usual way with a photomultiplier tube.

Photographic emulsions can be used to determine the distribution of radioactivity in tissue. In this technique, called radioautography, the film is placed in direct contact with a section of the tissue being studied. Although the film does not compare in sensitivity to other types of detection methods, this limitation can be partially overcome by extending the exposure time.

HOW INSTRUMENTS ARE USED

To Protect the Individual Worker

The amount of radiation to which an atomic energy worker is exposed may be accurately measured at various points in his working area, but this alone will not show how much radiation he has received in moving about within the area. Each worker usually carries pocket meters or dosimeters and a film badge on his person to measure the total radiation exposure he receives.

Photographic film badges are made with a wide variety of film emulsions. Each emulsion has a fairly limited range; for example, a common type covers a range from 0.02 to 3.0 roentgens. By combining several commercially available emulsions, this range of measurement may be extended, if desired, to several hundred roentgens.

For personnel monitoring, the film comes in a small dental-sized paper packet usually containing two films to get a wider range in sensi-

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tivity. These packets are inserted in a film holder or badge, which may also serve as a picture identification badge (see photograph, p. 39). Wrist and finger holders are also used for film badges. The badges have open windows over one portion of the packet to permit the passage of softer radiations and neutrons, and a second portion is covered by thin plates of cadmium to measure hard gamma radiation.

Emulsions with known exposures, used as standards, and unexposed blank emulsions are processed for control purposes at the same time as meter emulsions. After development and drying, the densities of the standard, control, and meter films are read on a densitometer. The density is a measure of the radiation exposure. Film badges are read weekly as a rule.

In addition to the film badge, each worker usually has two gamma *ionization chamber instruments* having a full-scale sensitivity of four times daily permissible exposure; these are read daily. Near nuclear reactors or other neutron sources, a modified pocket chamber sensitive to neutrons is worn.

The *quartz fiber electroscope* dosimeter resembles the pocket ionization chamber in appearance and the manner in which it is worn and charged. Unlike the film badge and pocket chamber, the electroscope may be read directly without the use of auxiliary equipment. Thus, a worker in a "hot" area may periodically check to make sure that the maximum permissible level has not been exceeded.

The quartz fiber dosimeters generally available at present are more delicate than the pocket chambers, so that their self-reading advantage is partially offset by decreased reliability and greater cost. However, a new quartz fiber electrometer developed at Argonne National Laboratory helps to overcome these difficulties (see p. 150).

In many operations or experiments, there is a predictable possibility that the worker's permitted daily radiation exposure will be exceeded in less than an eight-hour working period. In such cases a pocket radiation alarm—a buzzer connected to a small electrometer—is worn so that as soon as the maximum permitted exposure has been received an alarm will sound and the exposed worker will be relieved by another.

To Prevent Radioactive Contamination of Personnel

Where radioactive contaminants may be present in atomic energy laboratories and plants, protective garments, gloves, and shoe covers are worn, and monitors with survey instruments make routine checks for contamination.

Proportional counters are used to detect and measure alpha-emitting contamination on the hands of atomic workers. With proper

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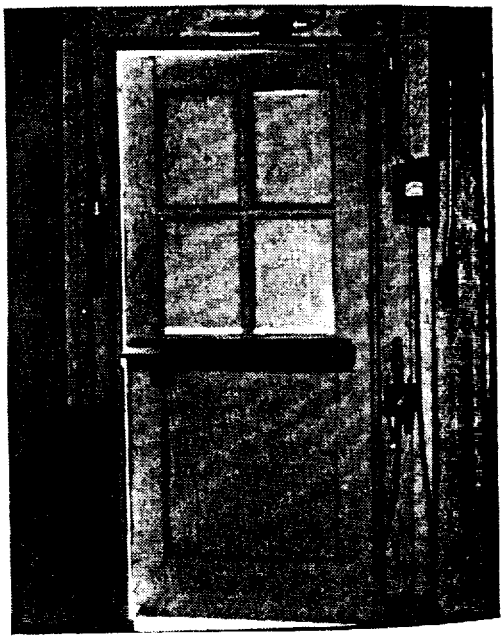
The worker at left is using a hand and foot proportional counter to check for possible radioactive contamination. The surveyor at right is using a Geiger counter probe to detect any contamination on the clothing of the worker in the center.

adjustment these instruments will detect alpha particles in the presence of beta and gamma radiation. The hands are inserted into pockets in the front of the instrument panel. Proportional counters, located on either side of each pocket, count the alpha radiation. The total count over a given interval is compared to a standard count at the maximum permissible level. Proportional counters are also used to count alpha activity on the shoes (see photograph, above). Beta



Series of Geiger counter tubes ("Octopus" or "Frisker") around doorway at Oak Ridge National Laboratory. Radioactive contamination on persons passing through doorway registers on the scale at right; above a certain level of contamination, an alarm would sound.

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and gamma contamination is also monitored with similar hand and foot counters which use banks of two to four Geiger tubes.

Clothing which may be contaminated is checked with portable equipment in which the detecting element is attached to a flexible cable. In laundries for contaminated clothing, Geiger counter tubes placed beneath metal mesh on a flat table detect beta and gamma emitters, and flat proportional counters with large surface areas are used to detect alpha contamination (see photograph, p. 51).

Geiger counter tubes hooked up to alarms are frequently mounted around laboratory doorways, to detect and give warning of radiation contamination on persons passing through (see photograph, opposite).

To Detect Radioactivity in the Body

In testing urine samples to check on ingestion of alpha-emitting materials by people, very stable instruments are required to separate the extremely low alpha counts from background radioactivity. A pulse ionization chamber, called a parallel plate alpha counter, is often used. In this instrument the evaporated sample is placed between two electrode surfaces which have different potentials. The pulses produced by the alpha particles from the sample are coupled directly to the grid of an amplifier tube. These pulses are amplified about 100,000 times before being fed into the recording circuit. Background counting rates of these instruments have been reduced to as low as a few counts an hour.

Proportional and scintillation counters with equally low background counting rates have been recently developed and are also used for counting urine samples.

To Control Radiation in Working Areas

To determine the amount of air contamination in laboratory and plant areas, air samples are taken by means of a collecting device such as a filter, electrical precipitator, or air impactor.

Filter collectors are particularly useful in finding alpha emitters. A measured volume of air is drawn through a special filter paper by means of a vacuum pump. The radioactivity on the paper represents the dust-borne activity in this volume of air. The maximum permissible level for all alpha emitters is generally set at two disintegrations per minute per cubic foot of air.

Occasionally the type of alpha emitter present in the air is not known. In such cases the sample is placed in a pulse height analyzer which sorts out the alpha pulses by amount, or height of energy which each possesses. By obtaining a pulse height distribution for a sample,

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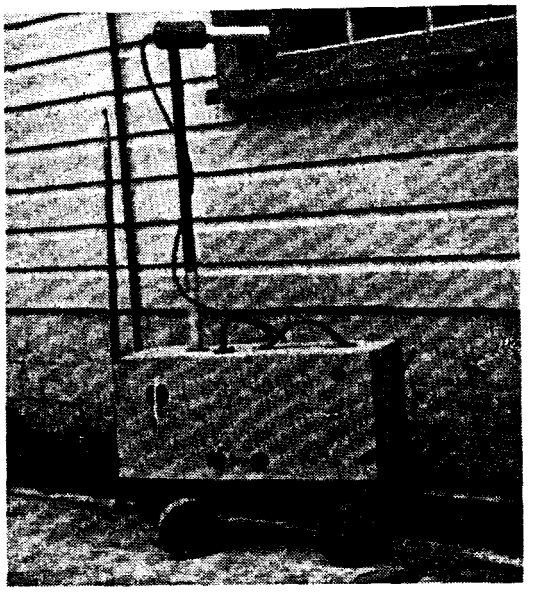
it may be possible to identify the radioactive atoms producing the activity, since the energy of the alpha particles varies according to the kind of atom that emits them.

When an electrostatic precipitator (see photograph, below) is used to collect radioactive dust samples, air drawn through the collector head passes a bare wire with a negative potential of about 11,000 volts.



Electrostatic precipitator in use at Oak Ridge National Laboratory to measure air-borne radioactive contamination around a building.

Charged dust particles collect on a removable aluminum foil within the wall of the tube. The collection efficiency of this instrument is about 99 percent with slow air flow.

The toxic effects of some radioactive materials depend upon the size of the inhaled particles. Particle size may be measured with a device called a cascade *particle impactor*. Air passes through a series of jets of decreasing size, and as the jets become smaller the air speed increases. At each stage of the device the air stream is forced to turn sharply. The momentum of a particle prevents it from making the turn, and particles collect on suitably placed surfaces. Larger particles fall out during the first stage and smaller particles at each succeeding stage. A filter paper at the last stage collects the residues. The collecting surfaces are usually glass microscope slides.

INSTRUMENT CALIBRATION AND MAINTENANCE

Maintenance, servicing, and calibration of radiation detection instruments at a major atomic energy project is a large undertaking. At the Hanford Works, for example, more than 800 portable survey instruments, close to 500 stationary instruments, and approximately 20,000 personnel meters are in use. The personnel meters are of several types, including pocket ionization chambers to measure gamma

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ray exposure, film badges and finger rings for gamma and beta exposures, and boron-coated pocket chambers for detecting neutrons. Almost two million pocket meter readings and one-half million badge readings are made annually.

Each of the various instruments is calibrated, that is, tested for accuracy and adjusted, 5 to 15 times a year on a regular schedule. In all, Hanford makes about 15,000 calibrations yearly on instruments and about 100,000 on personnel meters. In calibrating an instrument, a complete test is made of the instrument's response over its entire range.

Each installation has a special shop for calibration work, so designed that only the carefully controlled standard reference source of radiation can affect the instruments. At Oak Ridge National Laboratory, where a new calibration building is being constructed, the radiation source (cobalt 60) for calibration will be placed in a deep concrete well covered by a sheet of lead. Automatic arrangements will be provided for raising the source to various levels in the well. The amount of radiation reaching various locations above and around the well can be measured for all levels of the source within the well. Thus to calibrate an instrument, it will be placed near the well and the source raised in the well to a level that will provide an exactly known amount of radiation at the instrument. If the instrument fails to register this amount, it is adjusted until it reads correctly. By adjusting the amount of radiation, the instrument can be tested at any point on its scale.

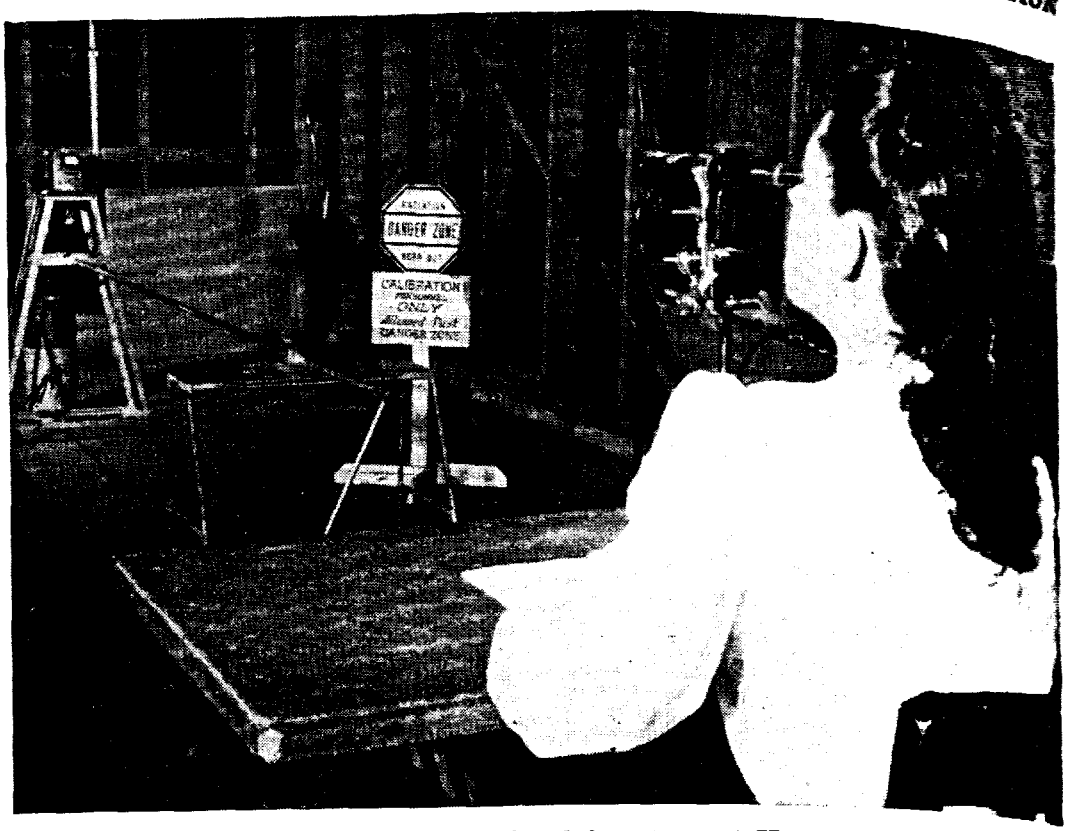
For calibration of survey ionization chambers a radium source may also be used. By placing the source at various distances from the chamber, desired intensities of gamma radiation may be obtained.

At Hanford, instruments are normally calibrated at regular intervals in a special laboratory (see photograph, p. 150). In the field when survey instruments are regularly used, a less thorough test or standardization is performed on each instrument daily. In this test the response of the instrument at selected points on its scale is compared with the known output of weak radiation sources.

Slow neutron meters are calibrated by means of a neutron source surrounded by graphite or paraffin. This device enables the operator to select neutron beams of desired intensity for use as standards.

PRESENT TRENDS IN RADIATION DETECTORS

The emphasis today in instrument development and design is upon improving and standardizing the various types of instruments. Instruments are being designed to withstand rougher treatment, to be less affected by temperature and moisture, and to be as maintenance-



A portion of the instrument calibration laboratory at Hanford (still under construction when photograph was taken). At the far left the instrument ("Cutie-pie") on the stand is being checked for accuracy by exposure to a radioactive source in the heavy cylinder back of the stand. The source can be raised and lowered in the cylinder by remote control. The worker at the right records the readings on the instrument which she reads by means of a telescope.

free as possible. More sensitive instruments are being designed which can be more easily operated, requiring less training for the operating personnel. More stable circuits requiring fewer controls are under development.

Virtually every atomic energy installation has an instrument laboratory. In each, research and development of improved instruments for the special purposes at that laboratory are stressed. Where basic discoveries are made, the information is promptly passed on to the other laboratories.

An example of special significance for personnel monitoring is the quartz fiber electrometer being developed at the Argonne National Laboratory. This instrument has a very simple design and high sensitivity, yet it is rugged and stable in construction so that it will remain accurately calibrated almost indefinitely. Compared with the quartz fiber meters incorporated in older pocket dosimeters, this meter is nearly 50 times more sensitive. One alpha particle passing through and ionizing the gas around the fiber produces a deflection of several divisions on the scale. It is believed that this electrometer will also

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have many uses in chemical assay work, and in laboratory measurements generally.

A new instrument to protect persons who work near neutron sources has been developed recently at Oak Ridge National Laboratory. The reading registered by this instrument when exposed to neutrons depends upon both the neutron intensity (number per unit time) and the energies of the neutrons in such a way that it indicates directly the tissue damage that the neutron exposure would cause.

An improved air ionization chamber alpha survey meter has recently been developed at the gaseous diffusion plant in Oak Ridge. This instrument has more than five times the sensitivity of the older types and is exceptionally rugged and stable in operation. The increased sensitivity and stability result from a unique direct current amplifier, which is being adapted to other AEC uses.

Development of Geiger tube instruments is under way to increase the sensitivity of the tube, to make it less fragile, and give it longer life.

Proportional counter development work centers around the design of a more compact, lightweight power supply. The heavy batteries needed to supply the approximately 2,000 volts for operating the counter may weigh several times as much as the rest of the instrument. Designers also hope to reduce the adverse effect of humidity on the proportional counter; new insulators are being tested and guard ring structures and drying agents are being employed.

Special Techniques and Applications

One serious problem in making proportional counters and ionization chambers for alpha detection is to make a window thin enough to admit the alphas and yet strong enough to withstand the minor shocks of ordinary usage. Such thin films can be made from rubber hydrochloride, which is commercially available. Also, very thin films of nylon can be obtained by placing a drop of a nylon solution on the surface of very clean water. The solution spreads rapidly to a very thin layer, which can be lifted off, with care, as an ultra-thin film. Used as a window, this film admits alpha particles with very little loss of energy. In many cases, the thin windows must be made electrically conducting; for this purpose, an improved technique of applying a microscopically thin metal coating is being used.

Advances have been made in molding plastics and in the techniques of polishing and engraving the molds for plastic parts of instruments. For special engraving needs, a diamond point was ground and polished to extreme sharpness at the Argonne National Laboratory. With it, ruled lines only 2.5 ten-thousandths of an inch wide at the

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base and with very smooth sides can be engraved in plastic molds. By this method, meter scales can be formed directly, in one molding operation, on the surface of plastic lenses used in direct-reading electrometers. The lenses with scales can therefore be produced rapidly and at a fraction of their previous cost, resulting in a considerable saving in both materials and time of assembly.

Instrumentation Developments for Civil Defense

Instrument specialists at several of the major laboratories and plants in the atomic energy program were asked in the fall and winter of 1949 to take part in developing radiological safety-type instruments for civil defense use. As a result six instrument projects in this field have been started:

a) The Instruments Branch of the Health and Safety Division, New York Operations Office, is developing a simple high-range Geiger counter survey meter, using inexpensive components and a special Geiger counter capable of measuring up to 100 roentgens per hour of gamma radiation. Two prototypes of this instrument were completed on March 1, 1950, and 20 commercial-type units will be delivered soon. It is hoped that this instrument may be produced in quantity for less than $15.

b) The Instrument Development Division, Argonne National Laboratory, is undertaking to develop quartz fiber-type dose rate meters. A reliable and inexpensive model of this instrument should be completed before 1951, and an essentially finished instrument should be ready by January 1952.

c) The Instrument Group, Physics Division, Oak Ridge National Laboratory, has developed a simple ionization chamber type dose rate meter. This instrument has the general shape and size of a package of cigarettes and will be production engineered by a capable industrial concern, and testing quantities will be produced. Delivery under this contract is expected by January 1951.

d) The Atomic Energy Project, University of California at Los Angeles, is continuing its development of a colorimetric dosimeter, which consists of a number of capsules containing liquids that change color at predetermined total radiation exposures. Many models of this dosimeter have been completed, and studies are under way to determine its shelf life and the stability of the chemical solutions under various conditions.

e) The Atomic Energy Project, Rochester University, is developing a chemical dosimeter depending on the change of electrical con-

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ductivity resulting from exposure to gamma radiation. As this project is still in its preliminary phases, no target dates have as yet been established.

f) The Instrumentation and Health Physics Department, Brookhaven National Laboratory, has been developing a portable scintillation counter which should operate successfully in high-intensity gamma fields where other instruments may tend to fail. Prototype models are expected to be completed early in 1951.

Thirty-eight industrial concerns were approached recently to obtain ideas on the development of simple, inexpensive radiation detection instruments which might be used in civil defense organizations by relatively untrained individuals. As a result of these contacts, 27 proposals have been received from 15 companies. These proposals are being reviewed and contracts may soon be initiated on several of them.

In addition to these AEC and industrial projects, the Commission is sponsoring a research program at the Naval Radiological Defense Laboratory, Hunter's Point, California, on the problem of detection instruments for civil defense, and also the further industrial development of an electrostatic dosimeter invented by a scientist at the California Institute of Technology, Pasadena.

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IX

THE COSTS OF RADIATION PROTECTION

Providing adequate protection against radiation hazards is a considerable factor in both capital investment and operating expenses of the atomic energy program.

Since radiation must be dealt with, elaborate studies to determine how much more cheaply the program could operate without radiation would not yield enough practical cost-control data to justify the substantial expense of attempting them. To determine reliably what part of the cost of a nuclear reactor is chargeable to radiation safety would be as impossible and as useless as determining what part of the cost of a furnace is chargeable to the fact that a furnace produces intense heat, and so cannot be made of cheaper materials such as wood.

Some elements of the costs due to radiation protection, however, are clear without extensive studies. Health physics expenses, for example, are incurred almost wholly in the interest of radiological safety, and health physics budgets in various installations run between three and four percent of operating budgets. Oak Ridge National Laboratory, a representative atomic energy center, is spending $407,000 a year on health physics service operations. For a laboratory staff of 2,000 persons, this works out to $204 per person per year—compared with $17 per worker for nonradiological safety service, $88 for fire protection, and $60 for medical service. Oak Ridge estimates that it costs, on an average, $106 a year to equip a laboratory worker with protective clothing and personal radiation meters, not including laundry or reading the meters and keeping individual exposure records.

A SAMPLE CASE STUDY

The foregoing figures represent only a small part of the costs involved in radiation protection. Other data are available that roughly indicate the magnitude of the total costs. Engineers have made a number of cost estimates in connection with AEC's construction program. For purposes of this report, they have (*a*) selected an estimate for one type of plant that processes large quantities of highly radioactive material and (*b*) prepared a preliminary estimate for a substitute plant to perform the same processes on the same amount and

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kinds of material, but assuming that the material would not be radioactive in this second plant.

In the following tables and discussion, Case I is a plant to operate with radioactive materials; Case II is the nonradioactive substitute. The difference between the Case I and Case II totals represents the full cost of radiation protection in the kind of operation covered by the study. The actual figures are not given here but the ratios between estimates for the two types of plants have been maintained.[1]

Comparative Construction Costs

Where a plant could be built for one million dollars to perform certain processes on nonradioactive material (Case II), the cost would go over 12 million dollars to deal with the same amount of material identical in every respect except that it is radiocative (Case I). Thus, the capital investment in the Case I plant is 1,100 percent greater than

must be controlled from a distance and that, once the plant is started, there are areas that a maintenance crew could never enter safely.

Such a plant requires special pumps and valves, special connectors for all utility lines, and special process equipment, all of it precisely made and custom-designed to permit remote control, repair, and maintenance. Complete reliability of operation, and longevity far beyond that required in other industries, are essential. Costly instruments are necessary to control operations and unique tools must be built to make repairs and replacements. Some facilities could not be serviced without dismantling the whole structure, with the result that multiple sets of such facilities are built in.

Other capital cost disparities. Like process equipment, *utility lines* must be built into the plant structure. Unusually heavy and trouble-free utility lines are required and, since remote parts of the system cannot be reached by repair crews, stand-by duplicate sets of facilities are included.

Since the Case I plant would have to cope with radioactive dusts and vapors, it requires elaborate *artificial ventilation*, an unusually large flow of fresh air at all times plus thorough filtering of all ventilating air before it is discharged outdoors. In contrast, the Case II plant, being almost entirely outdoors, would require only minor provision for artificial ventilation. This difference accounts for the fact that the ventilation system for Case I would cost 88 times as much as ventilation for Case II.

The cost of facilities for *storing process materials* is higher in Case I because, in addition to the normal process materials, large amounts of other materials are used in converting radioactive waste into nonhazardous or less hazardous forms. The disparity becomes even greater in the costs of facilities to *handle wastes*, for the radioactive plant requires expensive storage tanks and waste-processing equipment that Case II does not. In this respect the radioactive plant is 16 times as costly as the nonradioactive substitute.

Comparative Operating Expenses

It appears from this study that, counting all operating expenses, it is 177 percent more costly to perform certain routine processing operations with radioactive material than with nonradioactive material. Or, by a different calculation applied to the final figures in the following table of comparative operating expenses, 64 percent of the total cost of operations in the radioactive plant—nearly two-thirds—is incurred solely because it is necessary to provide radiation protection.

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The following table gives the detailed differences in annual operating expenses:

	Case I	*Case II*
Direct labor	$87,000	$69,000
Process materials	158,000	129,000
Supervision	26,000	24,000
Maintenance labor	46,000	36,000
Maintenance materials	19,000	9,000
Analytical control services	76,000	38,000
Steam and water	116,000	116,000
Electrical and instrument	34,000	27,000
Transportation	21,000	20,000
Process research and development	6,000	6,000
Health physics service	77,000	0
Laundry service	12,000	3,000
Plant security	91,000	91,000
Miscellaneous expense (fire protection, janitor service, office and shop supplies, etc.)	81,000	79,000
"Out of pocket" expenses	850,000	647,000
Depreciation	1,217,000	100,000
Total annual operating expenses	$2,067,000	$747,000

Disparities in Direct Operating Costs

Only 3.7 percent of the total operating expenses is charged directly to radiation protection in Case I—that is, the *health physics* account. In various other items, however, the radioactive plant incurs heavier expenses than the plant without this problem.

Treatment and safe handling of *radioactive waste* is much more costly than conventional industrial waste procedure.

Remote control and maintenance would be unnecessary in Case II, so that such a plant would require fewer operators and supervisors. With the radiation hazard, maintenance operations require cumbersome procedures preceded by careful plans, tests, and dress rehearsals that often consume several times as much labor as the actual service job on the "hot" equipment.

Higher Cost of Depreciation

As far as "out of pocket" expenses are concerned, the Case I plant is only 31 percent more costly than the Case II plant. In operation, however, an original capital investment is progressively dissipated in wear and tear and obsolescence, so that no statement of operating expenses is complete without a charge for depreciation.

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In this study the composite rate of depreciation is assumed to be 10 percent a year. When the charge for depreciation is included, the extreme disparity between the original construction cost in Case I and Case II exerts its due weight in the final total of comparative operating expenses.[2]

ADDED COST OF RESEARCH

The foregoing estimates deal with a situation in which radiation protection costs may be either more or less severe than the unknown average. The facilities and operations of the program are much too varied to support sweeping inferences from any one case. In contrast with major facilities that cost millions of dollars, for example, a small tracer-scale laboratory can be equipped for as little as $3,000.

In a research laboratory, the payroll is a more significant element than the investment in buildings and equipment in total costs, but in research, too, the costs of radiation make up a large fraction of total costs.

Several senior staff members at Argonne National Laboratory have made a collective judgment on how much longer it takes to perform a representative research procedure inside a "hot cave" than on radiologically "cold" materials. Items considered were the special handling required for radioactive specimens, the extra time for getting the job set up inside the cave, and the "dry run" to test the operating plan for safety (see Chapter IV). Assuming that the cave is equipped with the best available remote control manipulators and large, clear

[2] Actually, it will take some time to establish reasonably reliable rates of depreciation for an industry so young and novel as atomic energy. Moreover, the concerted pursuit of more efficient methods in this industry may cause existing plants to be replaced by newer processes with more than average frequency. Omitting this unpredictable element of extraordinary obsolescence, however, the 10 percent rate represents a reasonable engineering and accounting judgment for the Case I type of plant at the time of this report.

Applying the 10 percent rate in Case I, it is believed that a much lower rate of depreciation—perhaps 5 or 6 percent—would properly apply to Case II, the nonradioactive substitute. The radioactive plant would frequently find it necessary, for example, to scrap contaminated equipment which could be repaired and returned to service in a nonradioactive industry. Moreover, the Case I plant would be subject to greater normal obsolescence than the Case II plant. This is so because the processes to handle radioactive material must be largely "built in" the plant so intimately that such a plant would be especially hard to modernize as improved processes became available. The Case II substitute plant would be much more flexible in this respect.

If depreciation of 5 or 6 percent were assumed for the Case II plant, the extra cost of radiation protection in Case I would loom up even larger. To be conservative, however, the Case II plant in this study is charged the same 10 percent rate of Case I.

It is understood, of course, that there is a degree of overlap between the final figures on construction cost and on operating expense. That is, having spent $12,170,000 to build the radioactive plant, the out-of-pocket expenses of the plant would thereafter be not $2,067,000 a year but $850,000 a year. To state the true cost of operations in the customary manner of industrial financial reporting, however, it is necessary to divide the original investment by the number of years in the estimated useful life of the plant, and to include the result of this division as an annual expense item.

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windows, they estimate that radioactive work takes at least five times as many man-hours as identical operations performed on nonradioactive materials outside the cave.

According to this estimate, a scientist or technician working under the stated circumstances is able to apply only 20 percent of his time and manual efficiency to getting ahead with his experiment, and 80 percent of his salary is properly chargeable to the presence of radiation. (This ratio would vary, of course, from operation to operation. Moreover, the ratio for a whole research center would be lower than that for "hot cave" operators because it would include personnel who work with radioactive materials only intermittently or not at all.)

The Argonne group also considered the situation when a number of samples are already laid out in the cave—after the "dry run" and other preliminaries have been completed. In this situation, they estimate that the actual manipulations take at least three times as long as "cold" operations on nonradioactive material.

Costs of "Hot Caves"

This degree of efficiency in work behind shields was achieved only through substantial investments to reduce the cumbersomeness and awkwardness of remote-controlled research. The Argonne metallurgy cave and remote-controlled equipment pictured on page 86 represent an outlay of $40,000. The noncoloring glass window on the front of this cave, measuring 54 by 24 inches and 3 feet thick, cost $8,000. Glass manufacturers currently charge $2 a pound for cerium-stabilized, noncoloring glass.

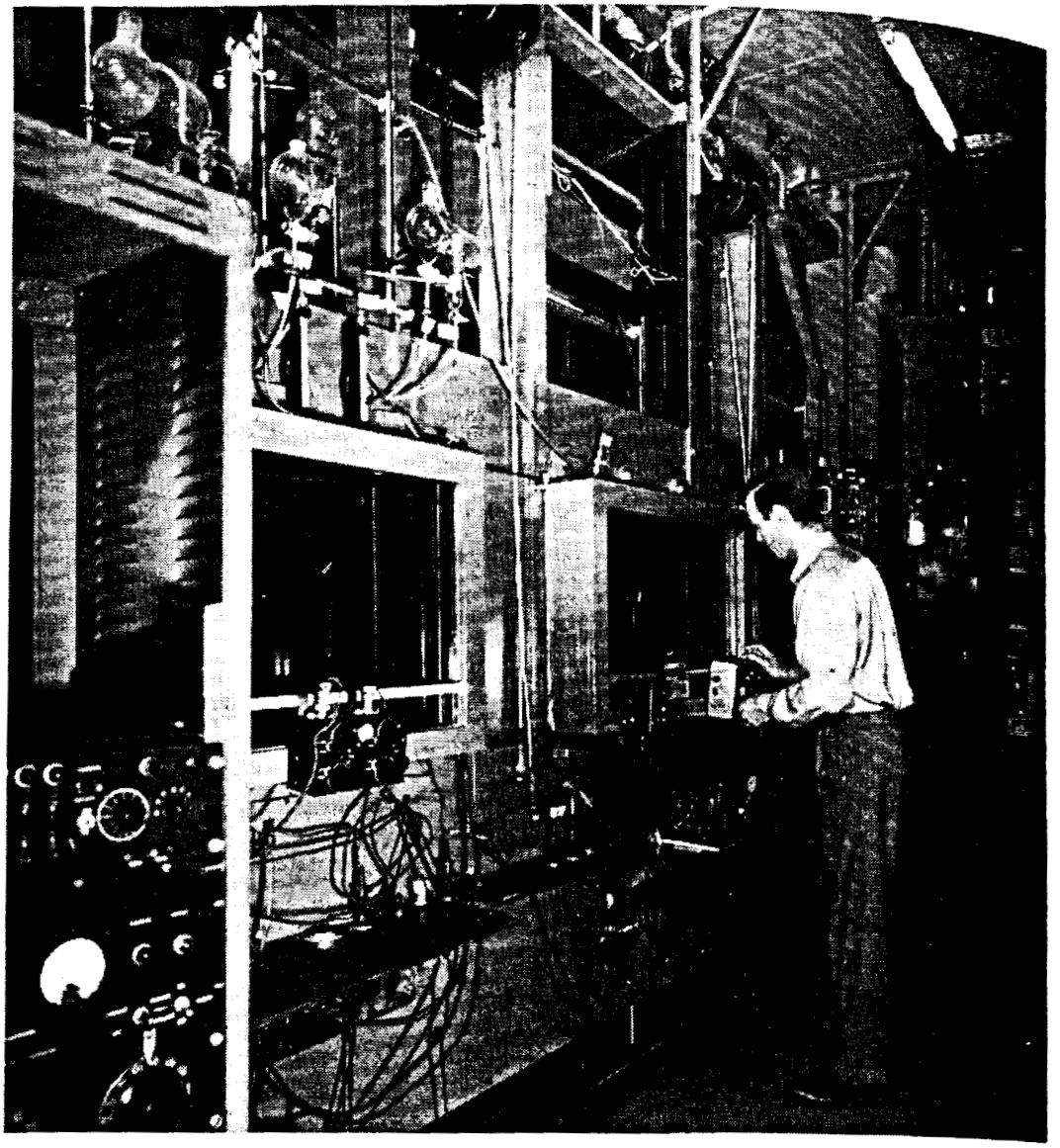
Another Argonne cave, for a special radiochemical separations process (p. 160), cost $80,000, including a switch-operated electrical manipulator, four viewing windows, and various other facilities. A similar process on "cold" materials could have been carried out in a standard-equipped chemistry laboratory at an added cost of $2,000 for the special process equipment.

A single right-and-left pair of all-mechanical master-slave manipulators of current design costs $10,000, but might be reduced to $5,000 a pair if three identical pairs were made at once.

Some Sample Costs

Here are some other sample costs of radiation protection:

The building and equipment used to package and ship radioisotopes at Oak Ridge, the *atomic apothecary* described in Chapter III, represent an investment of 2.4 million dollars including the analytical laboratory. Comparable costs for an ordinary drug-handling operation would obviously be only a fraction as great.



This cave for radiochemical research at Argonne represents an investment of $80,000; the same operations could be performed on nonradioactive materials in a conventional laboratory with a special equipment investment of only $2,000. Among other facilities, this cave has switch-operated manipulators—the controls are in the operator's hands—and blowers to maintain suction of filtered air from the room through the enclosure. One of the inlet air filters shows on the baseboard in front of the operator.

As well as can be determined from available information, the cost per piece of *laundering* radioactive-contaminated work clothing at Los Alamos is about half again as great as the cost of ordinary laundering.

Lead bricks used as shielding in some laboratory work cost, on the market, $4 and $5 each.

Chemox masks, which generate oxygen, worn where atmospheric contamination is unusually severe, cost $150 each. Simpler *respirators*, consisting of filters and nose-pieces, cost $12 to $15 each.

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The laboratories use thousands of pairs of *surgeons' rubber gloves*, at a cost of about $2.50 a pair.

Most commercially made *radiation detection instruments* cost between $200 and $350 each. Pocket meters, two of them for each radiation worker, cost about $10 each. The heavy machines that check hands and feet for contamination at laboratory exits cost $3,000. Some types of sensitive counter tubes used in detection instruments cost $70 to $80 and more.

Containers for radioactive material weigh much more than the material, swelling *transportation costs*. A "cold" sample, for example, is mailed from Berkeley, California, to Oak Ridge for 3 to 25 cents. Upon irradiation in the Oak Ridge reactor, it gives off gamma rays and requires a lead-shielded container for the return trip to Berkeley. These containers weigh from 20 to 240 pounds and the express charges run from $5 to $60, including final return of the container to Oak Ridge.

At best, radiation protection promises to remain costly. With time and advancing knowledge, today's standards on permissible exposures may be changed, and more effective and economical protective measures may be devised. Until advancing science proves these improvements possible, the AEC can fulfill its obligations only by taking all feasible precautions to safeguard workers in the program and the general public against the potential hazards of atomic energy production and development.

Part Two

Highlights of 1950 in Atomic Energy Programs

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MAJOR DEVELOPMENTS JANUARY–JUNE 1950

From January through June 1950, production operations in the national atomic energy program proceeded at the highest rate in the history of the project. At the same time, the current program was recast to implement the President's directive of January 31 (see Foreword), and decisions were made and plans formed for constructing the new facilities necessary to implement that directive fully.

Policies and procedures in various phases of administration—security, finance, and information control and service—were reviewed and altered with an eye to improvements or economies. Some advance was made toward the goal of self-government and private ownership of property in the presently Government-owned communities housing the workers at Oak Ridge, Hanford, and Los Alamos.

The main developments of the 6 months in major parts of the program are summarized briefly below. The record of the full 12 months of 1950 will be reported in the Ninth Semiannual Report, due in January 1951.

Production of Fissionable Materials

The production of uranium 235 and plutonium from January through June was at a new record rate, exceeding that of 1949. Back of this growth in output was a general speed-up in procurement of uranium ores, processing of feed materials for the Oak Ridge and Hanford plants, and operation of the plants themselves. This was brought about without a comparable increase in operations cost, and the industry in the past 6 months produced uranium 235 and plutonium at the lowest unit costs yet attained.

Increasing the Uranium Supply

Procurement of uranium ores from foreign sources continued at a satisfactory rate, and progress was made toward arranging for increased future supplies.

Domestic production of uranium continued to increase, and plans

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were made for further expansion of operations on the Colorado Plateau. In addition, exploration and prospecting during the past 2 years offer promise of new production in western United States outside the Colorado Plateau area.

In January of this year, the Uravan, Colorado, plant of the United States Vanadium Corporation was placed in operation after being idle since 1945. This is the largest plant on the Colorado Plateau and in the past was operated solely for the production of vanadium. Extensive plant revisions and additions were made to provide for efficient recovery of uranium.

The Climax Molybdenum Company announced that it will construct a processing plant at Grand Junction, Colorado, through the Climax Uranium Company, and will undertake extensive development and mining operations. The company will finance all construction and operations and will sell a uranium concentrate to the Commission under a unit price contract.

On March 15, 1950, the AEC opened an ore-buying depot at Marysvale, Utah, to provide a market for development ores being produced from some uranium deposits discovered last year in that area. The surface ores contained only secondary uranium minerals; but primary minerals are being encountered in some of the deeper mine workings, and there is a possibility of developing pitchblende ore at depth.

The deposit of primary uranium ores in the Sunshine Mine, Coeur d'Alene District, Idaho, discovered in 1949 by an AEC geologist and geologists of the Sunshine Mining Company and the Bunker Hill and Sullivan Mining and Refining Company, is being further explored.

The Jones & Laughlin Ore Company is planning to prospect the pitchblende deposit it discovered late in 1949 on the upper peninsula of Michigan. Detailed sampling and drilling, as well as a general survey, will be undertaken.

The Canadian Government recently announced a special price arrangement for low-grade, high-cost ores. It is expected that this will stimulate increased prospecting and development, particularly in the Lake Athabaska Region where a number of promising uranium deposits were discovered during the past two seasons.

New types of radiation detection instruments promise to speed up the work of exploration, both in United States and Canada. Progress is being made in developing processes for more effective recovery of uranium from ores and low-grade uranium-bearing materials.

Weapons Production and Development

Atomic weapons and fissionable material were produced at the rate authorized by the President for calendar year 1950.

The President approved the plan for carrying out his January 31 directive " . . . to continue . . . work on all forms of weapons including the so-called hydrogen or super-bomb."

Building of permanent structures for laboratory development work proceeded on schedule. Planning and construction was carried on for weapons tests at the Eniwetok Proving Ground. Studies on the feasibility of radiological substances as a method of warfare were continued.

Nuclear Reactor Development

During the past half year reactor development proceeded at a growing pace in the general pattern outlined in the Seventh Semiannual Report. There were, however, changes in direction and emphasis to adapt this experimental phase of the national atomic energy program to changing circumstances and needs.

Progress on Experimental Reactors

At the Reactor Testing Station in Idaho, construction has started on the building to house the experimental breeder reactor (EBR), the first major reactor in the high neutron energy range; the core is being fabricated at the Argonne National Laboratory. Completion is scheduled for 1951, with a total cost, exclusive of research and development, of approximately 3.3 million dollars. This reactor is designed to test the possibility of creating fissionable material faster than the reactor consumes it, the process known as "breeding."

The Fluor Corporation of Los Angeles was selected as contractor for construction of the materials testing reactor (MTR) at the Reactor Testing Station. The core is being constructed by the Oak Ridge National Laboratory, in consultation with Argonne National Laboratory. Operating in the thermal, or slow, neutron energy range, this reactor will give research workers a much-needed tool—a reactor in which to test materials under a neutron bombardment more intense than is produced in any other known reactor. The estimated cost for this reactor, not including research and development, is about 18 million dollars of which the cost-plus-fixed-fee construction contract with Fluor covers about 10 million. The balance of the work will be done under a number of fixed-price contracts let through competitive bidding.

The Submarine Thermal Reactor (STR), the first designed for power and for military use, is planned for construction as a land-based prototype at the Reactor Testing Station. The Rust Engineering Company, of Pittsburgh, was selected as subcontractor for the Westinghouse

Electric Corporation to perform the architect-engineering work, and Westinghouse, working with Argonne National Laboratory, will build the reactor core. The estimated total cost of the installation is about 26 million dollars.

Processing Facilities

A processing plant for recovering nuclear fuel from used reactor fuel elements is to be built at the Idaho Reactor Testing Station. The Foster Wheeler Corporation, of New York City, was selected to design the plant building and to assist the Oak Ridge National Laboratory in process design. Design will be substantially completed in the second half of 1950; the estimated cost is approximately 16 million dollars, not including architect-engineering and major site development.

Two evaporation plants, the first of their kind for concentrating liquid radioactive wastes, were put in operation at the Knolls Atomic Power Laboratory and the Oak Ridge National Laboratory. Besides reducing the volume of wastes at each location, these plants provide operating data for future design.

Knolls Laboratory Program Revision

In February 1950, the General Electric Company submitted a feasibility report on the intermediate power-breeder reactor (IP-BR) and requested authorization to proceed with construction. After consideration of the report, the Commission on March 20 deferred construction. Subsequently the AEC and the General Electric Company worked out a reorientation of the research and development program at Knolls Atomic Power Laboratory. The Commission approved the proposal and General Electric was instructed to give first priority to a program of assistance to Hanford; second priority to the submarine intermediate reactor (SIR) in which fission of fuel atoms would be caused by neutrons in the intermediate energy range; third priority to completion of power-breeder reactor research useful to the SIR and an orderly close-out of the IP-BR project; and fourth priority to general programmatic development in the reactor field. Development of the West Milton reactor site, already under way at the time of the deferment, is being completed.

With deferment of the intermediate power-breeder reactor, research and development by the Knolls Atomic Power Laboratory on the submarine intermediate reactor (SIR) was increased substantially. It will utilize the greater part of investigations previously made for the IP-BR. Present plans contemplate construction of a land-based SIR prototype at West Milton, near Schenectady, N. Y.

Homogeneous Reactor Program

The Commission approved a project of the Oak Ridge National Laboratory for research and development of a low power homogeneous reactor. As described in the Seventh Semiannual Report, a homogeneous reactor will have the fuel and moderator in a homogeneous mixture. Tentative approval was given for assembling the reactor, subject to (*a*) review by the Reactor Safeguard Committee of a hazards study, (*b*) review of costs after a site is chosen, and (*c*) approval of a final feasibility study. A limit on cost has been approved for the assembly.

Nuclear Power for Aircraft

Early in the year, a Technical Advisory Board to the Oak Ridge National Laboratory, composed of more than a score of aeronautic and nuclear scientists with Dr. Wheeler Loomis, University of Illinois physicist, as chairman, was formed as a working group to accelerate the development of nuclear power for aircraft. Planning meetings were held in March and in May. Assembling again in June and July at Oak Ridge, the members are functioning both as a board and as individuals working with scientists and engineers at the Oak Ridge National Laboratory and the NEPA Project at Oak Ridge.

Research Reactors

During January 1950, the AEC approved continued investigations by North American Aviation, Inc., looking toward an improved low-power research reactor which would cost about one million dollars to build. It is expected that approximately $400,000 will be spent on these investigations over the next year and a half to 2 years. This program will include a mock-up of the reactor core and preparation of final construction drawings. It is hoped that eventually reactors of this type can be used at university research centers.

The AEC is cooperating with the Consolidated University of North Carolina in connection with the desire expressed by that institution to build a low-power reactor at no cost to the Government. Arrangements are being made through the Oak Ridge Operations Office to grant cleared personnel from the University access to information so that a formal proposal may be drawn up and submitted to the AEC.

The Argonne National Laboratory's heavy-water-moderated reactor (CP-3), used for research purposes for several years, was shut down in January for inspection of its uranium fuel rods. These are now being replaced with new fuel elements. The unit is expected to be back in operation soon.

In March 1950, Argonne National Laboratory began to develop a design for a new research reactor, CP–5. The preliminary schedule calls for technical feasibility and hazards reports to be submitted for Commission consideration in the near future.

Oak Ridge School of Reactor Technology

To provide a means of training more men in reactor technology, this school was opened at the Oak Ridge National Laboratory March 1, 1950 with 19 men from AEC contractor companies and government agencies enrolled for an interim one-year course. A new group of 50 will start a regular one-year term on September 1; this group will include about equal numbers of recent college graduates and experienced engineers from Government and industry.

Construction of New Facilities

Major new facilities being constructed are listed below under the Operations Offices that administer the construction contracts.

Oak Ridge. Construction of the K–29 and K–31 additions to the gaseous diffusion plant proceeded on schedule despite adverse weather conditions, the steel strike, and other labor disputes. Conversion to natural gas as a fuel for the power plant at Oak Ridge has been accomplished.

Chicago. During the past 6 months the 61 million dollar construction program at Argonne National Laboratory was about two-thirds completed. The physics and metallurgy hot laboratory was finished and the experimental waste disposal building was nearly completed; both were occupied.

A contract in the amount of $2,578,650 was awarded in June to the Sollitt Construction Company of Chicago for construction of the Argonne Cancer Hospital at the University of Chicago.

Hanford. Construction is under way at Hanford on new production facilities. Additional waterworks facilities are under construction at Hanford and remodeling of a permanent biochemistry laboratory was almost completed.

Sante Fe. Construction to transform the Los Alamos Scientific Laboratory's temporary, wartime plant into a permanent research establishment advanced during the past 6 months. Nineteen construction projects were placed under contract through competitive bidding, including a major research laboratory. Construction of AEC facili-

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ties operated by the Sandia Corporation of Albuquerque, New Mexico, reached a peak during the past 6 months and was largely completed by the end of June 1950. Total plant and installed equipment at Sandia when completed will amount to about 32.5 million dollars.

Construction of semipermanent facilities and rehabilitation of the Eniwetok Proving Ground have progressed satisfactorily.

New York. Construction went forward on new facilities for feed materials work, including a new plant for preparation of green salt (uranium tetrafluoride, UF_4), a new uranium metal plant, and a plant for converting brown oxide to uranium hexafluoride (UF_6). When completed, these facilities are expected to increase production and further reduce costs.

Other construction. At Brookhaven, the first unit of a new biology laboratory has been completed, and part of the staff has moved out of temporary wooden buildings. After some difficulties the research reactor was brought near readiness for operation, and Brookhaven's major particle accelerator, the Cosmotron, advanced on schedule.

The AEC is supporting the design and construction of a synchrotron at the California Institute of Technology which will accelerate electrons to an energy of one billion electron volts. An improved linear accelerator to be used for a classified research program is being designed and constructed for the Commission jointly by the University of California Radiation Laboratory and the California Research and Development Company.

Developments in Research

Research contracts. At the end of the fiscal year 1950, basic research contracts in physical sciences supported directly by the Commission totalled 10.1 million dollars. Those supported with Commission funds through the joint program of the AEC with the Office of Naval Research totalled about 9.4 million dollars. Basic research contracts in biology and medicine totalled approximately 7.8 million dollars under direct AEC support and 2.9 million dollars under joint AEC–ONR support. Nearly all of the basic research contracts included above are with universities.

There has been a substantial reduction in the joint program; as the Office of Naval Research reduces still further its activities in this type of research the Commission will assume full support of a number of projects now under the joint program.

Particle accelerator research. Research with the 184-inch cyclotron at the University of California Radiation Laboratory supported the

5001125

theory that a neutral meson exists in addition to previously identified positive and negative mesons. During the past 6 months two new elements have been identified. The first, element number 97, was named berkelium in honor of the city in which the Radiation Laboratory is located. It was prepared by bombarding americium (element 95) with 35-Mev helium ions in the 60-inch cyclotron. The second, element number 98, named californium, was prepared by a similar bombardment of curium (element 96). Both new elements are radioactive.

At Los Alamos Scientific Laboratory, bombardment of tritium gas with high-velocity tritons (nuclei of H 3) produced evidence that under certain conditions two neutrons may adhere together very briefly and give the effect of a double neutron. Further work will be needed to confirm the existence of these so-called dineutrons and, if they exist, to explore their properties.

Agricultural research. Study of the effect of gamma radiation on growing tomato plants at Brookhaven National Laboratory showed that plants which received 5,400 roentgens over a 36-hour period, and some that received a total of 3,600 *r* over a month, showed no visible effects. However, tomato plants which received 20,000 *r* at a rate of 150 an hour lost chlorophyll and were retarded in growth. Removed from radiation, these last tomato plants resumed normal growth but did not regain lost growth.

Several agricultural experiment stations, using phosphate fertilizers tagged with radioactive phosphorus, found that super-phosphate, phosphoric acid, and monoammonium phosphate are readily taken up by plants, but that tricalcium phosphate is generally not so readily used. Plants take up rock phosphate more rapidly from a soil of high acidity.

Drugs research. Digitoxin, extracted from plants grown at the University of Chicago and Argonne National Laboratory in an atmosphere containing radioactive carbon dioxide, was used to study by radiotracer methods the metabolic and physiological behavior of the drug. It had been assumed for years that digitoxin, used in treating certain types of heart diseases, was slowly metabolized and excreted, but the study showed this drug, on the contrary, is rapidly metabolized and the breakdown products rapidly excreted.

Cancer Research Hospital at Oak Ridge. The hospital under the Medical Division of the Oak Ridge Institute of Nuclear Studies, which opened May 1950, will study the treatment of malignant diseases with radioactive materials.

3001126

The new hospital will not immediately make possible any new treatment for people but is studying the potentials of new treatments on laboratory animals. Its location at Oak Ridge will enable it to use short-lived radioactive elements which cannot be shipped long distances.

The hospital, with only 30 beds, is a research hospital and does not have all facilities for diagnosis, surgery, and X-ray therapy available in many fine medical centers throughout the country. Hence, only a few selected cases can be studied at a time. Studies planned include: (*a*) the possibility of using radioactive gallium in treating, first, experimental cancer in animals, and later human cancer; (*b*) the unique properties of radioactive ruthenium in treating surface cancers; (*c*) the possibility of using radioactive manganese in treating cancer of the thyroid; (*d*) the mechanism of action of antimony compounds in cancer by using radiotracer techniques; (*e*) development of gamma ray therapy using a powerful radioactive cobalt source for cancer research in conjunction with the Post-Graduate School of Medicine, University of Texas, and the M. D. Anderson Hospital, Houston, Texas.

Patients will be accepted at the Medical Division Hospital only when referred there by the southern medical schools which cooperate in this program.[1] Arrangements have been completed for accepting senior residents of southern medical schools for 3-month periods of training.

Atomic Bomb Casualty Commission. The Atomic Bomb Casualty Commission of the National Research Council, with the support of the AEC, continued its studies of bomb survivors in Hiroshima and Nagasaki. To date, information has been collected on more than 150,000 persons in the bombed areas. The data include periodic physical examinations, blood studies, growth records, observations of pregnancy and child birth, and studies of special injuries such as eye cataracts.

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[1] Medical schools cooperating in the Oak Ridge Cancer Research Program: ALABAMA, Medical College of Alabama, Birmingham. ARKANSAS, School of Medicine, University of Arkansas, Little Rock. GEORGIA, College of Medicine, University of Georgia, Augusta; School of Medicine, Emory University, Atlanta. KANSAS, School of Medicine, University of Kansas, Kansas City. KENTUCKY, School of Medicine, University of Louisville, Louisville. LOUISIANA, School of Medicine, Louisiana State University, New Orleans; School of Medicine, Tulane University, New Orleans. MISSISSIPPI, School of Medicine, University of Mississippi, University. NORTH CAROLINA, Bowman-Gray School of Medicine, Wake Forest College, Winston-Salem; School of Medicine, Duke University, Durham; School of Medicine, University of North Carolina, Chapel Hill. OKLAHOMA, School of Medicine, University of Oklahoma, Oklahoma City. SOUTH CAROLINA, Medical College of the State of South Carolina, Charleston. TENNESSEE, Meharry Medical College, Nashville; College of Medicine, University of Tennessee, Memphis; School of Medicine, Vanderbilt University, Nashville. TEXAS, School of Medicine, Baylor University, Houston; Medical Branch, University of Texas, Galveston; M. D. Anderson Hospital, University of Texas, Houston; Southwestern Medical College, Dallas. VIRGINIA, Medical College of Virginia, Richmond; School of Medicine, University of Virginia, Charlottesville.

5001127

Following the discovery that radiation similar to that released in an atomic bomb burst had caused cataract formation in the eyes of several research workers in this country, an ophthalmic survey was started in Hiroshima in 1949. So far, a limited survey has revealed about 40 certain cases of radiation cataract and an additional 40 suspected cases. A full-scale ophthalmological study is now under way at Hiroshima and a similar survey of survivors at Nagasaki is also planned. Full understanding of this effect on the eyes will require a long-range study, as will any possible genetic changes and effects on growth.

The AEC plans to continue support of the Atomic Bomb Casualty Commission; and a tentative budget allowance for fiscal 1951 has been approved to cover construction of facilities and operations.

The Fellowship Program

The AEC fellowship program is an important means of supporting research by increasing the number of competent scientists in fields of interest to the Commission. The program was reorganized following the decision of the National Research Council to withdraw partially from the program,[2] as indicated in the Seventh Semiannual Report. Under the provisions in Section 102 of the 1950 Independent Offices Appropriation Act requiring FBI investigation and subsequent determination by the Commission of the loyalty of all fellows, the National Research Council, which previously administered the entire fellowship program, now participates as follows:

Predoctoral fellowships.—The Council administers renewals of fellowships previously awarded, whether for secret or nonsecret work.

Postdoctoral fellowships.—The Council administers fellowships on a reduced basis for work that requires access to restricted data.

The major effect of the National Research Council's decision was to eliminate from its program all new predoctoral fellowships and those postdoctoral fellowships that do not require access to restricted data.

The Commission has supplemented the fellowship program under the National Research Council through a regional predoctoral fellowship program in both the biological and physical sciences. This program is administered for the Commission under contracts by four regional offices as follows: Associated Universities, Inc. (Northeastern region); Midwestern AEC Fellowship Board under the University of Chicago; Oak Ridge Institute of Nuclear Studies, Inc. (Southeastern region); and the Western AEC Fellowship Board under the University of California (Appendix 5).

[2] Seventh Semiannual Report to Congress of the U. S. AEC, January 1950, p. 148.

5001128

While the fellowship program has been reorganized for administrative purposes, the National Research Council continues to review the academic qualifications of all applicants, thus assuring uniformly high academic standards throughout the program.

A total of 160 new fellowships was awarded, subject to FBI investigation and Commission loyalty determination, as compared with a total of 238 fellowships awarded during the corresponding period of 1949.

NATIONAL RESEARCH COUNCIL PROGRAM

	Physical Sciences		Biol. Sciences		Medical Sciences	
	Predoct.	Postdoct.	Predoct.	Postdoct.	Postdoct.	Total
Active fellowships (June 30, 1950)	125	25	111	10	42	313
New awards	------	4	------	3	4	11

AEC REGIONAL PROGRAM

Northeastern	28	------	11	------	--------	39
Southeastern	6	------	4	------	--------	10
Midwestern	65	------	6	------	--------	71
Western	22	------	7	------	--------	29

In addition to the combined fellowship program being administered by the National Research Council and the AEC Regional Boards, predoctoral fellowships in radiological (health) physics formerly included in the National Research Council program are now administered by the Oak Ridge Institute of Nuclear Studies (see Chapter VII). A fellowship program for training a limited number of industrial physicians will be inaugurated by the AEC in the 1950–51 academic year. The two years of training planned should provide qualified industrial physicians who are critically needed at atomic energy installations. The first candidates selected will be trained at the School of Medicine, University of Rochester, Rochester, N. Y., and at the School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania.

Private Enterprise and Self-Government in Communities

In line with its broad objective of divesting itself of responsibility for detailed operation of the communities to the fullest extent feasible, the Commission has considered ways of encouraging private financing of real estate development at Oak Ridge, Tennessee, and Richland, Washington.

During the past 6 months, a study was made for the Commission by the Frederick M. Babcock Company of Washington, D. C., on the feas-

ibility of obtaining rental housing through private capital investment. This study revealed that a major deterrent is the low level of rent which exists in Government-owned and -operated housing at Oak Ridge and Richland, despite the average combined rent and utility increases of approximately 18 percent at Oak Ridge and 16 percent at Richland, made in 1949. Further study is being made of the rent levels.

A special panel of authorities on real estate and municipal management is being constituted to advise and guide the Commission on community operation. The Commission hopes to find a way, if possible, to dispose of the property in the towns to private ownership, and to place the communities on a self-governing basis. The Commission appointed Richard G. Scurry of Dallas, Texas, to head the panel, which will be asked to study steps which might be taken to these ends and the effects they might have on the primary purposes of the three communities—providing housing and community facilities that will attract and hold the people required to operate the plants and laboratories.

The Commission's experience demonstrates that there are formidable problems to be solved before the towns can be transformed into normal American communities. For the Government to attempt to withdraw from community operation hastily might jeopardize the whole atomic energy program by producing chaotic communities during the period of transformation. The panel on community operations is expected to give detailed advice and recommendations, with due regard to the special security requirements, as to how far and by what steps the Commission may move toward withdrawal in the near future without jeopardy to the fundamental job of maintaining production of fissionable materials and creation of weapons designs.

The Commission, considering plans for the long-term development of Oak Ridge, authorized the Manager of Oak Ridge Operations to continue studies of town incorporation, to study the possibility of long-term lease of land for private building.

A study was begun under contract by the Public Administration Service, a nonprofit organization in Chicago, on the feasibility of incorporating the community of Richland and disposing of the utilities and real estate.

At Los Alamos, several activities, such as the Los Alamos Medical Center, the White Rock and Los Alamos school systems, and the golf course, were transferred to administrative control by residents under contract arrangements.

A formal contract was executed in February 1950 between the Commission and the Los Alamos County Board of Education for operation of the schools. The Commission continues to contribute the physical plant and a smaller amount of funds, but the Board has "complete

freedom with respect to application of academic policies and procedures as prescribed by the State of New Mexico." During fiscal year 1950, the annual cost per pupil was $290–$310, whereas the budgeted cost for fiscal 1951 is $250–$260. The school enrollment in September 1949 was 1,435. By May 1950, this had increased to 1,657, and an additional 850 students are expected in September 1950.

Transfer of the Los Alamos medical, hospital, and dental services to a new, nonprofit corporation, the Los Alamos Medical Center, was accomplished by a contract dated March 1, 1950. A new medical center building was begun under contract in May 1950, with completion scheduled for late 1951.

Labor-Management Relations

A total of six work stoppages occurred in the atomic energy program during the first half of 1950, one in an AEC operating plant and the remainder in construction work.

At Knolls Atomic Power Laboratory, Schenectady, N. Y., 34 steamfitters between May 15 and May 24 joined in a walkout involving some 350 steamfitters of the General Electric Company. The employees on AEC jobs returned to work after the Atomic Energy Labor Relations Panel intervened in the dispute, which concerned negotiations for a wage increase.

All other work stoppages occurred in construction of new facilities:

At Oak Ridge (gaseous diffusion plant) February 13–21.

At Oak Ridge (gaseous diffusion plant) April 17–21 and May 24–30.

At Hanford, Washington, several weeks delay in obtaining pipefitters for a construction project.

At Arco, Idaho (Reactor Testing Station) April 14–21.

The Panel intervened successfully in the Oak Ridge disputes. For the first time the Panel issued a formal recommendation following the February dispute, to the effect that the disputed work be continued under existing arrangements. The Panel's report to the President for the period November 1949 through May 1950 is given in Appendix 9. During June, the Panel intervened and averted a possible work stoppage in a dispute at Oak Ridge over the terms of a wage contract.

Inventory of Facilities

The AEC completed the inventory and cost appraisal of its plant and equipment during 1950. The assistance of engineering and public accounting firms was necessary at the Oak Ridge, Hanford, and Santa Fe Operations Offices where the costs of facilities taken over by the AEC were difficult to determine. The other Operations Offices, with-

out outside assistance, established accounts and property accounting systems which are now being reviewed by a public accounting firm and an engineering firm.

The inventory program and property records will assemble sound plant investment data on a current basis and improve control over the AEC's plant and equipment. Total cost of the Commission's plant and equipment and construction work in progress as of December 31, 1949, was slightly in excess of 2 billion dollars before provision for depreciation.

Provisions for Security

A special panel, headed by John S. Bugas, vice president for Industrial Relations, Ford Motor Company, was appointed in December to study the security system maintained by the Commission and its contractors and its requirements for top personnel. Other members of the panel were David L. Hopkins, executive vice president and director, The Safe Deposit and Trust Company, Baltimore, Md.; Dr. Paul E. Klopsteg, director of research, Technological Institute, Northwestern University, Evanston, Ill.; and J. Arthur Mullen, president, Glenvale Products, Detroit, Mich.

The panel made an intensive review over a period of four months, and returned an analytical report and recommendations. The Commission staff acted at once upon the analysis of deficiencies in the detailed organizational and procedural arrangements to protect physical, personnel, documentary and other phases of security, involving all divisions and operations offices, and to install corrective measures. The Commission now has under review the recommendations on general organizational arrangements.

The Commission has expressed its warmest thanks to the panel for its conscientious, painstaking study.

A major development in physical security provisions during the past 6 months was the installation at Hanford by the Department of the Army of a garrison of antiaircraft troops. The purpose is protection of the Hanford Works against military assault.

Information Services

In January 1950, a working committee of five members from the Ad Hoc Committee on Technological Information for Industry was established to evaluate the extent to which technological information useful to industry is being made available. Members of this group were given complete security investigation and clearance to enable them to enter restricted areas and examine restricted information files.

Preliminary conclusion reached by the working committee, after

considering the abstract file maintained by the Patent Branch of the AEC, was that little technological information that would be useful to industry in the field of patents is being withheld by the AEC. The committee is continuing its work by examining files in other areas, particularly in the technology of electromagnetic separation in phases that are not related to weapons operations.

Control of Atomic Energy Information

The Commission's procedures for control of atomic energy information must continually draw the line between releasing so much information as to give material assistance to interests inimical to this Nation and withholding so much that America's own progress and security suffer. The basic objective of AEC information control policy, therefore, is to disseminate information that will advance this Nation's program while giving as little aid as possible to inimical interests. The procedures for supporting this policy must be kept flexible to adjust promptly and effectively to changes in the American program or to known facts as to rival developments.

As stated in the Seventh Semiannual Report to the Congress, the announcement by the President on September 23, 1949, that an atomic explosion had occurred in the USSR added to the necessity of adjustments in declassification procedures. Similarly, events of the past 6 months have necessitated constant evaluation of the Commission's policies and procedures in declassification and in positive information control.

On January 31, 1950, the President "directed the Atomic Energy Commission to continue its work on all forms of atomic weapons, including the so-called hydrogen or super-bomb." Shortly thereafter, it was announced that Dr. Klaus Fuchs, who had been a member of the British mission which helped build the first atomic bomb at Los Alamos during the war, had been a Russian agent from 1943 to 1949.

Each of these events, adding to the many facets and developments of our atomic energy program, has contributed in some measure to shaping the Commission's policies for the control of atomic energy information. Technical studies have been under way looking toward adjustments of controls on information held in common by the three Nations—Canada, the United Kingdom, and the United States—which took part in the wartime atomic energy development.

Information Relating to Thermonuclear Weapons

The current situation with regard to thermonuclear weapons is quite unlike that which existed with regard to fission-type weapons at the

conclusion of World War II. The thermonuclear project is now under way. It cannot be discussed in the past tense. And, since it is to be assumed that a potential enemy is making atomic weapons, and possibly also undertaking a hydrogen-bomb project, information concerning the status of progress of this Nation's program, or the findings of certain research endeavors, would be of very great value to him.

Pending a careful and considered determination of what could be said without jeopardizing the security of the program, therefore, the Commission in March requested the assistance and cooperation of all of its employees, contractors, and consultants in seeking to avoid for the time being the release of technical information which, even though of itself unclassified, would expand the known technical knowledge of thermonuclear weapons or be interpreted by virtue of the project connection of the speaker as reflecting the Commission's program with respect to such weapons.

Since this request was made, the Commission, through further discussions and instructions, has defined more specifically for project-connected personnel the technical and programmatic information on the thermonuclear weapons program which is affected by security considerations.

Information Control Policy

The Commission recognizes that the information control problems relating to the thermonuclear weapons project are only a part of a far broader problem in safeguarding restricted information in the fields of science and technology. Secrecy, if unwisely applied, can go far beyond its objective of safeguarding vital information—it can stifle and smother freedom of research and freedom of inquiry in nonrestricted areas, and from this the Nation could only suffer a net loss.

To provide guidance on this problem, the Commission late in May formally adopted and issued to all present and former project personnel a statement of its information control policy. This statement is included as Appendix 10 of this report.

5001134

APPENDIX 1

U. S. Atomic Energy Commission, Principal Staff, and Managers of Operations Offices

Atomic Energy Commission	Gordon Dean, *Chairman.* Thomas E. Murray. Sumner T. Pike. H. D. Smyth. (Vacancy.)
General Manager	Carroll L. Wilson.
Deputy General Manager	Carleton Shugg.
Secretary to Commission	Roy B. Snapp.
Director of Intelligence	Walter F. Colby.
Executive Officer, Program Council.	David B. Langmuir.
Director of Classification	James G. Beckerley.
General Counsel	Joseph Volpe, Jr.
Controller	Lindsley H. Noble.
Director, Division of Research	Kenneth S. Pitzer.
Director, Division of Production	Walter J. Williams.
Director, Division of Engineering	George G. Brown.
Director, Division of Military Application.	Brig. Gen. James McCormack, Jr.
Director, Division of Reactor Development.	Lawrence R. Hafstad.
Director, Division of Biology and Medicine.	Dr. Shields Warren.
Director, Division of Organization and Personnel.	Fletcher C. Waller.
Director, Public and Technical Information Service.	Morse Salisbury.
Director, Division of Security	Francis R. Hammack (*Acting*).
Managers of Operations Offices:	
Chicago (Illinois)	A. Tammaro.
Hanford (Washington)	David F. Shaw.
Idaho	L. E. Johnston.
New York (New York)	Wilbur E. Kelley.
Oak Ridge (Tennessee)	Richard W. Cook.
Raw Materials (Washington, D. C.).	Jesse C. Johnson.
Santa Fe (New Mexico)	Carroll L. Tyler.
Schenectady (New York)	James C. Stewart.

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500135

APPENDIX 2

MEMBERSHIP OF COMMITTEES

STATUTORY COMMITTEES

Joint Committee on Atomic Energy—Eighty-first Congress

This committee was established by the Atomic Energy Act of 1946 (Sec. 15) to make "continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy." The committee is kept fully and currently informed with respect to the Commission's activities. Legislation relating primarily to the Commission or to atomic energy matters are referred to the committee. The committee's membership is composed of nine Members of the Senate and nine Members of the House of Representatives.

Senator BRIEN MCMAHON (Connecticut), chairman.
Representative CARL T. DURHAM (North Carolina), vice chairman.
Senator RICHARD B. RUSSELL (Georgia).
Senator EDWIN C. JOHNSON (Colorado).
Senator TOM CONNALLY (Texas).
Senator MILLARD E. TYDINGS (Maryland).
Senator BOURKE B. HICKENLOOPER (Iowa).
Senator EUGENE D. MILLIKIN (Colorado).
Senator WILLIAM F. KNOWLAND (California).
Senator JOHN W. BRICKER (Ohio).
Representative CHET HOLIFIELD (California).
Representative MELVIN PRICE (Illinois).
Representative PAUL J. KILDAY (Texas).
Representative HENRY M. JACKSON (Washington).
Representative W. STERLING COLE (New York).
Representative CHARLES H. ELSTON (Ohio).
Representative CARL HINSHAW (California).
Representative JAMES E. VAN ZANDT (Pennsylvania).
WILLIAM L. BORDEN, executive director.
HAROLD BERGMAN, deputy director.

Military Liaison Committee

This committee was established by the Atomic Energy Act of 1946 (Sec. 2. (c)) as a group which the Commission shall advise and consult with on all atomic energy matters which the MLC deems to relate to military applications. According to the Act, the committee and the Commission are to keep each other informed of such matters pending before the Commission and of atomic energy activities of the Department of Defense. The committee may make recommendations to the AEC and refer matters considered adverse to the responsibilities of the Department of Defense to the Secretary, who, if he concurs, may refer them to the President for decision. In 1949, an amendment to the Act

5001136

provided that the membership should be composed of representatives of the Army, Navy, and Air Force, and a committee chairman appointed by the President.

Hon. ROBERT LEBARON, chairman.
Maj. Gen. KENNETH D. NICHOLS, United States Army.
Brig. Gen. HERBERT B. LOPER, United States Army.
Rear Adm. RALPH A. OFSTIE, United States Navy.
Rear Adm. TOM B. HILL, United States Navy.
Maj. Gen. FRANK F. EVEREST, United States Air Force.
Brig. Gen. ROSCOE C. WILSON, United States Air Force.
Brig. Gen ALVIN R. LUEDECKE, executive secretary, United States Air Force.

General Advisory Committee

This committee was established by the Atomic Energy Act of 1946 (sec. 2. (b)). The nine civilian members are appointed by the President to advise the Commission on scientific and technical matters relating to materials, production, and research and development. Under the Atomic Energy Act, the committee shall meet at least four times in every calendar year; the committee held its first meeting in January 1947, and to date has averaged six meetings a year.

Dr. J. ROBERT OPPENHEIMER, chairman; director, Institute for Advanced Study, Princeton, N. J.
Dr. OLIVER E. BUCKLEY, president, Bell Telephone Laboratories, New York, N. Y.
Dr. JAMES B. CONANT, president, Harvard University, Cambridge, Mass.
Dr. LEE A. DUBRIDGE, president, California Institute of Technology, Pasadena, Calif.
Dr. ENRICO FERMI, professor of physics, Institute for Nuclear Studies, University of Chicago, Chicago, Ill.
Dr. I. I. RABI, professor of physics, Columbia University, New York, N. Y.
Dr. HARTLEY ROWE, vice president and chief engineer, United Fruit Co., Boston, Mass.
Dr. GLENN T. SEABORG, professor of chemistry, University of California, Berkeley, Calif.
Dr. CYRIL S. SMITH, director, Institute for the Study of Metals, University of Chicago, Chicago, Ill.
Dr. JOHN H. MANLEY, secretary; assistant to the director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

PATENT COMPENSATION BOARD

This board was established in April 1949 pursuant to Section 11 of the Atomic Energy Act of 1946, which provides that certain proceedings upon applications for just compensation or awards or for the determination of a reasonable royalty fee shall be held before such a board. The board has had 5 sessions; 10 cases have been filed, of which two have been finally determined by the Board.

CASPER W. OOMS, chairman; of Dawson & Ooms, Chicago, Ill.; former U. S. Commissioner of Patents.
ISAAC HARTER, chairman, Babcock & Wilcox Tube Co., Beaver Falls, Pa.
JOHN V. L. HOGAN, consulting engineer, Hogan Laboratories, Inc., New York, N. Y.

500137

PERMANENT PANEL APPOINTED BY THE PRESIDENT—ATOMIC ENERGY LABOR RELATIONS PANEL

The members of this panel were appointed by the President in April and June 1949 to take jurisdiction and mediate labor management disputes which threaten to interfere with essential operations of the Atomic Energy Commission. To date the panel has acted upon 10 labor management disputes in AEC installations. It operates under procedures designed to safeguard continuity of operations, while not inhibiting free collective bargaining between AEC contractors and unions. In December 1949 and in May 1950, the panel reported to the President on its activities.

WILLIAM H. DAVIS, chairman; of Davis, Hoxie & Faithfull, New York, N. Y.; chairman, Patent Survey Committee, U. S. Department of Commerce.
AARON HORVITZ, lawyer and arbitrator, New York and New Jersey.
EDWIN E. WITTE, chairman, department of economics, University of Wisconsin, Madison, Wis.

SENIOR RESPONSIBLE REVIEWERS

The Manhattan District appointed and the Atomic Energy Commission reaffirmed the need for the Committee of Senior Responsible Reviewers. The committee consists of a reviewer for the major phases of the AEC program and is the principal advisor to the AEC on declassification matters, making recommendations for formulating and modifying the rules and guides for classifying scientific and technical information.

Dr. W. C. JOHNSON, chairman, department of chemistry, University of Chicago, Chicago, Ill.
Dr. J. M. B. KELLOGG, division leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. W. F. LIBBY, professor of chemistry, University of Chicago, Chicago, Ill.
Dr. R. L. THORNTON, professor of physics, University of California, Berkeley, Calif.
Dr. FREDERIC DE HOFFMANN, secretary; alternate assistant director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

ADVISORY BODIES TO THE ATOMIC ENERGY COMMISSION

Advisory Committee on Biology and Medicine

This committee was created in September 1947 as the result of recommendations to the Commission by its Medical Board of Review. The principal function of this committee is to recommend to the Commission general policies in the field of medical and biological research and health. Since its inception, the committee has held 22 meetings and a report of each meeting is forwarded to the Commission.

Dr. ALAN GREGG, chairman; director for medical sciences, Rockefeller Foundation, New York, N. Y.
Dr. ERNEST W. GOODPASTURE, vice chairman; dean, school of medicine and professor of pathology, Vanderbilt University, Nashville, Tenn.

5001158

Dr. DETLEV W. BRONK, president, Johns Hopkins University, Baltimore, Md.; president, National Academy of Sciences.
Dr. EDWARD A. DOISY, director, department of physiology and biochemistry, St. Louis University School of Medicine, St. Louis, Mo.
Dr. E. C. STAKMAN, chief, division of plant pathology and botany, University of Minnesota, Minneapolis, Minn.
Dr. CURT STERN, professor of zoology, University of California, Berkeley, Calif.
Dr. JOSEPH T. WEARN, dean, school of medicine, Western Reserve University, Cleveland, Ohio.

Advisory Committee on Chemistry

This committee was appointed in June 1949 to advise on policy concerning the AEC program of supporting basic unclassified chemistry research in universities, and the relationship of this program to the AEC's own chemistry research program. Most of the work of the committee is accomplished by individual consultation as specific problems arise; the one formal meeting of the group was held in June 1949.

Dr. FARRINGTON DANIELS, professor of chemistry, University of Wisconsin, Madison, Wis.
Dr. G. B. KISTIAKOWSKY, professor of chemistry, Harvard University, Cambridge, Mass.
Dr. JOSEPH E. MAYER, professor of chemistry, University of Chicago, Chicago, Ill.
Dr. GLENN T. SEABORG, professor of chemistry, University of California, Berkeley, Calif.
Dr. DON M. YOST, professor of chemistry, California Institute of Technology, Pasadena, Calif.

Advisory Board on Contract Appeals

This board was established in February 1950. One or more of its three members hears contract appeals arising under the "disputes clause" of AEC contracts and subcontracts and makes recommendations to the General Manager concerning the disposition of such appeals. Five cases are pending before the board. Rules are being prepared to govern the handling of such appeals by the board.

SHELDEN ELLIOTT, dean of the law school, University of Southern California, Los Angeles, Calif.
HERBERT F. TAGGART, assistant dean of the school of business administration, University of Michigan, Ann Arbor, Mich.; former president, American Accounting Association.
CLARK C. VOGEL; of Riker, Emery & Danzig, Newark, N. J.; instructor, Rutgers University School of Law.

Advisory Committee on Cooperation Between Electric Power Industry and AEC

The appointment of this temporary committee was announced in August 1949. Its purpose is to conduct first-hand examination of programs and technical information in reactor development and to recommend ways to establish continuing cooperation between the electric power industry and the AEC. The committee has visited a number of AEC installations and conferred with AEC and laboratory staff and is now preparing a report of its findings.

5001139

PHILIP SPORN, chairman; president, American Gas & Electric Co., New York, N. Y.
EDWARD W. MOREHOUSE, vice president, General Public Utilities Corp., New York, N. Y.
WALTER SEYMOUR, power advisor, Economic Cooperation Administration Mission to Greece.

Advisory Committee for Equipment and Material Control

This committee was appointed in November 1948 to give the Commission staff an opportunity to discuss periodically with a representative industrial group problems which arise in the Commission's export control operations. Meetings are held with committee members about once a year.

FREDERICK H. WARREN, chairman; chief, export control branch, Division of Production, AEC, Washington, D. C.
R. W. ALBRIGHT, vice president and general manager, Distillation Products Industries, Rochester, N. Y.
Dr. A. O. BECKMAN, president, Beckman Instruments, Inc., South Pasadena, Calif.
GEORGE H. BUCHER, vice chairman of board, Westinghouse Electric Corp., Pittsburgh, Pa.
Dr. RICHARD S. MORSE, president, National Research Corp., Cambridge, Mass.
H. B. NEAL, president, Kinney Manufacturing Co., Boston, Mass.
C. S. REDDING, president, Leeds & Northrup Co., Philadelphia, Pa.
JOHN A. VICTOREEN, chairman of board, The Victoreen Instrument Co., Cleveland, Ohio.

Idaho Engineering Advisory Committee

This committee, whose appointment was announced in January 1950, is to advise the Idaho Operations Office on engineering phases of the development and operations of the Atomic Energy Commission's Reactor Testing Station. Meetings are held about once a month with the staff of the Idaho office.

Gen. L. J. SVERDRUP, chairman; president, Sverdrup & Parcel, Inc., consulting engineers, St. Louis, Mo.
Dr. H. M. CROTHERS, vice president and dean of engineering, South Dakota State College, Brookings, S. Dak.
W. W. HORNER; of Horner & Shifrin, consulting engineers, St. Louis, Mo.

Advisory Committee on Isotope Distribution

This committee was originally appointed by the Manhattan District to advise on the off-project distribution of isotopes. The Commission approved its continuation in December 1947 to aid in establishing new policies on distributing radioactive materials and to review existing policies. The committee reviews all initial applications for use of radioisotopes in human beings, and all other requests for their use in research, education, and industry which are referred to it by the Commission.

Dr. G. FAILLA, chairman; professor of radiology, College of Physicians and Surgeons, Columbia University Medical School, New York, N. Y.
Dr. H. A. BARKER, division of plant nutrition, College of Agriculture, University of California, Berkeley, Calif.

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Dr. HENRY BORSOOK, head, department of biochemistry, division of biology, California Institute of Technology, Pasadena, Calif.

Dr. AUSTIN M. BRUES, director, biology division, Argonne National Laboratory, Chicago, Ill.

Dr. HAROLD COPP, assistant professor of physiology, Radiation Laboratory, University of California, Berkeley, Calif.

Dr. ROBLEY D. EVANS, professor of physics, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. HYMER L. FRIEDELL, director, department of radiology, Lakeside Hospital, Western Reserve University, Cleveland, Ohio.

Dr. A. H. HOLLAND, JR., director, office of research and medicine, AEC, Oak Ridge, Tenn.

Dr. JOSEPH W. KENNEDY, chairman, department of chemistry, Washington University, St. Louis, Mo.

Dr. ROBERT F. MEHL, director, Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh, Pa.

Dr. L. F. NIMS, chairman, biology department, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. PAUL C. AEBERSOLD, secretary; chief, isotopes division, AEC, Oak Ridge, Tenn.

Patent Advisory Panel

This panel was appointed in January 1947 to make a general review and appraisal of the problems raised by the patent provisions of the Atomic Energy Act of 1946. It makes informal reports and recommendations to the Commission and its staff on various questions of policy and procedure relating to patents and inventions.

H. THOMAS AUSTERN; of Covington, Burling, Rublee, O'Brian & Shorb, Washington, D. C.

WILLIAM H. DAVIS; of Davis, Hoxie & Faithfull, New York, N. Y.; chairman, Patent Survey Committee, U. S. Department of Commerce.

JOHN A. DIENNER; of Brown, Jackson, Boettcher & Dienner, Chicago, Ill.; former president, American Patent Law Association.

HECTOR M. HOLMES; of Fish, Richardson & Neave, Boston, Mass.

CASPER W. OOMS; of Dawson & Ooms, Chicago, Ill.; former U. S. Commissioner of Patents.

Advisory Committee on Personnel Management

This committee of leading authorities from government, industry, and education was named in September 1948 to provide the Atomic Energy Commission with a continuous review of its personnel management practices and to evaluate the best personnel methods of government and industry in determining over-all AEC policies. The committee meets once a month and usually reports orally to the staff.

ARTHUR S. FLEMMING, chairman; president, Ohio Wesleyan University, Delaware, Ohio; member of the Commission on Organization of the Executive Branch of the Government.

LAWRENCE A. APPLEY, president, American Management Association, New York, N. Y.

ALVIN E. DODD, honorary president, American Management Association, New York, N. Y.

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L. CLAYTON HILL, professor of industrial relations, University of Michigan, Ann Arbor, Mich.

WALLACE SAYRE, professor of public administration, School of Business and Civic Administration, City College of the City of New York, N. Y.

THOMAS G. SPATES, vice president for personnel administration, General Foods Corp., New York, N. Y.

Personnel Security Review Board

This board was appointed in March 1949 primarily to review specific personnel security cases which arise under the Commission's administrative review procedure and make recommendations concerning them to the General Manager. The board, in its monthly meetings, also advises the Commission on the broader considerations regarding personnel security, such as criteria for determining eligibility for security clearance, and personnel security procedures.

GANSON PURCELL, chairman; of Root, Ballantine, Harlan, Bushby, & Palmer, Washington, D. C.; former chairman, Securities and Exchange Commission.

ARTHUR S. FLEMMING, president, Ohio Wesleyan University, Delaware, Ohio; member of the Commission on Organization of the Executive Branch of the Government; former U. S. Civil Service Commissioner.

BRUCE D. SMITH, director, United Corp., New York, N. Y., and Lehigh Coal & Navigation Co., Philadelphia, Pa.; former special assistant to chairman, War Manpower Commission.

Committee on Raw Materials

This committee was appointed in October 1947 to review the Atomic Energy Commission's raw materials program and to advise on questions of exploration, development, and procurement. The committee has met seven times since its formation.

Dr. DONALD H. MCLAUGHLIN, chairman; president, Homestake Mining Co., San Francisco, Calif.

EVERETTE L. DEGOLYER, DeGolyer & McNaughton, petroleum geologists, Dallas, Tex.

THOROLD F. FIELD, consulting mining engineer, Duluth, Minn.

J. K. GUSTAFSON, consulting geologist, M. A. Hanna Co., Cleveland, Ohio.

WILBER JUDSON, vice president and director, Texas Gulf Sulphur Co., New York, N. Y.

WALTER L. MAXSON, metallurgist, Oliver Iron Mining Co., Duluth, Minn.

ERNEST H. ROSE, chemical engineer, Tennessee Coal, Iron & Railroad Co., Birmingham, Ala.

WALTER O. SNELLING, director of research and consulting chemist, Trojan Powder Co., Allentown, Pa.

ORVIL R. WHITAKER, consulting mining engineer, Denver, Colo.

CLYDE E. WILLIAMS, director, Battelle Memorial Institute, Columbus, Ohio.

Reactor Safeguard Committee

This committee was established in the fall of 1947 to advise the Commission on the hazards of the operation of reactors. The committee reviews safety studies made by the contractors on proposed reactors from the standpoint of completeness

and accuracy and may make recommendations for modifications or further study. This committee of experts in the fields of physics, chemistry, sanitary engineering, meteorology, and medicine meets whenever problems arise which require their consideration. In the past this has been about four times a year.

Dr. EDWARD TELLER, chairman; assistant director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. MANSON BENEDICT, chemical engineer, Hydrocarbon Research Inc., New York, N. Y.
Dr. HYMER L. FRIEDELL, director, department of radiology, Lakeside Hospital, Western Reserve University, Cleveland, Ohio.
Col. BENJAMIN HOLZMAN, meteorologist, Office of Director of Research and Development, U. S. Air Force, Washington, D. C.
Dr. JOSEPH W. KENNEDY, chairman, department of chemistry, Washington University, St. Louis, Mo.
Dr. FREDERICK SEITZ, professor of physics, University of Illinois, Urbana, Ill.
Dr. JOHN A. WHEELER, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. ABEL WOLMAN, head, department of sanitary engineering, Johns Hopkins University, Baltimore, Md.

Security Survey Panel

This panel was appointed in December 1949 to survey the organization, administration, and functions of the security operation in the AEC. The panel members visited the Commission's installations and met extensively during the first 3 months of 1950. A report of their findings, submitted in April 1950, is now under study by the Commission.

JOHN S. BUGAS, chairman; vice president for industrial relations, Ford Motor Co., Detroit, Mich.
DAVID LUKE HOPKINS, executive vice president and director, The Safe Deposit & Trust Co., Baltimore, Md.; vice president of board of trustees, Johns Hopkins University, Baltimore, Md.
Dr. PAUL E. KLOPSTEG, director of research, Technological Institute, Northwestern University, Evanston, Ill.; chairman, board of governors, Argonne National Laboratory, Chicago, Ill.; and member of executive committee, American Institute of Physics.
J. ARTHUR MULLEN, president, Glenvale Products, Detroit, Mich.; vice president, Standard Life & Accident Insurance Co., Detroit, Mich.

Stack Gas Problem Working Group

The appointment of this group was authorized in May 1948 to advise the Commission on the development of methods and equipment for keeping the atmosphere at and near AEC installations free of toxic or radioactive contamination. The group has held five meetings. Individual members also give consulting advice on specific proposals and problems.

Dr. ABEL WOLMAN, chairman; head, department of sanitary engineering, Johns Hopkins University, Baltimore, Md.
Dr. PHILIP DRINKER, professor of industrial hygiene, Harvard University School of Public Health, Boston, Mass.
Dr. LYLE GILBERTSON, research division, Air Reduction Sales Co. Laboratory, New York, N. Y.

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Dr. GEORGE R. HILL, director, department of agricultural research, American Smelting & Refining Co., Salt Lake City, Utah.

Dr. H. F. JOHNSTONE, professor of chemical engineering, University of Illinois, Urbana, Ill.

Dr. W. P. YANT, director of research, Mine Safety Appliances Co., Pittsburgh, Pa.

Ad Hoc Committee on Technological Information for Industry

This committee was appointed in July 1949 to advise the Commission on ways to improve the dissemination of its technical information to industry. A working committee was cleared and appointed in January 1950 to examine the Commission's technological files and processes with a view to recommending material which should be submitted for declassification. The working group has met three times since its appointment; it submitted a number of recommendations in February 1950 and is continuing its study of atomic energy technological developments.

SIDNEY D. KIRKPATRICK, chairman; member of working committee; vice president and director of editorial development, McGraw-Hill Book Co., Inc., New York, N. Y.

HENRY A. BARTON, director, American Institute of Physics, New York, N. Y.

H. E. BLANK, editor, Modern Industry, New York, N. Y.

GENE HARDY, Washington editor, Chilton Publications, Inc., Washington, D. C.

KEITH HENNEY, member of working committee; consulting editor, Electronics and Nucleonics, McGraw-Hill Publishing Co., Inc., New York, N. Y.

EDWARD KREUTZBERG, editor, Penton Publishing Co., Washington, D. C.

WALTER J. MURPHY, editor, Chemical and Engineering News, American Chemical Society, Washington, D. C.

CHARLES S. RICH, editor, Electrical Engineering, American Institute of Electrical Engineers, New York, N. Y.

GEORGE F. SULLIVAN, managing editor, The Iron Age, Chilton Publications, Inc., New York, N. Y.

GEORGE STETSON, editor, Mechanical Engineering, American Society of Mechanical Engineers, New York, N. Y.

E. E. THUM, member of working committee; editor, Metal Progress, American Society for Metals, Cleveland, Ohio.

S. A. TUCKER, member of working committee; standards manager, The American Society of Mechanical Engineers, New York, N. Y.

F. J. VAN ANTWERPEN, member of working committee; editor, Chemical Engineering Progress, American Institute of Chemical Engineers, New York, N. Y.

Dr. ALBERTO F. THOMPSON, secretary; chief, technical information branch, public and technical information service, AEC, Washington, D. C.

Technical Information Panel

This panel, representing the major AEC research contractors, was appointed in June 1948 to advise the Commission on all aspects of its technical information services. Meetings are held three times a year to consider technical information problems and to make recommendations toward improving the Commission's technical information services.

Dr. ALBERTO F. THOMPSON, chairman; chief, technical information branch, public and technical information service, AEC, Washington, D. C.

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Dr. RUSSELL BALDOCK, research physicist, isotope research and production division, Carbide & Carbon Chemicals Division, Union Carbide & Carbon Corp. (Y-12), Oak Ridge, Tenn.

Dr. HENRY A. BLAIR, director, Atomic Energy Project, University of Rochester, Rochester, N. Y.

BREWER F. BOARDMAN, chief, technical information division, office of research, AEC, Oak Ridge, Tenn.

W. E. DREEZEN, administrative aide to director, Ames Laboratory, Ames, Iowa.

Dr. M. M. HARING, director, Mound Laboratory, Miamisburg, Ohio.

SYLVAN HARRIS, manager, documents department, Sandia Corp., Albuquerque, N. Mex.

W. L. HARWELL, head, patents and declassification department, Carbide & Carbon Chemicals Division, Union Carbide & Carbon Corp. (K-25), Oak Ridge, Tenn.

JOHN F. HOGERTON, technical reports director, The Kellex Corp., New York, N. Y.

Dr. E. J. MURPHY, assistant to research director, Carbide & Carbon Chemicals Division, Union Carbide & Carbon Corp. (ORNL), Oak Ridge, Tenn.

Dr. G. M. MURPHY, professor of chemistry, New York University, N. Y.

Dr. DANIEL J. PFLAUM, chief, materials and information branch, division of research, AEC, Washington, D. C.

DENNIS PULESTON, head, information and publications division, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. RICHARD F. RILEY, chief, radiation chemistry section, Atomic Energy Project, University of California, Los Angeles, Calif.

Dr. CHARLES SLESSER, director, technical information and declassification service, AEC, New York, N. Y.

Dr. RALPH CARLISLE SMITH, assistant director for classification and security, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. J. R. STEHN, physicist, theoretical physics division, Knolls Atomic Power Laboratory, Schenectady, N. Y.

C. G. STEVENSON, chief librarian, General Electric Co., Richland, Wash.

Dr. R. K. WAKERLING, chief, information division, Radiation Laboratory, Berkeley, Calif.

Dr. H. D. YOUNG, director, information division, Argonne National Laboratory, Chicago, Ill.

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APPENDIX 3

MAJOR RESEARCH CENTERS OF THE U. S. ATOMIC ENERGY COMMISSION

Ames Laboratory (Iowa State College, contractor)
Ames, Iowa

Director—Dr. FRANK H. SPEDDING
Associate Director—Dr. H. A. WILHELM
Assistant to Director—Dr. E. I. FULMER
Senior Physicist—Dr. G. W. FOX

Argonne National Laboratory (University of Chicago, contractor)
Chicago, Ill.

The participating institutions are:

Battelle Memorial Institute
Carnegie Institute of Technology
Case Institute of Technology
Illinois Institute of Technology
Indiana University
Iowa State College
Kansas State College
Loyola University (Chicago, Ill.)
Marquette University
Mayo Foundation
Michigan College of Mining and Technology
Michigan State College
Northwestern University
Notre Dame University
Ohio State University
Oklahoma Agricultural and Mechanical College
Purdue University
St. Louis University
Washington University (St. Louis, Mo.)
Western Reserve University
University of Chicago
University of Cincinnati
University of Illinois
University of Iowa
University of Kansas
University of Michigan
University of Minnesota
University of Missouri
University of Nebraska
University of Pittsburgh
University of Wisconsin

Director—Dr. WALTER H. ZINN
Deputy Director—Dr. NORMAN HILBERRY
Assistant Director—Dr. T. S. CHAPMAN

Brookhaven National Laboratory (Associated Universities, Inc., contractor)
Upton, Long Island, N. Y.

The participating institutions are:

Columbia University
Cornell University
Harvard University
Johns Hopkins University
Massachusetts Institute of Technology
Princeton University
Yale University
University of Pennsylvania
University of Rochester

President, Board of Trustees, AUI---------- Dr. FRANK D. FACKENTHAL
Director, Laboratory---------- Dr. LELAND J. HAWORTH
Assistant Director, University Liaison---------- Dr. ROBERT A. PATTERSON
Assistant Director, Biology and Medicine---------- Dr. DONALD D. VAN SLYKE

Knolls Atomic Power Laboratory (General Electric Co., contractor)

Schenectady, N. Y.

General Manager---------- WILLIAM H. MILTON, JR.
Director---------- Dr. K. H. KINGDON

Los Alamos Scientific Laboratory (University of California, contractor)

Santa Fe, N. Mex.

Director---------- Dr. NORRIS E. BRADBURY
Assistant to the Director---------- Dr. JOHN H. MANLEY
Technical Associate Director---------- Dr. DAROL K. FROMAN

Mound Laboratory (Monsanto Chemical Co., contractor)

Miamisburg, Ohio

Director---------- Dr. M. M. HARING
Assistant Director---------- Dr. JOSEPH J. BURBAGE
Assistant Director---------- Dr. ROBERT A. STANIFORTH
Executive Director---------- PRESCOTT SANDIDGE

Oak Ridge Institute of Nuclear Studies (contractor)

Oak Ridge, Tenn.

The sponsoring universities of the Institute are:

Agricultural and Mechanical College of Texas	University of Alabama
Alabama Polytechnic Institute	University of Arkansas
Catholic University of America	University of Florida
Duke University	University of Georgia
Emory University	University of Kentucky
Georgia Institute of Technology	University of Louisville
Louisiana State University	University of Mississippi
Mississippi State College	University of North Carolina
North Carolina State College	University of South Carolina
Rice Institute	University of Oklahoma
Tulane University of Louisiana	University of Tennessee
Vanderbilt University	University of Texas
Virginia Polytechnic Institute	University of Virginia

Chairman of Council---------- Dr. LOUIS A. PARDUE
Vice Chairman of Council---------- Dr. G. H. BOYD
President of Institute---------- DR. PAUL M. GROSS
Vice President of Institute---------- Dr. J. W. BEAMS
Scientific and Educational Consultant---------- Dr. GEORGE B. PEGRAM
Executive Director of Institute---------- Dr. WILLIAM G. POLLARD

Oak Ridge National Laboratory (Carbide & Carbon Chemicals Division, Union Carbide & Carbon Corp., contractor)

Oak Ridge, Tenn.

Director	Dr. C. E. Larson
Executive Director	S. C. Barnett
Research Director	Dr. A. M. Weinberg
Assistant Research Director	Dr. J. A. Swartout

Radiation Laboratory (University of California, contractor)

Berkeley, Calif.

Director	Dr. Ernest O. Lawrence
Associate Director	Dr. Donald Cooksey
Assistant Director	William M. Brobeck
Director, Crocker Laboratory—Medical Physics	Dr. Joseph G. Hamilton
Director, Donner Laboratory of Medical Physics	Dr. J. H. Lawrence
Assistant Director, Donner Laboratory	Dr. Hardin Jones

Reactor Testing Station

Idaho Falls, Idaho

Manager, Idaho Operations Office	L. E. Johnston
Assistant Manager	W. C. Funk

Rochester Atomic Energy Project (Rochester University, contractor)

Rochester, N. Y.

Director	Dr. Henry A. Blair
Assistant Director for Education	Dr. J. Newell Stannard
Business Manager	C. M. Jarvis

Sandia Laboratory (Sandia Corp., subsidiary of Western Electric Co., Inc., contractor)

Sandia Base, Albuquerque, N. Mex.

President	George A. Landry
Vice President	F. Schmidt

Westinghouse Electric Corp., Atomic Power Division (contractor)

Pittsburgh, Pa.

Manager, Westinghouse Atomic Power Division	C. H. Weaver
Assistant Manager	E. L. Kuno
Technical Director	Dr. Charles M. Slack
Director of Research	Dr. W. E. Shoupp

University of California, Los Angeles, Atomic Energy Project (University of California, contractor)

Los Angeles, Calif.

Director	Dr. Stafford Warren
Business Manager	Robert J. Buettner

APPENDIX 4

Distribution of Isotopes From Isotopes Division

OAK RIDGE, TENN.

DOMESTIC	NUMBER OF SHIPMENTS				
	Aug. 2, 1946, to June 30, 1947	July 1, 1947, to June 30, 1948	July 1, 1948, to June 30, 1949	July 1, 1949, to May 31, 1950	Total to May 31, 1950
Shipments classified by broad field of utilization:					
Radioactive Isotopes:					
Medical Therapy	407	884	1,564	2,306	5,161
Animal Physiology	280	712	890	1,038	2,920
Physics	82	175	271	300	828
Chemistry	74	188	254	209	725
Plant Physiology	49	107	195	259	610
Industrial Research	42	68	135	182	427
Bacteriology	11	53	79	58	201
Other		4	187	337	528
Total	945	2,191	3,575	4,689	11,400
Stable Isotopes:					
Physics	27	175	245	263	710
Chemistry	12	69	68	66	215
Animal Physiology	16	35	33	23	107
Industrial Research		21	4	6	31
Plant Physiology		5	9	2	16
Bacteriology		2	4		6
Other			6	2	8
Total	55	307	369	362	1,093
Shipments classified by kind of Isotope:					
Radioactive Isotopes:					
Iodine 131	276	741	1,213	1,762	3,992
Phosphorus 32	260	747	1,221	1,411	3,639
Carbon 14	88	134	148	197	567
Sodium 24	32	113	152	286	583
Sulfur 35	31	35	89	106	261
Gold 198, 199	63	23	39	63	188
Calcium 45	22	40	55	70	187
Iron 55, 59	26	34	48	48	156
Cobalt 60	24	22	55	64	165
Potassium 42	23	24	53	81	181
Strontium 89, 90	7	15	17	28	67
Other (61)	93	263	485	573	1,414
Total	945	2,191	3,575	4,689	11,400
Stable Isotopes:					
Deuterium oxide (heavy water)	31	115	116	76	338
Deuterium (hydrogen 2)	22	97	79	86	284
Boron 10 and 11	2	35	32	33	102
Helium				7	7
Oxygen 18		23	17	17	57
Electromagnetic concentrated		37	125	143	305
Total	55	307	369	362	1,093

DISTRIBUTION OF ISOTOPES FROM ISOTOPES DIVISION—Continued

DOMESTIC	TOTAL NUMBER OF SHIPMENTS TO MAY 31, 1950	
	Radioactive	Stable
Shipments classified by State and Territory:		
Alabama	29	1
Arizona	1	----------
Arkansas	42	----------
California	1,041	65
Colorado	48	2
Connecticut	207	36
Delaware	30	7
Florida	68	----------
Georgia	165	6
Illinois	864	175
Indiana	164	32
Iowa	83	4
Kansas	16	2
Kentucky	49	----------
Louisiana	189	6
Maine	2	----------
Maryland	771	33
Massachusetts	1,284	123
Michigan	388	28
Minnesota	416	26
Mississippi	4	----------
Missouri	376	15
Montana	1	5
Nebraska	85	----------
New Hampshire	2	----------
New Jersey	137	32
New Mexico	18	----------
New York	1,495	111
North Carolina	161	11
Ohio	774	119
Oklahoma	19	8
Oregon	112	5
Pennsylvania	669	93
Rhode Island	3	1
South Carolina	38	----------
Tennessee	326	11
Texas	497	29
Utah	48	2
Virginia	91	2
Washington	101	7
West Virginia	1	1
Wisconsin	313	46
District of Columbia	265	49
Hawaii	7	----------
Total	11,400	1,093

FOREIGN	TOTAL NUMBER OF SHIPMENTS TO MAY 31, 1950	
	Radioactive	Stable
Shipments classified by country:		
Argentina	45	----------
Australia	93	----------
Belgium	87	----------
Brazil	23	----------
Canada	32	----------
Chile	4	----------
Colombia	3	----------
Cuba	2	----------
Denmark	98	----------
Egypt	1	----------
Finland	5	----------
France	26	----------
Iceland	2	----------
Italy	6	----------
Japan	6	----------
Mexico	1	----------
Netherlands	37	----------
New Zealand	7	----------
Norway	35	----------
Peru	7	----------
Spain	4	----------
Sweden	124	----------
Switzerland	28	----------
Turkey	4	----------
Union of South Africa	27	----------
United Kingdom:		
Bermuda	14	----------
British West Africa	1	----------
England	88	----------
Uruguay	3	----------
Total	813	----------
Shipments classified by kind of isotope:		
Phosphorus 32	380	----------
Iodine 131	196	----------
Carbon 14	77	----------
Sulfur 35	47	----------
Iron 55, 59	33	----------
Cobalt 60	24	----------
Calcium 45	19	----------
Strontium 89, 90	8	----------
Other	29	----------
Total	813	----------

APPENDIX 5

FELLOWSHIP BOARDS FOR AEC FELLOWS FOR 1950–1951

FELLOWSHIP BOARDS OF THE NATIONAL RESEARCH COUNCIL

Postdoctoral Research in Physical Sciences

Dr. ROGER ADAMS, chairman; professor and head, department of chemistry, University of Illinois, Urbana, Ill.

Dr. CARL D. ANDERSON, professor of physics, California Institute of Technology, Pasadena, Calif.

Dr. KENNETH T. BAINBRIDGE, professor of physics, Harvard University, Cambridge, Mass.

Dr. GEORGE GLOCKLER, professor of physical chemistry and head, department of chemistry and chemical engineering, The State University of Iowa, Iowa City, Iowa.

Dr. WILLIAM W. RUBEY, principal geologist, United States Geological Survey, Washington, D. C.

Postdoctoral Research in Biological and Agricultural Sciences

Dr. R. G. GUSTAVSON, chairman; chancellor, University of Nebraska, Lincoln, Nebr.

Dr. H. K. HARTLINE, professor of biophysics, Johns Hopkins University, Baltimore, Md.

Dr. G. EVELYN HUTCHINSON, professor of zoology, Yale University, New Haven, Conn.

Dr. W. J. ROBBINS, director, New York Botanical Garden; professor of botany, Columbia University, New York, N. Y.

Dr. L. J. STADLER, professor of field crops, University of Missouri, Columbia, Mo.

Postdoctoral Research in Medical Sciences

Dr. HOMER W. SMITH, chairman; professor of physiology, New York University Bellevue Medical Center, New York, N. Y.

Dr. PAUL B. BEESON, professor of medicine and chairman, department of medicine, Emory University School of Medicine, Atlanta, Ga.

Dr. AUSTIN M. BRUES, director, biology division, Argonne National Laboratory, Chicago, Ill.; associate professor of medicine, University of Chicago, Chicago, Ill.

Dr. SAM L. CLARK, professor of anatomy and associate dean, Vanderbilt University School of Medicine, Nashville, Tenn.

Dr. HYMER L. FRIEDELL, director, department of radiology, Lakeside Hospital, Western Reserve University, Cleveland, Ohio.

Dr. JOSEPH G. HAMILTON, associate professor of experimental medicine and radiology and associate professor of medical physics, Crocker Laboratory, University of California, Berkeley, Calif.

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Predoctoral Research in Physical Sciences

Dr. HENRY A. BARTON, chairman; director, American Institute of Physics, New York, N. Y.
Dr. JOHN C. BAILAR, JR., professor of chemistry, University of Illinois, Urbana, Ill.
Dr. TOM W. BONNER, professor of physics, Rice Institute, Houston, Tex.
Dr. J. WILLIAM BUCHTA, professor of physics and chairman, department of physics, University of Minnesota, Minneapolis, Minn.
Dr. G. A. HEDLUND, professor of mathematics, Yale University, New Haven, Conn.
Dr. CHARLES C. PRICE, professor of chemistry and head, department of chemistry, University of Notre Dame, Notre Dame, Ind.

Predoctoral Research in Biological Sciences

Dr. DOUGLAS WHITAKER, chairman; professor of biology and dean of graduate study, Stanford University, Palo Alto, Calif.
Dr. J. H. BODINE, professor of zoology, The State University of Iowa, Iowa City, Iowa.
Dr. HOWARD B. LEWIS, John Jacob Abel university professor of biological chemistry, University of Michigan, Ann Arbor, Mich.
Dr. RAYMOND E. ZIRKLE, professor of radiobiology, Institute of Radiobiology and Biophysics, University of Chicago, Chicago, Ill.

REGIONAL PREDOCTORAL FELLOWSHIP BOARDS OF THE AEC

EASTERN FELLOWSHIP BOARD

(Administered by Associated Universities, Inc., Upton, Long Island, N. Y.)

Physical Sciences

Dr. T. B. DREW, head, department of chemical engineering, Columbia University, New York, N. Y.
Dr. R. W. DODSON, chairman, chemistry department, Brookhaven National Laboratory, Upton, Long Island, N. Y.
Dr. J. C. BOYCE, chairman, department of physics, New York University, New York, N. Y.

Biological Sciences

Dr. L. F. NIMS, chairman, biology department, Brookhaven National Laboratory, Upton, Long Island, N. Y.
Dr. H. H. ROSSI, assistant professor of radiology (physics), Radiological Research Laboratory, College of Physicians and Surgeons, Columbia University, New York, N. Y.
Dr. D. D. VAN SLYKE, assistant director, Brookhaven National Laboratory, Upton, Long Island, N. Y.

MIDWEST FELLOWSHIP BOARD

(Administered by the University of Chicago, Chicago, Ill.)

Biological and Physical Sciences

Dr. WARREN C. JOHNSON, chairman; chairman, department of chemistry, University of Chicago, Chicago, Ill.

Dr. ERNEST F. BARKER, chairman, department of physics, University of Michigan, Ann Arbor, Mich.
Dr. EDWARD CREUTZ, professor of nuclear physics, Carnegie Institute of Technology, Pittsburgh, Pa.
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Dr. TITUS C. EVANS, head, Radiation Research Laboratory, College of Medicine, State University of Iowa, Iowa City, Iowa.
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APPENDIX 6

AEC CONTRACT RESEARCH ON RADIATION EFFECTS AND RADIATION PROTECTION [1]

Amherst College. H. H. Plough, Research in Radiobiology and Chemical Genetics.—Mutant strains of *Salmonella* will be produced by radiation and a study made of the biochemical mechanisms whereby the genes control metabolic or growth changes in bacterial cells.[2]

Army Medical Center. G. M. McDonnell, Antibiotic Therapy in the X-ray Irradiation Syndrome.—Study of the use of aureomycin in the X-irradiation syndrome and its effect on decreasing mortality, reducing or eliminating the hemorrhagic phenomena that accompany lethal doses of irradiation, and relief of symptoms of syndrome.

Arthur D. Little, Inc. Earl Stafford, W. J. Smith, Thornton Stearns, Development of Improved High-Efficiency Air Filter.—An improved high-efficiency air filter has been developed and design information and specifications are being sent to prospective commercial manufacturers. A routine method for determining absolute performance characteristics of air filters has been devised, improved filter installation schemes have been designed, and work is progressing on the development of standard air-sampling filter papers.

Air Reduction Co. L. I. Gilbertson and A. Muller, Development of Incinerator for AEC Plant Contaminated Combustible Wastes.—Design and specifications of a chemical scrubber for removal of I 131 from dissolver off gases have been prepared. A pilot plant incinerator for handling solid combustible wastes was developed and is now being operated at Knolls Atomic Power Laboratory.

Bureau of Mines, Department of the Interior. Richard C. Corey, Development of Incinerator for Off-Area Users of Radioisotopes.

California Institute of Technology. G. W. Beadle, The Genetic and Cytological Effects of High Energy Radiation.—Mutant strains of *Neurospora crassa* and *Drosophila melanogaster* produced by radiation are being studied to determine the exact chemical process that is interfered with by the genetic change. The chromosome rearrangements in corn exposed to radiation in the Bikini tests are being studied for a critical comparison with X-ray treatment. The work with corn includes a genetical biochemical study of the development of the endosperm.[2]

California, University of. J. H. Lawrence, Immediate and Delayed Biochemical and Biological Effects of Irradiation on Animal Tissue.—To develop methods of causing radioactive materials to be selectively deposited in tissues, especially the lymphatic tissues. Specifically irradiated spleen, liver, and bone marrow will be investigated individually, with particular reference to biochemical assessment of tissue metabolism changes and possible relation to histological changes. Survey will be made of some of the enzyme systems within the body which may be impaired by *in vivo* irradiation. Also study of the responses in plasma protein levels as they are affected by specific irradiation of liver, spleen, bone

[1] Contracts listed as of May 31, 1950.
[2] Contracts Administered through Office of Naval Research, Washington, D. C.

5001154

marrow, or lymphatic tissue and compared to whole body irradiation, including survey of the plasma protein functions by standard electrophoretic and ultracentrifugation equipment.

Cedars of Lebanon Hospital. Paul E. Rekers, Relationship of Flavanoid Structures to Radiation Protection.—To study further the protective action of selected chemical compounds on the course of irradiation disease, and to explore the mode of action, or mechanism of action of these compounds.

Chicago, University of. Paul C. Hodges, Studies in Radioautographic Techniques.—Studies will be made of methods of producing a sharper image in fluoroscopic work, and an effort is being made to devise a method for X-raying the small intestine with 35 mm films.[2]

Chicago, University of.—C. Phillip Miller, The Bacteriological Aspects of Radiation Sickness.—Investigation of the effects of radiation on: (1) The animal host—using dogs and mice. The study is to include: (*a*) Effect of small doses of radiation, e. g., LD–50 and LD–25; (*b*) Systematic determination of bacterial flora at all levels of the gut; (*c*) Effect of various antibiotics on intestinal flora of normal and irradiated subjects and on bacteremia in irradiated subjects; and (*d*) Susceptibility of irradiated animals to infection. (2) Bacteria normally or potentially pathogenic for the host. (*a*) Induction by irradiation of easily detectable mutants; (*b*) determination whether virulence can be enhanced by irradiation; (*c*) production of bacterial endotoxin containing a tracer element.

Chicago, University of. R. E. Zirkle, The Design and Construction of a Microbeam of Light Atomic Nuclei for Biological Investigation.—The radio microbeam for biological investigations would have a cross section small in comparison with the single cell. Such a microbeam would permit selective irradiation of a part of individual cells and thereby contribute to the knowledge of cellular processes.[2]

Children's Medical Center of Boston.—M. H. Wittenberg, Effects of Radiation Therapy during Infancy and Childhood on the Growth of the Spine.—Re-examination of 100 to 110 patients previously X-rayed over the lumbar spine at the Children's Hospital. Study will be made to evaluate the possible growth disturbance produced by the previous X-ray therapy.

Columbia University. G. Failla, Dosage Determination; Biological Action of Ionizing Radiation; Training Program.—Determination of the dose of ionizing radiations at any desired point or region in the biological system, in terms of the energy absorbed per gram of tissue; study of the biological action of ionizing radiations by the administration of radiation from sources outside the tissue or within the tissue (radioisotopes); training of physicists in radiologic physics and radiobiology.

Columbia University (Barnard). Aubrey Gorbman, The Biological Effects of Radiation from Excessive Amounts of Radioiodine.—This project investigates whether thyroid hormone synthesis develops in a stepwise manner or if the ability to form new hormone develops suddenly. The studies include (1) the effects upon the thyroid and neighboring tissues of radiotoxic doses of radioiodine; (2) an analysis of the function of the thyroid on unborn mice.[2]

Columbia University. David Nachmansohn, Effects of Exposure to Radioactive Material and X-ray Irradiation on Nerve Tissue.—A study using radioactive isotopes of the effect of beta particles and gamma rays on nerve structure and

[2] Contracts Administered through Office of Naval Research, Washington, D. C.

5001155

function using the single nerve fiber of the giant squid. Especially concerned with effect of radiation on reaction of nerve to pharmacological agents.[2]

Connecticut Agricultural Experiment Station. J. G. Horsfall, Therapy of Plant Disease by Nuclear Radiations.—Use of radioactive materials as tracers to better understand action and movement of possible chemotherapeutic materials. Also exploration of possibilities of use of radiation from radioactive materials as direct therapeutic agents in diseases of plants.

Delaware, University of. Mary A. Russell, Comparison of the Effects of X-rays, Neutrons, and Mustard Compounds on the Growth and Development of the Corn Seedling.—Effects on growth of roots of exposure to X-rays, neutrons, and mustard compounds are compared. The cytological effects of such treatments to growth types are being studied.[2]

Denver, University of. Fred D'Amour, The Physiologic and Pathologic Effects of Radioactive Cobalt.—The physiological effects of the cobalt ion will be compared with those of the radioactive isotope. The effects of radioactive cobalt on various physiological processes such as hematopoieses, endocrine function, and production of carcinoma are being studied.

Florida, University of. A. A. Bless, Radiation Injury.—Study of bioelectric potentials as a measure of radiation injury to plants and animals.

Harvard University. H. L. Blumgart, Radioactive Therapy of Graves' Disease.—Use of radioactive iodine in therapy in Graves' disease and other thyroid disorders.[2]

Harvard University. D. C. Cogan, Production of Cataracts by Neutrons and other Radiations.—To determine the cataractogenic dose of neutrons and gamma rays as a function of acute exposures and as a function of fractional exposures at varying intervals.

Harvard University. Philip Drinker and Leslie Silverman, Testing, Evaluation, and Development of Air Cleaning Methods and Equipment.

Harvard University. O. Gates, Effects of Radiation on Development of Rat Embryos.—Study of the effects of radiation upon the development of the nervous system by irradiating female animals at varying stages during their pregnancies. X-ray is alleged to produce malformations of the brain such as microgyria in the developing fetus and this study should throw some light on the subject.

Harvard University. V. E. Kinsey, Effects of Neutrons and other Radiation on the Ocular Lens.—It is proposed to investigate the metabolism of normal lenses, and those from eyes previously irradiated with neutrons and various forms of short-wave radiation.

Harvard University. Karl Sax, Dosage Curves Under Varying Conditions of Time and Intensity of Radiation.—The cytological effects of X-ray and the short wave radiations are being investigated, as are the effects of various secondary factors such as low temperature, infrared, and supersonic radiation on chromosomal aberrations.[2]

Harvard University. S. Warren, Use of Isotopes as Therapeutic and Diagnostic Agents.—Chief concern is the evaluation of radioactive phosphorus in various types of leukemia, both before and after radiation therapy, the utilization of

[2] Contracts Administered through Office of Naval Research, Washington, D. C.

500156

radioactive phosphorus and radioactive calcium in studies of cell metabolism in relation to the growth and development of leukemic and cancerous cells, and certain aspects of the alteration in uptake of P 32 following irradiation.

Haskins Laboratory, Inc. S. H. Hutner, The Microbiological Assay of Nucleic Acid Constituents Produced by Radiation.—It is proposed to develop microbiological methods for the identification and the quantitative assay of components of nucleic acids, with eventual aim of examining the blood of normal and injured animals to determine whether the extent of radiation sickness correlates with the release of nucleic acid derivatives.

Illinois, University of. A. C. Ivy, Irradiation of Gastric Mucosa.—Study of the effect of irradiation of gastric mucosa, in dogs with gastric fistulas, by means of the intragastric introduction of radioactive isotopes. If the results indicate the practicability of intragastric irradiation, the experiments will be applied to human subjects for inducing achlorhydria in the treatment of peptic ulcer and for the irradiation of certain types of gastric malignancies.

Illinois, University of. H. F. Johnstone, Fundamental Investigations of Properties and Characteristics of Aerosols.—Reports on the calculation of the size, distribution, and mass median diameter of aerosol particles from tranquil and stirred settling data have been completed and distributed. Reports on the analysis of factors affecting the efficiency of aerosol collection by impaction, and on the effects of temperature and velocity of gases on dispersion from stacks are being prepared.

Illinois, University of. L. Ridenour, Construction of a Radiocobalt Applicator.—An applicator for giving whole-body radiation to mice is being constructed. It will be used to study the lethal effect of radiation in mice, decoloration of hair, radiation-induced changes in the brain and liver, and enzyme reactions in irradiated tissue.[2]

Iowa, State University of. T. C. Evans, Quantitative and Morphologic Study of Radiation Induced Cataracts.—Exposing groups of mice to various doses of neutrons and X-rays to determine the relative effectiveness of these neutrons and X-rays on cataract production, and to learn everything possible about the mechanism of cataract formation.

Johns Hopkins University. W. D. McElroy and C. P. Swanson, Modification Through the Use of Supplementary, Environmental Factors of the Frequency of Gene and Chromosome Changes Induced by X-rays, Radioactive Isotopes, Ultra-Violet Light and Nitrogen Mustard.—Study involving experiments designed to provide a better understanding of the mechanics of induction of chromosomial and genic changes by mutagenic agents, and the frequency of these changes as modified through the use of supplementary environmental agents.

Johns Hopkins University. A. Wolman and C. E. Renn, Adsorption and Assimilation of Radioactive Materials by Surface Slimes.—Study of the adsorption and assimilation of radioactive wastes by bacterial slimes and the flow and dilution of controlled radioactive wastes. Findings will be useful in determining safe waste disposal measures.

Johns Hopkins University. A. Wolman, J. C. Geyer, C. E. Renn, D. Carritt, Mechanisms of Concentration of Radioactivity in Plumbing Systems.—Circulation of estuarian waters in relation to dispersion and diffusion of radioactive

[2] Contracts Administered through Office of Naval Research, Washington, D. C.

5001157

materials; adsorption of radioactive material by natural waterborne silts; behavior and distribution of radioactive material in incinerators when used for disposing of radioactive wastes.

Kansas, University of. F. E. Hoecker, Studies of the Biological Effects of Ionization.—The biological effects of electrons, neutrons, and alpha particles on cells are being studied and compared.[2]

Kansas, University of. R. E. Stowell, Cytochemical, Microchemical, and Biophysical Studies of Tumors and Effects of Radiation upon Cells.—Study of the structural, physical, and chemical changes produced in cells by ionizing radiation and a comparable study of cells in normal and abnormal growth including tumors.

Long Island Biological Association of Cold Spring Harbor. M. Demerec, Study of the Accumulation and Elimination of Deleterious Gene Mutations in Experimental Populations Exposed to Radiations.—This project concerns the accumulation of lethals, semilethals, viability modifiers, and their elimination by natural selection in populations (*Drosophila*) exposed chronically to relatively small amounts of radiation or to single high levels of radiation.

Massachusetts General Hospital. J. H. Means, The Effects of Radioactive Iodine on the Biology of the Thyroid Gland.—Study of radiation effects both early and late by biopsy of thyroid of patients of the Thyroid Clinic of the Massachusetts General Hospital. The effect of repeated tracer doses upon the biology of the normal human gland also to be studied.

Massachusetts Institute of Technology. R. Eliassen, Efficiency of Methods used in Removing Radioactive Substances from Water.—To explore the effectiveness of currently used water treatment processes for the removal of radioactive substances from drinking water and to survey developments in instrumentation to determine those most applicable to detecting and evaluating the nature and concentration of radioactive substances in municipal water supplies.

Massachusetts Institute of Technology. J. C. Trump, Sterilization of Foods and Drugs with High Energy Cathode Rays.—In this study, the effects of high energy X-rays in bacterial enzymes, vitamins, spores, and other organic forms will be investigated. Attempts will be made to improve methods for using such radiations to sterilize foods and drugs, to determine whether these high-energy radiations will harm these foods and to determine the economic practicality of large-scale use of these methods.[2]

Meharry College. P. F. Hahn, Use of Radioactive Gold in Treatment of Tumors.—Therapeutic and diagnostic studies of malignancies with use of isotopes, particularly colloidal gold 198.

Memorial Hospital (*Sloan Kettering Institute*). R. W. Rawson, Physiological Effects of Irradiation in Patients Receiving Large Doses of Iodine 131.—To determine the effect of irradiation of human beings with iodine 131 and to compare such effects with those observed in patients subjected to X-radiation.

Memorial Hospital (New York). H. Q. Woodward and C. P. Rhoads, Measurement of Effects of Irradiation on Bone and Bone-Phosphatase Activity.—A program of research and measurements pertinent to the effects of irradiation dosage on bone and bone-phosphatase activity.

[2] Contracts Administered through Office of Naval Research, Washington, D. C.

5001158

Memorial Hospital (New York). C. P. Rhoads, Cancer Research.—Part I.—Investigations Involving Use of Isotopes and Radiation in the Study of Protein Chemistry, Physics, Experimental Pathology, Immunochemistry, Immunology, and Special Tumors. Part II. Distribution of Isotopes in Therapy.[2]

Michigan, University of. F. H. Bethell, Study of Biological Effects of Radiation.—To determine the biological effects of ionizing radiation, the secondary manifestation of radiation injury, and the development of therapeutic means for combating changes induced by or resulting from such injury.

Michigan, University of. Reuben L. Kahn and Fred J. Hodges, Universal Serologic Reaction Following Irradiation.—Performance of universal serological tests on patients before and after irradiation, and on animals before and after irradiation. Investigation of different lipid antigens in the universal serological technique; serum fractions in the universal serological technique; technical variations of the universal serological technique.

Minnesota, University of. George E. Moore, The Study of Methods and Instruments to Improve the Localization of Radioactive Materials in the Body with Special Reference to the Diagnosis of Brain Tumors.—Radioactive diiodofluorescein (I–131) is used in an attempt to diagnose and localize brain tumors before operation. Also, attempts to use radioopaque dyes for the localization of brain tumors by roentgenography, hitherto unsuccessful, are continuing. Investigation of sensitivity of various counters and counter systems including scintillation counters, development construction of multiple counter apparatus.

Minnesota, University of. E. C. Stakman, The Effects of Radioactive Substances on Plant Pathogens and Other Micro-organisms.—The effect of radioactive substances in culture media on the production of valuable mutations in selected groups of micro-organisms of economic value is being determined. The cultural characteristics and physiology of induced mutants and the genetic effects of mildly radioactive substances on soil-borne plant pathogens will be studied.

Mount Sinai Hospital. S. Feitelberg, Investigation of Sewage Water Contamination by Radioactive Isotopes.—To determine experimentally the contamination of sewage water resulting from discharge of radioactive materials into drains under various conditions of flushing and rinsing and to determine residual radioactivity in drain fixtures (traps, etc.).

Mount Sinai Hospital. M. Loevinger, Measurement of Tissue Dose Due to Gamma and Beta Active Radioisotopes.—Present dosage standards for use of radiation in therapy have been based on X-ray and radium. The present study is one of a series financed by the AEC to determine comparable dosage standards for radioactive cobalt (cobalt 60) which has been suggested as an inexpensive substitute for radium in the treatment of cancer and other diseases requiring radiation.

National Academy of Sciences. Atomic Bomb Casualty Commission.—Long-range radiation studies of the inhabitants of the atom-bombed cities of Hiroshima and Nagasaki to determine the medical changes brought about in those exposed to the bomb explosion and the genetic changes, if any, of the ionizing radiations on the offspring of those exposed to the bomb explosion.

National Research Council. Investigation of the Incidence of Cataract in Persons Receiving Ionizing Radiations from Cyclotrons.—The investigations will include examinations by competent physicians and ophthalmologists, of persons

[2] Contracts Administered through Office of Naval Research, Washington, D. C.

5001159

known or suspected to have developed cyclotron-induced cataracts and the available data on the conditions and times of exposure.

New York Medical College. A. L. Copley, Study of Vascular Factors in Radiation Hemorrhage and Other Hemorrhagic Diatheses in Patients and Experimental Animals.—To study primarily the vascular factors in mechanisms which bring about capillary hemorrhage and the effects of various agents which may produce, inhibit, or counteract hemorrhagic manifestations in the terminal vascular bed.

New York University. Werner Grune (research initiated by R. Eliassen).—The purpose of this research is to determine the effects of radioactive substances and special materials on sewer systems and sewer treatment processes. It is hoped that mechanisms can be developed for removing radioactive substances from liquid wastes which are discharged into sewer systems.

New York University. Marion Sulzberger, Skin Changes Produced by Low Voltage Roentgen Ray Irradiation.—To determine possible influence of low voltage X-irradiation for treatment of dermatoses, upon incidence of skin cancers in some patients 2 to 12 years after therapy.[2]

North Carolina, University of. J. C. Andrews and M. K. Berkut, Tracer Studies and Irradiation in Dental Metabolism.—Study of the relationship between metabolic factors in tooth formation and susceptibility to decay, particularly in regard to fluorine intake.

North Carolina, University of. Donald P. Costello, Radiation Effects on Salamander Larvae.—Research to elucidate some of the effects of radiation from radioisotopes on living cells, using the tail tip of the larval salamander for the study of chromosome numbers and mitotic figures.

North Carolina State College. W. C. Gregory, The Effects of the Irradiation of Peanut Seed.—The possibilities of inducing mutants of value is being investigated by irradiation of seeds with appropriate levels of ionizing radiation. Progeny of irradiated seeds will be studied for chromosomal, morphological, and resistant mutants.

Northwestern University. J. Roscoe Miller, Radioisotope Unit for Investigation, Research, and Therapy.—Establishment of a radioisotope unit at Northwestern for: (A) Training of undergraduate and graduate students in use of isotopes in research, therapy, instrumentation, and radiological safety. (B) Provide isotopes for clinical therapy and research.[2]

Ohio State University. J. L. Morton, Use of Radioactive Cobalt 60 and Other Radioisotopes for Treatment of Cancer.—This study was proposed to develop the physical principles underlying the use of radioisotopes as a substitute for radium or X-ray in the treatment of cancer and allied diseases. Methods for measuring the radiation dosage will include use of photographic films and small ionization chambers having outside diameters as small as 5 millimeters.[2]

Ohio State University. M. L. Pool, Studies of Radioautographic Techniques.—Proposed to study methods and techniques of sharpening radioautographs by use of a very strong magnetic field.[2]

Oklahoma Agricultural & Mechanical College. A. Eisenstark, Study of Cytogenetic Effect of Irradiation, Using Radioactive Isotopes on Bacteria.—Radiophosphorus will be used to release energies within bacterial cells. *Azotobacter*

[2] Contracts Administered through Office of Naval Research, Washington, D. C.

500160

chroococcum exposed to various levels of radiation will be examined for cytological changes by means of the electron microscope, phase microscopy, and other techniques.

Oregon, University of. F. B. Queen, Evaluation of Body Content of Radium in Individuals with no Known Exposure.—To determine the total body content of radium in individuals of known residence with no known exposure to irradiation who have lived most of their lives in the Pacific Northwest (and before installation of the Hanford Fission Plant).

Oregon, University of. P. L. Risley, Localization of Radioactive Isotopes in Germ Cells and Reproductive Tissues During Quiescence and Activation.—Investigation of germinal tissues with respect to their chemical and metabolic requirements by use of radioisotopes. Purpose to administer radioisotopes to animal organisms of diverse kinds to determine if those now available can be demonstrated to localize in reproductive cells during different periods of relative quiescence and activity.[2]

Pittsburgh, University of. C. Moses and A. J. Allen, Effects of Neutrons from a Cyclotron on Mammals with Particular Reference to the Development of Cataracts.—Exposure of animals to doses of neutrons to determine the sequence of events leading to the development of cataracts.

Reed College. A. F. Scott, AEC Training Program.—Instruction will be given in basic nuclear science with special reference to the use of radioactive isotopes in the field of biology and medicine to such individuals as may be designated or approved by the Commission.

Tennessee, University of. F. S. Chance, The Effects and Use of Radioisotopes and of Radiation on Domestic Farm Animals.—Breeding and growth studies with cattle exposed to the dust "outfall" from the bomb at Alamogordo and histological and pathological studies of the tissues from some of these cattle. The use of radioisotopes in metabolism studies of farm animals will be investigated.

Tufts College. David Rapport, The Effects of Radiation Associated with Growth.—Effect of radiation and monochromatic ultraviolet light on normal and abnormal tissue homogenates, as indicated by alterations in the synthesis of ribose, and desoxyribose-nucleic acid—especially from histidine and pyrimidines.[2]

Union College. L. B. Clark, Biological Effects of High Voltage Radiation.—The biological effects of 1 million to 100 million volts produced by the synchrotron and betatron. The effect on physiological functions of the cells and enzyme systems of various levels of radiation are being studied. New techniques will be developed with micro-organisms and then extended to laboratory animals.[2]

U. S. Public Health Service, Department of Defense, ORNL (AEC). R. Morton, O. Placak, C. Straub, Decontamination of Radioactive Water Supplies.—New laboratory is being constructed. The initial phase of this project consists of evaluating existing civilian and military water treatment methods and equipment for removing radioactive contamination from water supplies.

U. S. Weather Bureau. R. Wanta, J. Z. Holland, Paul Humphrey, Meteorology in Relation to Disposal of Gaseous Effluents and Scheduling of Reactor and Chemical Operations.—Meteorological investigations are being carried out at Oak Ridge, Idaho, and in cooperation with Brookhaven National Laboratory.

[2] Contracts Administered through Office of Naval Research, Washington, D. C.

Studies of winds turbulence inversions and other meteorologic factors affecting disposal of gaseous effluents are being made.

U. S. Geological Survey. A. M. Piper, C. V. Theis, R. L. Hace, W. DeLanguna, G. De Buchanane, Hydrologic and Geologic Studies Related to Disposal of Liquid Wastes and Development of Water Supplies.—Studies of ground water flow and geology at Hanford, Los Alamos, Idaho, Brookhaven, Oak Ridge, Schenectady, and Chicago.

U. S. Public Health Service. C. C. Ruchhoft, Development of Methods of Waste Treatment and Disposal.—Development of biological and chemical methods of waste treatment in cooperation with Los Alamos Scientific Laboratory.

Virginia, University of. A. Chanutin, The Effects of X-Radiation on the Plasma Proteins.—Determine effect of radiation on plasma protein distribution of rats by ethanol fractionation procedures of *Collii.* The cholesterol, phospholipide, and total lipid carbon of these fractions will be determined.[2]

Virginia, University of. Chalmers L. Gemmill, The Effect of Beta Radiation on the Distribution of Phosphate in Red Blood Cells and in Cardiac Muscle.—A study of the transfer of radioactive phosphorus from the plasma into the red blood cell under the influence of various anesthetics, including a study of phosphate distribution between the various carbohydrate factors in the red blood cell and in the beating isolated heart.

Washington University, St. Louis. W. Allen, Use of Gamma Ray as a Therapeutic Agent in Carcinoma.—Use of colloidal gold 198 as a gamma-ray emitter in carcinoma therapy.[2]

Washington, University of. P. E. Church, Meteorological Studies.—To study the change of wind speed and direction with height in relation to the vertical temperature distribution (lapse rate) in the lowest 150 feet of the atmosphere at Seattle, Wash. The data and results obtained are basic to a better understanding of the whole problem of stack gas dilution.

Washington, University of. L. R. Donaldson, Basic Studies on Effect of Exposing Fish to X-ray Irradiation, and Resurveys of Bikini Expedition.—To gather information on the effects of exposing salmonoid fishes to X-ray. The over-all work program measures the irradiation effects on these species of salmonoid fishes that have long periods of fresh-water residence, and exposes those species to irradiation at the various stages of development during which they would normally be expected to be in fresh water.

Washington, University of. R. G. Fleagle, Meteorological Study.—To determine the empirical relationships between the coefficient of eddy diffusivity and temperature lapse rate, wind speed, and wind shear, in the lowest 150 feet of the atmosphere at Seattle, Wash. This project is basic to the attack on stack gas dilution problems.

Yale University. E. C. Pollard, Monomolecular Layers of Serological Agents.—The physical and biological effects of irradiating films of proteins with protons, electrons, gamma, and other rays.

[2] Contracts Administered through Office of Naval Research, Washington, D. C.

APPENDIX 7

Radiation Detection and Measurement Instrument Patents Available for Licensing

The following U. S. Letters Patents on radiation detection and measurement instruments owned by the United States Government as represented by the U. S. Atomic Energy Commission have been made available for licensing by the Commission. Licenses will be granted to applicants on a nonexclusive, royalty-free basis. Additional patents on radiation detection and measurement instruments, as well as other inventions, are being issued from the U. S. Patent Office from time to time. Abstracts will be published in the U. S. Patent Office *Register of Patents*, as in the past, and licenses issued to interested parties in accord with the policy of the Atomic Energy Commission.[1]

Pat. 2,436,084. IONIZATION CHAMBER. Issued Feb. 17, 1948, to B. L. Weller. Standard ionization chamber design has been modified with the intention of improving the reliability of the measurements and providing greater safeguards against the high voltages used in the instrument. This is accomplished by a system of guard rings and shields which prevent the appearance of high potentials across insulators and shield the different electrodes and leads from each other.

Pat. 2,437,476. DIFFERENTIAL TWIN CHAMBER NEUTRON METER. Issued Mar. 9, 1948, to H. M. Parker. This invention is designed to measure the intensity of neutron radiation in the presence of radiation of other types and especially of gamma rays. It also provides a means for detecting directional effects which may be eliminated in the final reading. The device consists of two ionization chambers, one filled with a gas like argon which is not ionized by neutron bombardment, the other filled with a gas rich in hydrogen, which is ionized by neutrons through the action of recoiling protons. The pressures in the two chambers are so adjusted that the ionization produced in each by equal gamma activities is equal. In order to measure neutron activity, the chamber walls are maintained at opposite potentials. The central conductors are connected to each other and a common lead goes to an electroscope. The chambers may be interchanged to detect directional effects.

Pat. 2,440,167. DIFFERENTIAL ION CHAMBER. Issued Apr. 20, 1948, to J. W. Broxon and W. P. Jesse. This invention is a device which may be operated to measure either the combined effects or the separate effects of slow neutrons and other penetrating radiation. The device consists, essentially, of three concentric cylinders, the spaces between them forcing two chambers of equal volume. The walls of the outer chamber are coated with some substance which emits alphas when bombarded with slow neutrons. The central cylinder is connected to the casing of the instrument through a galvanometer, and the other two cylinders may be maintained either at the same or opposite potentials. When they are at the same potential, the reading on the galvanometer is a measure of the total intensity of the penetrating radiation. When, on the other hand, the cylin-

[1] Patents listed as of May 2, 1950. Applicants for licenses should apply to the Chief, Patent Branch, Office of the General Counsel, U. S. Atomic Energy Commission, Washington 25, D. C., identifying the subject matter by patent number and title.

ders have opposite potentials, no reading is produced in the absence of slow neutron radiation since the ionizing effects of other radiation is the same in both chambers. The meter reading is then proportional to the intensity of slow neutron radiation.

Pat. 2,442,314. GEIGER COUNTER IMPROVEMENT. Issued May 25, 1948, to A. F. Reid. The alkyl mono-halides of two to six carbon atoms in their vapor phase have been found to be excellent quenching gases for Geiger counters. The halogen atom of the halide may be chlorine, bromine, iodine, or fluorine. The halide may be an ethyl, propyl, butyl, amyl, or hexyl halide. The mono-halides of higher chain length give better plateaus so that if an especially good plateau is desired, one of the amyl halides or hexyl halides should be used. As the atomic weight of the halogen atom decreases, the stability of the molecule increases and hence its lifetime. A useful range of pressures is 9 to 25 mm. Hg.

Pat. 2,443,365. SUPPORT FOR GEIGER-MUELLER COUNTERS. Issued June 15, 1948, to E. H. Wakefield. The apparatus consists of a Geiger-Mueller counter tube, an elongated radiation shield openable at one end, an elongated rigid support mounted in the other end of the shield and extending lengthwise in the shield cavity, a clamp slidable along the support, a counter tube rigidly secured to the clamp, an external insulated conductor extending into the shield cavity and connected to a conductor of the tube, means on the clamp securing one end of the external conductor in a fixed position relative to the tube, and a handle of electrically insulating material on the clamp and extending toward the openable end of the shield, whereby the tube may be moved along the support and remain free of tension on its conducting leads.

Pat. 2,458,632. IONIZATION CHAMBER. Issued Jan. 11, 1949, to J. H. Parsons. This device is a means for eliminating or reducing losses in high frequency electrical circuits. High frequency impulses are transmitted with a minimum of attenuaton. The instrument consists of a pair of parallel plate electrodes spaced in confronting relationship, a hollow cylindrical casing around, which is grounded, an electronic amplifying circuit having an input coupled to the collecting electrode, and an additional electrical shielding member connected to the cathode of the amplifying circuit and interposed between the collecting electrode and the casing.

Pat. 2,465,886. ELECTRICAL MEASURING APPARATUS. Issued Mar. 29, 1949, to O. G. Landsverk and E. O. Wollan. An improved fountain pen type electroscope for use in portable instruments measuring radioactivity is described. The rate of discharge of the electroscope is observed through a microscope, the light source of which may be made to flash after a predetermined interval; a timing means is adapted to indicate visually on an indicator the passage of a fixed time after its actuation.

Pat. 2,465,938. RADIATION MEASURING DEVICE. Issued Mar. 29, 1949, to F. R. Shonka. An improved ionization chamber for the measurement of particles and radiations emanating from radioactive materials is described. The improvement decreases the responsive time of the instrument. The apparatus consists of an ionization chamber circuit having a voltage supply, a direct-current electronic amplifier which has a cathode, an anode, a control electrode and an anode impedance; an input circuit is connected to the ionization chamber circuit and an output circuit adapted to produce an output voltage varying with the amount of ionization occurring in the chamber; a switch is provided for connecting the ionization chamber and voltage supply in series with the resistance.

5001164

Pat. 2,472,365. ALPHA PARTICLE COUNTING. Issued June 7, 1949, to C. J. Borkowski. An alpha-particle counting device is described which incorporates high geometry and a simple working mechanism for the easy determination of the degree of ionization in regions of the body, especially the hands. It contains an alpha-counting ionization chamber in which the high voltage electrode is the collecting electrode, and is in the form of a tube having an axially aligned rod which is connected to an amplifier.

Pat. 2,474,773. RADIATION DETECTOR. Issued June 28, 1949, to W. R. Baker. An electronic circuit is described which is used to amplify the pulses obtained in an ionization chamber. In particular, a cathode follower type preamplifier tube is provided, which has a very high effective input impedance and a relatively low time constant.

Pat. 2,479,271. IONIZATION CHAMBER CIRCUIT. Issued Aug. 16, 1949, to F. R. Shonka. An ionization chamber circuit and arrangement are described which eliminate the harmful effects of the grid-current of the vacuum tube connected with the control electrode of the chamber. In addition to the source of radioactivity which is being measured, a supplemental radioactive source is introduced which, by means of the circuit described, removes from the control electrode of the direct current amplifier the charge which it accumulates by reason of the collection of charge within the electronic tube. This procedure is especially useful in connection with an ionization chamber used for measurement of integrated radioactivity, for which the harmful grid-current effect would otherwise cause serious difficulty when the chamber is run over a period of several hours.

Pat. 2,479,600. IONIZATION CHAMBER. Issued Aug. 23, 1949, to C. J. Borkowski. An ionization chamber, simple in design and easy to assemble is described. It comprises a cylindrical glass envelope having two tapered ends, one end fitted with a stopcock and the other with a glass plug; a connecting rod is centered in the plug and serves as a central collecting electrode, while conducting material coated on the inside of the chamber serves as the other electrode.

Pat. 2,481,506. FAST NEUTRON METER. Issued Sept. 13, 1949, to C. C. Gamertsfelder, Jr. An apparatus for accurately measuring the intensity of neutron radiations in the presence of gamma radiations is described. There are two chambers arranged concentrically with respect to each other and around a rod electrode; both chambers are equally responsive to gamma radiations but the outer chamber is also responsive to neutrons; collecting fields of opposite charge are placed on the chambers. The net magnitude of the current generated in the two units is equal to the response to the neutron bombardment alone.

Pat. 2,481,964. FAST NEUTRON METER. Issued Sept. 13, 1949, to E. O. Wollan. An apparatus for the exclusive measurement of fast neutrons is described. It consists of two ionization chambers connected by a tube, each chamber containing two electrodes; the electrodes from the two chambers are connected, one pair forming the output terminal and the other pair the input terminal. The first chamber is filled with a gas of atomic weight not greater than four; the second chamber contains gas of atomic weight greater than four. Both chambers have a similar response to gamma rays, but one chamber has enough gaseous hydrocarbon added to permit proton recoil measurements to be made.

Pat. 2,483,991. RADIATION EXPOSURE METER. Issued Oct. 4, 1949, to E. O. Wollan, L. A. Pardue, and Norman Goldstein. This radiation exposure meter

consists of photographic film sensitive to gamma and X-rays. The film is contained in a metal box provided with an opening to admit radiation. A filter is placed over the film, the properties of the filter and the film being such that the film will be blackened equally by equal numbers of roentgens of radiation of various frequencies within a certain range. Two or more sheets of film of different sensitivities may be used so as to increase the range of exposures which may be accurately measured.

Pat. 2,485,469. METHOD AND MEANS FOR DETECTING IONIZATION. Issued Oct. 18, 1949, to James S. Allen and B. B. Rossi. The utilization of a mixture of monatomic and polyatomic gases in an ionization chamber is disclosed. Mixtures comprising not less than 80 percent argon and not more than 20 percent carbon dioxide at about atmospheric pressure are useful. The carbon dioxide content may be as little as 0.5 percent, the percentage employed being a fraction of the voltage, the pressure in the chambers and the ionizing event to be detected.

Pat. 2,485,516. SHALLOW PLANE PROPORTIONAL COUNTER. Issued Oct. 18, 1949, to R. W. Thompson. An improved proportional counter is described in which a pair of parallel plate cathodes of high transparency are used in conjunction with an anode of novel design. The effective counting area is substantially increased while uniformity of response is retained. The use of a plurality of planiform electrode assemblies makes a device which is particularly adapted for the determination of the characteristics of ionizing particles by multiple coincidence and anticoincidence methods.

Pat. 2,490,298. RADIATION DETECTING APPARATUS. Issued Dec. 6, 1949, to A. Ghiorso and Carroll M. Gordon. An argon filled radiation detection counting chamber fitted with an air-lock system for introducing samples. Means are provided to prevent pollution of the counting chamber when the air-lock is open to introduce the sample to the counting chamber and for transferring the sample from the air-lock to the counting chamber.

Pat. 2,491,220. NEUTRON DETECTOR. Issued Dec. 13, 1949, to Emilio G. Segre and Clyde E. Wiegand. A detector of two metal cylinders co-axially mounted, the inner cylinder being open at one end and the space between the inner and outer cylinder being closed and filled with boron trifluoride at a pressure of about

series of parallel aluminum plates which are covered with a layer of bismuth. An electrical potential is applied between alternate plates. The presence of high-energy neutrons is indicated by the fission of bismuth and subsequent ionization of the filling gas and conduction between the plates.

Pat. 2,494,641. RADIATION COUNTER. Issued Jan. 17, 1950, to Herbert L. Anderson and Philip G. Koontz. An improved beta ray counter obtained by using a thin aluminum tube as the outer electrode of the G. M. type counter is disclosed. A novel end construction prevents collapse of the evacuated tube and a novel anode supporting structure prevents exposure of the operator to high voltages.

Pat. 2,495,650. COINCIDENCE PROPORTIONAL COUNTER. Issued Jan. 24, 1950, to John M. Blair and James M. Hush. An argon-filled coincidence proportional counter is constructed in such a manner as to eliminate the high background effects due to argon recoil nuclei, thereby making it possible to accurately detect proton recoils from a hydrogenous recoil radiator in the sensitive portion of the cathode tube chamber.

Pat. 2,496,123. IONIZATION CHAMBER. Issued Jan. 31, 1950, to Jack East and Spofford G. English. A radioactive responsive apparatus of a breach-type screen low geometry parallel plate alpha chamber in which different known geometries may readily be obtained by inserting a proper screen member is disclosed. The screen member may be a part of the removable sample holding assembly and serve as a part of the high-voltage electrode.

Pat. 2,496,819. PULSE GENERATOR. Issued Feb. 7, 1950, to Albert R. Simpson. A pulse generator capable of accurately simulating the pulses derived from radiation detection apparatus such as a Geiger-Mueller tube during normal operation is disclosed. A series of identical groups of pulses variable as to height and spacing adjustable within the group may be produced.

Pat. 2,496,886. RADIATION ALARM AND MEASUREMENT DEVICE. Issued Feb. 7, 1950, to Everett W. Molloy and William H. Hinch. A simple slide-back voltmeter system is provided which may be utilized for the measurement of any direct voltage but is particularly adapted for use in conjunction with an ionization chamber in a portable radiation meter.

Pat. 2,497,823. RADIATION MEASURING DEVICE FOR AIR FILTERS. Issued Feb. 14, 1950, to Everett W. Molloy. Radiation in the atmosphere is detected by apparatus wherein the air of the atmosphere is drawn through a filter paper upon which the particulate matter in the air is deposited. The radioactivity of the collected matter is measured by an ionization chamber.

Pat. 2,499,830. AIR PROPORTIONAL COUNTER. Issued March 7, 1950, to Everett W. Molloy. An alpha sensitive proportional counter designed to operate at atmospheric pressure and with air as the ionizing medium. A coarse mesh screen outer electrode freely admits alpha particles to the counter.

Pat. 2,505,919. PROPORTIONAL COUNTER. Issued May 2, 1950, to J. A. Simpson, Jr. A proportional counter sensitive to alpha particles adapted for probing beakers and other small containers is described. The outer electrode is a tube of small diameter with a permeable window at one end. The anode is in the form of a loop mounted close to the window and is adjustable to allow variation in the operating voltage.

Pat. 2,506,419. METHOD AND APPARATUS FOR DETECTING IONIZING PARTICLES. Issued May 2, 1950, to Elizabeth R. Graves. A counting device and electrode assembly for detecting fission fragments in the presence of other ionizing particles is disclosed.

Pat. 2,506,435. RADIATION MEASUREMENT. Issued May 2, 1950, to B. B. Rossi and J. S. Allen. High amplitude voltage pulses from a radiation counter are produced by periodically impressing a potential upon the electrodes greater than the sparking potential of the tube. An ionizing event occurring while this voltage is impressed creates a large voltage surge.

5001168

APPENDIX 8

Radiation Detection and Measurement Instruments Manufactured for Use by AEC

Able Scientific Glass Apparatus Co., 6859 South Anthony Avenue, Chicago 37, Ill.—Geiger Counter Tubes.

Abrams Instrument Corp., 600–620 East Schiawassee Street, Lansing, Mich.—Parallel Plate Alpha Scalers; Electromatic Registers.

Amperex Electronic Corp., 25 Washington Street, Brooklyn, N. Y.—Geiger Counter Tubes; Voltage Regulator Tubes.

Ansco Division, General Aniline and Film Corp., Binghamton, N. Y.—Densitometers.

Applied Physics Corp., 30 West Green Street, Pasadena 2, Calif.—Vibrating Reed Electrometer.

Atomic Instrument Co., 160 Charles Street, Boston, Mass.—Geiger Counter Scalers; Geiger Counter Monitors; Geiger Counter Tubes; Coincidence Analyzers; Linear Amplifiers; Regulated High Voltage Supplies; Lead Shields.

Atomic Research Corp., Colorado Springs, Colo.—Geiger Counter Survey Meters.

The Austin Co., 19 Rector Street, New York 6, N. Y.—Beta, Gamma Hand and Foot Monitors.

Ballantine Laboratories, Boonton, N. J.—Geiger Counter Tubes.

Barker and Williamson, Inc., Upper Darby, Pa.—Alpha Hand Monitors.

Arnold O. Beckman Co., 1020 Misson Street, South Pasadena, Calif.—Gamma Pocket Dosimeters; Charging Box for Dosimeters.

Beckman Instruments, Inc., 820 Misson Street, South Pasadena, Calif.—Micromicroammeter; Ultrohmeters; Electrometer Tubes; Alpha Beta Gamma Monitors, Beta Gamma Monitors; Gamma Pocket Alarms; Gamma Survey Meters, Ionization Chamber Type; Alpha Beta Gamma Survey Meters; Geiger Counter Survey Meters.

Berkeley Scientific Co., Sixth and Nevin Avenue, Richmond, Calif.—Geiger Counter Scalers; Geiger Counter Survey Meters; Alpha, Beta, Gamma Survey Meters; Counting Rate Computers.

Brown Instrument Co., Wayne and Roberts Street, Philadephia 44, Pa.—Recording Electrometers.

Cambridge Instruction Co., 72 East Forty-fifth Street, New York. N. Y.—Ryerson-Lindeman Electrometers; Charging Box for Dosimeters. Gamma Pocket Dosimeters. Neutron Monitors.

Central Scientific Co., 1700 West Irving Park oRad, Chicago, Ill.—Electromagnetic Registers.

Chatham Electronics Corp., Newark, N. J.—High Voltage Supplies.

Cyclotron Specialties Co., Moraga 8, Calif.—Electromagnetic Registers; Geiger Counter Tubes; Geiger Counter Scalers.

The Detectron Co., Cole Branch P. O. Box 8683, Los Angeles 46, Calif.—Geiger Counter Survey Meters; Geiger Counter Monitors.

Distillation Products, Inc., 755 Ridge Road West, Rochester 13, N. Y.—Dipping Type Geiger Counter Tubes.

E. I. du Pont de Nemours and Company, Inc., 626 Schuyler Avenue, Arlington, N. J.—X-Ray Film for use in Film Badges.

Eastman Kodak Co., Rochester, N. Y.—Film for use in Film Badges; Films for Detecting Nuclear Tracks; Spectroscopic Plate Film and other Photographic Emulsions for use in Nuclear Studies.

Eck and Krebs Co., 131 West Twenty-fourth Street, New York 11, N. Y.—Geiger Counter Tubes.

Eclipse Pioneer Division, Bendix Aviation Corp., Peterborough, N. J.—Geiger Counter Survey Meters.

Electronic Products Co., 111 East Third Street, Mount Vernon, N. Y.—Geiger Counter Tubes; Voltage Regulator Tubes.

El-Tronics, Inc., 1920 Lincoln-Liberty Building, Philadelphia 7, Pa.—Geiger-Counter Scaler; Geiger Counter Counting Rate Meter; Geiger Counter Assessory Equipment; Geiger Counter Survey Meter; Geiger Counter Classroom Demonstrators.

Fisher Research Laboratories, 1961–65 University Avenue, Palo Alto, Calif.—Geiger Counter Survey Meters.

Frederic Flader, 583 Division Street, North Tonawanda, N. Y.—Geiger Counter Scalers.

General Electric Co., Electronics Department, Syracuse, N. Y.—Electrometer Tubes; Decimal Type Scalers, Boron Lined Counter Tubes for Neutron Detection; Scintillation Type Survey Meters; Charger Readers for Pocket Chambers; Alpha Survey Meters; Beta Gamma Hand and Foot Monitors; Ionization Chambers.

General Radio Co., 275 Massachusetts Avenue, Cambridge 39, Mass.—Geiger Counter Counting Rate Meter.

Geophysical Instrument Co., Key Boulevard and Nash Street, Arlington, Va.—Geiger Counter Tubes; Geiger Counter Survey Meters; Geiger Counter Monitors.

Geophysical Measurement Corp., 802–805 Wright Building, Tulsa 3, Okla.—Geiger Counter Tubes; Proportional Counter Tubes for Neutron Detection; Geiger Counter Survey Meters.

Fred C. Henson Co., 3511 East Colorado Street, Pasadena, Calif.—Gamma Pocket Dosimeters; Chargers for Pocket Dosimeters; Quartz Fibre Survey Meters.

Herbach and Rademan Co., 522 Market Street, Philadelphia, Pa.—Geiger Counter Tubes.

Hewlett Packard Co., 399 Page Mill Road, Palo Alto, Calif.—Wide Band Amplifier.

W. S. MacDonald Co., Inc., 33 University Road, Cambridge 38, Mass.—Scintillation Counters and Related Equipment.

Hoffman Radio, 3761 South Hill Street, Los Angeles 37, Calif.—Geiger Counter Survey Meters.

5001170

Hollingsworth and Vose Co., 1937 Walsh Street, East Walpole, Mass.—Filter Paper.

International Resistance Co., North Broad Street, Philadelphia, Pa.—High Megohm Resistors.

Instrument Div., Kelley-Koett Manufacturing Co., 212 West Fourth Street, Covington, Ky.—Charger Readers for Pocket Chambers; Automatic Timers for Scaler Operation; Chargers for Dosimeters; Gamma Pocket Chambers; Gamma Pocket Dosimeters; Geiger Counter Tubes; Beta Gamma Hand and Foot Monitors; Geiger Counter Scalers; Parallel Plate Alpha Scalers, Neutron Pocket Chambers; Neutron Pocket Dosimeters; Geiger Counter Survey Meters; Alpha Beta Gamma Survey Meters; Gamma Survey Meters—Ionization Chamber Type.

H. S. Martin Co., 1916–1920 Greenleaf Street, Evanston, Ill.—Geiger Counter Tubes.

Mine Safety Appliances Co., Braddock, Thomas, and Meade Streets, Pittsburgh 8, Pa.—Airborne Particle Collector, Filter Paper Type; Airborne Particle Collector, Electrostatic Type.

Mid West Electronic Laboratory, 636 Keeline Building, Omaha, Nebr.—Geiger Counter Survey Meters.

North American Phillips Co., Inc., 100 East Forty-second Street, New York 17, N. Y.—Geiger Counter Tubes; Geiger Counter Survey Meters.

Nuclear Development Laboratories, P. O. Box 7034, Kansas City, Mo.—Geiger Counter Tubes.

Nuclear Instrument and Chemical Corp., 223–233 West Erie, Chicago, Ill.—Charger-Reader for Pocket Chambers; Geiger Counter Scaler; Geiger Counter Tubes; Linear Amplifier; Dual Purpose Timer; Alpha Probes for Proportional Counters; Alpha Proportional Counter Scalers; Flow Type Geiger Counter; Parallel Plate Alpha Counter Scaler; Geiger Counter Survey Meters; Alpha Survey Meter, Proportional Type; Survey Meter for Neutron Detection; Gamma Pocket Chambers.

Nuclear Measurements Corp, 3339 Central Avenue, Indianapolis, Ind.—Alpha Beta Gamma Scaler, Proportional Counter Type; Alpha Beta Gamma Counter Chambers.

Nucleonic Corp. of America, 497 Union Street, Brooklyn 31, N. Y.—Geiger Counter Tubes, Geiger Counter Scalers; Geiger Counter Monitors; Geiger Counter Survey Meters for Alpha Beta and Gamma Detection.

Omaha Scientific Co., 3623 Lake Street, Omaha 4, Nebr.—Geiger Counter Survey Meters.

Ohmer Electronics, 5230 North Kedzie Avenue, Chicago, Ill.—Geiger Counter Scalers.

Photovolt Corp., 95 Madison Avenue, New York 16, N. Y.—Densitometers.

Potter Instrument Co., 136–56 Roosevelt Avenue, Flushing, N. Y.—Scaling Equipment; Geiger Counter Scalers.

Production Instrument Co., 710 West Jackson Boulevard, Chicago 6, Ill.—Electromagnetic Registers.

Precision Radiation Instruments, Inc., 5478 Wilshire Boulevard, Los Angeles 36, Calif.—Geiger Counter Survey Meters.

R. C. Scientific Co., 335 Culver Blvd., Playa Del Rey, Calif.—Scintillation Counter Monitors; Scintillation Counter Heads.

Radiation Counter Laboratories, Inc., 1844 West Twenty-first Street, Chicago, Ill.—Geiger Counter Tubes; Linear Amplifiers; Lead Shields; Geiger Counter Survey Meters; BF_3 Neutron Counters; Proportional Counter Monitors; Alpha Hand Monitors; Proportional Counter Scalers; Geiger Counter Scalers.

Radio Corp. of America, RCA-Victor Division, Scientific Instrument Department, Camden, N. J.—Scaling Equipment; Geiger Counter Monitors; Beta Gamma Hand and Foot Monitors.

Radioactibe Products, 3201 East Woodbridge Street, Detroit 7, Mich.—Geiger Counter Scalers; Geiger Counter Monitors; Beta Gamma Survey Meters, "Cutie Pie" Type; Power Supplies; Linear Amplifiers.

Radiophone Co., 2439 East Colorado Street, East Pasadena, Calif.—Geiger Counter Survey Meter; Geiger Counter Monitors.

Raytheon Manufacturing Co., Special Tube Section, 55 Chapel Street, Newton 58, Mass.—Electrometer Tubes; Geiger Counter Tubes; Alpha Survey Meter, "Poppie" type.

Reed Laboratories, Inc., 41 South High Street, Akron 8, Ohio—Thin Window Material for use with Alpha Detection Chambers.

Research Equipment and Service Co., 1155 East Sixty-first Street, Chicago 37, Ill.—Geiger Counter Windowless Flow Type.

A. M. Samples Machine Co., 506 North Central Avenue, Knoxville, Tenn.—Film Badges.

Service Diamond Tool Co., Radioactivity Instrument Division, 2505 Burdett Street, Ferndale 20, Mich.—Geiger Counter Survey Meter for Prospecting.

Spencer-Kennedy Laboratories, Inc., 186 Massachusetts Avenue, Cambridge 39, Mass.—Wide Band Chain Amplifiers.

Special Instruments Laboratories, Inc., 1003 Highland Avenue, Knoxville, Tenn.—Recording Type Registers; Automatic Sample Changer and Analyzer; Geiger Counter Survey Meter for Prospecting.

Sylvania Electric Products, Inc., 70 Forsyth Street, Boston 15, Mass.—Geiger Counter Tubes; Alpha Beta Gamma Survey Meters.

Technical Associates, 3730 San Fernando Road, Glendale 4, Calif.—Lead Shield; Geiger Counter Tubes; Alpha Hand Monitor; Geiger Counter Scaler; Geiger Counter Monitor; Geiger Counter Survey Meter; Gamma Survey Meter, Ionization Chamber Type; Alpha Beta Gamma Survey Meter, Ionization Chamber Type.

Telemark, Inc., 79 Prospect Street, Stamford, Conn.—Proportional Counting Rate Meter for Alpha Detection; Proportional Counting Rate Meter for Neutron Detection.

Tracerlab, Inc., 55 Oliver Street, Boston, Mass.—Automatic Sample Changer; Geiger Counter Tubes; Lead Shields; Pre-Set Timer; Geiger Counter Scalers; Geiger Counter Monitors; Geiger Counter Survey Meters; Beta Gamma Survey Meter, "Cutie Pie" Type; Geiger Counter Gas Flow Type.

Two-Way Communications Service, Traverse City, Mich.—Geiger Counter Survey Meters.

5001172

U. S. Electronic Co., 262 Conner Street, New Haven 11, Conn.—Wide Band Amplifiers.

Veeder-Root Inc., Hartford 2, Conn.—Electromagnetic Registers.

N. Wood Counter Laboratories, 5646–5648 Harper Avenue, Chicago 37, Ill.—Geiger Counter Tubes; BF_3 Neutron Counter Tubes.

Victoreen Instrument Co., 3800 Perkins Avenue, Cleveland, Ohio—Charger Reader for Pocket Chambers; Gamma Pocket Chambers; Projection String Electrometer for reading Pocket Chambers; Wide Band Amplifier; Power Supply for Beta Gamma Survey Meters; Geiger Counter Tubes; High Megohm Resistors; Electrometer Tubes; Geiger Counter Monitor; Gamma Monitor "Proteximeter"; Geiger Counter Survey Meters; Alpha Beta Gamma Survey Meters; Gamma Survey Meters, Ionization Chamber Type.

Western Radiation Laboratories, 1107 West Twenty-fourth Street, Los Angeles 7, Calif.—Geiger Counter Survey Meters.

Westinghouse Electric Corp., P. O. Box 868, Pittsburgh, Pa.—Electrometer Tubes.

Weston Electrical Instrument Corp., Newark, N. J.—Densitometers.

S. S. White Dental Manufacturing Co., Department E, East Fortieth Street, New York 16, N. Y.—High Megohm Resistors.

Whitehead and Hoag, Co., Newark, N. J.—Film Badges.

5001173

APPENDIX 9

Report to the President by the Atomic Energy Labor Relations Panel

November 1, 1949, to May 31, 1950

The Atomic Energy Labor Relations Panel began its first year of activity on June 4, 1949. The events from that date to October 31, 1949, were summarized in an earlier report.[1] This report covers the period from November 1, 1949, to May 31, 1950.

During this time, Panel assistance has been sought in six disputes. One of these disputes is still before the Panel. Three were settled by the Panel in the course of informal discussions, thus avoiding the necessity for official intervention. The sixth case was settled when, during the Panel's preliminary investigation, the parties agreed to submit their differences to final and binding arbitration. This dispute, however, involving the Maxon Construction Co. and the International Hodcarriers, Building and Common Laborers of America, AFL, at Oak Ridge, broke out again in the form of a serious wildcat walkout after the Panel had disposed of it but before the arbitration board appointed by the parties could make its award. The strike was ended through the efforts of the union officials on May 31. This matter is discussed in greater detail below under Case No. 9.

A summary of the six cases follows:

CASE NO. 5—AEC INSTALLATION: *Oak Ridge*—Construction on Pipe Line; PARTIES: Oman Construction Co.; Buildings Trades Council, AFL.

Background of Case. In order to assure an adequate supply of fuel for Oak Ridge, the Atomic Energy Commission undertook to link its Oak Ridge facilities with the transcontinental gas line. The AEC let out a contract for this job to the Tennessee Gas Co.

The Tennessee Gas Co. sublet the actual construction of the pipe line to the Oman Construction Co. Completion of the project was due on a certain date, with financial penalties established for failure to meet the agreed time schedule.

Oman was a nonunion contractor. Once the job reached the Oak Ridge boundary, the AFL established a picket line and all construction work wihin the Oak Ridge area was halted. The strike began on December 6, 1949.

On December 7, 1949, the following telegram was sent by the AEC to the Panel:

"There is presently in existence in Oak Ridge a labor stoppage of major construction projects including the vitally needed K–29 gaseous diffusion plant. Our information is that no dispute exists between the AEC contractors, i. e., Maxon Construction Co., J. A. Jones and John Johnson, etc., and their employees, but that this stoppage arises out of a dispute between the Building Trades and the Oman Construction Co. . . . We request the Atomic Energy Labor Relations Panel look into this matter and take such action therein, as in its judgment, is appropriate for it to do."

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[1] Seventh Semiannual Report of the U. S. AEC to Congress, Appendix 8

5001174

In cooperation with the Federal Mediation and Conciliation Service, the Panel undertook to get the men back to work. It developed that this dispute involved the basic issue of union and nonunion contractors working within the same atomic energy facility, a principle that transcended the importance of the particular dispute in this particular instance. In this case, the overlapping of the Oman contract within the Oak Ridge area was of a very short duration. The Panel therefore called upon the Building Trades Council to resume activity on this vital job and at the same time indicated that it would promptly examine with the Council the broad questions involved. On December 9 the pickets were withdrawn.

The Panel met with representatives of the Building Trades Council in Washington on January 6, 1950. This meeting started a series of discussions which are still in progress on the application of Panel procedures to the special problems of the construction industry. These discussions have involved AEC officials, members of both the Building Trades Council and representatives of contractor organizations. The problems are numerous and complex, but it is hoped that a written statement on Panel procedures in the construction industry will be forthcoming within the next few months.

CASE NO. 6—AEC INSTALLATION: *Oak Ridge*—Construction on K–29—K–31; PARTIES: Primary: Kaighin & Hughes Co.; United Association of Plumbers & Steamfitters, AFL; Secondary: Maxon Construction Co., Union Carbide & Carbon Corp.; United Gas, Coke & Chemical Workers, CIO.

Background of Case. This dispute arose over the assignment of work in connection with the "pickling" or special cleaning of pipe that was being installed in the K–29—K–31 plant at Oak Ridge.

The Atomic Energy Commission's prime contractor on this job was the Maxon Construction Co. The installation of pipe was subcontracted by Maxon to Kaighin & Hughes. The employees of Kaighin & Hughes were represented by the United Association of Plumbers and Steamfitters, AFL.

Some of the pipe had to be "pickled" in a section of the K–25 plant which is operated by the Union Carbide and Carbon Corp. and manned by members of the United Gas, Coke and Chemical Workers, CIO. When the dispute arose, the "pickling" operation within the K–25 plant was being performed by members of the CIO. The Steamfitters claimed that this process was an integral part of the work required in the preparation of pipe before installation and therefore was work which properly belonged to them. On February 13, 1950, five members of the steamfitters union refused to load pipe into a truck destined for the pickling plant. For their refusal, the men were discharged. This lead to a general walkout.

On February 21, the parties requested the Panel to enter the dispute. The Panel gave assurances that it would if the men returned promptly to work under the existing arrangement for pickling the pipe.

Panel Recommendations. Meetings were held on March 3 and 4 in Washington, D. C. All interested parties were present throughout these meetings, while the Panel listened to the various arguments. When it became apparent that no agreement could be effected through mediation, the Panel members said that they would study the testimony that had been submitted and would prepare a recommendation.

On April 12 the recommendation was mailed to the parties.[2] The Panel suggested that the work within K–25 continue to be performed by the regular em-

[2] The complete details of this case were attached to the mimeographed recommendation mailed to the parties.

5001175

ployees of that plant. In making this recommendation, the Panel emphasized the special considerations that were involved. It would cost an estimated $450,000 to duplicate the "pickling" plant within K–25, an alternative that was recognized by all parties as obviously impractical. The Panel also found that it would be impractical and wasteful of manpower to have the AFL employees of Kaighin & Hughes follow the pipe into the K–25 plant for its cleaning operation. Since the amount of wages involved, compared to the total labor costs of the construction project, were *de minimus*, the Panel emphasized that it issued its recommendations without finding it necessary to pass judgment or to establish any precedent as to whether or not this special cleaning of the pipe was construction, and therefore properly within the jurisdiction of the steamfitters.

CASE NO. 7—AEC INSTALLATION: *Mound Laboratory*, Miamisburg, Ohio; PARTIES: Monsanto Chemical Co.; United Gas, Coke & Chemical Workers, CIO.

Background of Case. Panel Case No. 1 concerned negotiations for the first contract between the parties involved in this dispute. This matter was settled by Panel mediation on August 9, 1949.[3]

Shortly after the contract was signed, the union took issue with the company over the slotting of various individuals into the job classification which were made part of the agreement. The union wished to submit the difference to arbitration. The company claimed that the issues were not arbitrable under the terms of the contract.

The Panel was first informed of this dispute on December 28, 1949, when Martin Wagner, president of the union, phoned William H. Davis, panel chairman. At this time, there were still unresolved some 20 individual slottings. In the course of this conversation, Mr. Davis and Mr. Wagner reviewed various approaches for further negotiation under the terms of the existing contract.

Between December 28 and March 14, negotiations on the determination of the slottings continued at the local level and with the assistance of the Federal Mediation and Conciliation Service. The various alternatives to arbitration were explored, including that of first submitting the primary question of whether or not the issue itself was arbitrable to an arbitrator.

At the request of the union, the Panel met with some of its local and international officers in Washington on January 20 to further explore the possible avenues for reaching agreement. The inappropriateness for the Panel to enter a dispute of this kind during the term of a contract was explained to and accepted by the union representatives. The various approaches to arbitration were discussed informally. The Panel also suggested the kind of factual information that would be helpful to both the union and management in making a fair disposition of the classification issues still in dispute.

There were several more contacts between the union and the Panel over this matter, and in each instance the Panel was able to persuade the union to renew its bargaining efforts. On March 14, when, in the opinion of the Panel, the effectiveness of local negotiations had been fully exhausted, Mr. John Hawn, director of Labor Relations, was reached by phone. At the request of the Panel, he agreed to look into the matter. Upon the constructive foundation already laid by the local negotiators, Mr. Hawn and Mr. Joseph Joy, international representative of the union, were able to reach agreement within 2 weeks on all matters still in dispute. Their success was reported to the Panel on March 27.

This case illustrates and reinforces the Panel's conviction that great restraint must be exercised before a third party should actively take part in the collective

[3] For details, see "Report for Period June 1 to October 31, 1949," Appendix 8, Seventh Semiannual Report to Congress.

bargaining process. Although the Panel's repeated insistence to "throw" this matter back onto the bargaining table may have appeared at times to the union like a bureaucratic "run-around," the resulting agreement that was eventually worked out by the parties themselves is unquestionably better and more constructive than would have resulted from Panel intervention.

CASE NO. 8—AEC INSTALLATION: *Sandia Laboratory*, Albuquerque, N. Mex.; PARTIES: Western Electric Co.; Metal Trades Department, AFL.

Background of Case: On November 1, 1949, the Western Electric Co., replaced the University of California as the operator of the Sandia Base. Early in January the Metal Trades Department of the AFL began to seek bargaining rights for the employees of the base. Difficulties were encountered in establishing a bargaining unit to which the parties could agree. Numerous meetings under the auspices of the National Labor Relations Board were held in an attempt to arrange a consent election, but security problems complicated the discussions and progress was slow. By April the union felt that a full NLRB hearing to determine the unit would be necessary. The union wished to avoid this procedure because of the delay that it would entail. The ordinary process would be even more time consuming in this instance because of security considerations. On April 10, 1950, James A. Brownlow, president of the Metal Trades Department, asked the Panel to intervene.

Mr. Brownlow met with the Panel in New York on April 10. In this meeting the Panel said that it would investigate the facts before deciding whether or not to take the case, and a trip was arranged for Aaron Horvitz, Panel member, and Donald Straus, Panel secretary, to visit Sandia on April 24. The Panel's underlying interest in this matter was to look into the effectiveness of that recommendation contained in the Report of the President's Commission on Labor Relations in the Atomic Energy Installations which said:

"That, subject to the security provisions . . . management and labor at Government-owned, privately operated atomic energy installations make every endeavor to determine bargaining units and representatives by agreement and consent election in preference to contested proceedings before the National Labor Relations Board."

The twofold reason given for this recommendation was "the avoidance or minimizing of controversy at this (early) stage of the relationship" and also the desire to prevent, for security reasons, the open and much publicized discussions and factual probings that attend an NLRB hearing.

In arranging for the visit of Messrs. Horvitz and Straus, Mr. Davis discussed this section of the Report to the President with various top officials of the Western Electric Co. Whether or not these informal talks had any bearing on the subsequent developments is not known by the Panel. In any event, on April 20 news was received from the NLRB that a consent election had been arranged for May 11, thus making the trip to Albuquerque unnecessary.

CASE NO. 9—AEC INSTALLATION: *Oak Ridge*—Construction on K–29—K–31; PARTIES: Maxon Construction Co.; International Hodcarriers, Building and Common Laborers Union, AFL.

Background of Case. On April 15, 1950, the laborers of Local 818 began to walk off the construction job at the K–29—K–31 construction site at Oak Ridge. Maxon Construction Co., the primary contractor, sent a telegram to the union's international president informing him of the strike. On April 20, at the re-

quest of both the AEC and the union, the Panel sent a telegram to Local 818 calling upon its officers "to see that the men return to work forthwith according to the Atomic Energy Labor Relations Panel Plan" and stating that Mr. Horvitz and Mr. Straus would be in Oak Ridge on the following Monday to investigate the dispute.

While at Oak Ridge, Messrs. Horvitz and Strauss discovered that the strike arose over dissatisfaction with the wage rate. The contractors at Oak Ridge paid the rates set in negotiations between the various building trades unions and the Knoxville Chapter of the Associated General Contractors. For common labor the Knoxville rate, and therefore the Oak Ridge rate, was 95 cents. The laborers' union representatives claimed that the Oak Ridge rates should be separately negotiated; they denied that the Oak Ridge local was tied by contract to the Knoxville agreement; and they further argued their point by showing that the construction rate for labor at Oak Ridge was from 14 to 24 cents lower than that for common labor in maintenance.

The Maxon Co. said that it was merely operating according to the labor practice of the J. A. Jones Construction Co., another construction contractor in the area who was there before Maxon began its job. One of the issues in dispute was whether or not the Knoxville building trades labor contract covered the Oak Ridge area. There was no clear-cut evidence on this question.

The information collected at Oak Ridge was brought back to New York for a Panel meeting on April 26. As a result of this meeting, and of subsequent discussions with officials of the union, the Maxon Construction Co., and national officials of the Associated General Contractors, the Panel sent the following telegram on May 2 to Joseph Moreschi, international president of the union, to the president of the local, and to the Maxon Construction Co.:

"The matter in dispute between the Maxon Construction Company and Local 818 of the International Hodcarriers, Building and Common Laborers of America, AF of L, is wage rates of members of Local 818 in construction work on the K–29 and K–31 projects at Oak Ridge. Such a dispute if it cannot be finally settled by agreement between the parties should, in the opinion of the Atomic Energy Labor Relations Panel, be settled by voluntary arbitration as is customary in construction work. We therefore request the parties to enter into an agreement to immediately submit the dispute to final and binding arbitration. At such an arbitration hearing all interested parties including members of the Knoxville Chapter of the Associated General Contractors and any other interested contractors operating in the area as well as members of the Knoxville Building Trades Council should be invited to present their views. We hope that the parties will be able to agree upon the arbitration forthwith, and without further consideration by the Panel. If, however, the parties want any assistance from the Panel in making these arrangements please let me know at once."

WILLIAM H. DAVIS, *Chairman.*

On the following day, telegrams were received by the Panel from both parties agreeing to the recommended procedure. Aaron Horvitz was asked by the parties to serve as arbitrator. It is contrary to Panel policy for one of its members to act as an arbitrator in atomic energy cases. In this instance, however, at the insistence of the parties that his familiarity with the complicated background of the case would greatly facilitate an early hearing and award, Mr. Horvitz consented to serve as the impartial member of a three-man tribunal.

The hearing was held on May 24 at Oak Ridge. The arbitrators took the testimony and left that afternoon. Before the end of the day shift, the laborers

began to walk off the job, stating that they had expected the arbitration board to render its decision before leaving. Next morning, pickets appeared at all gates and practically no laborers reported for work.

On May 25 the Panel sent the following telegram to Fred Stratton, business agent of the local:

"The laborers' strike at the K–29—K–31 construction site is in violation of the Panel procedures and the arbitration proceedings to which their union has agreed. The arbitrators chosen by the union and the employer have completed their hearings and will render an award as soon as they have been able to study the record and make their findings. Meanwhile, the Panel directs the laborers at the K–29—K–31 site to return to work in conformance with their pledges to the Panel and to the arbitrators."

A similar telegram was sent to Richard Gray, president of the AFL Building Trades Council, with the request that he "immediately notify all international presidents involved and also the Knoxville Building Trades Council that the strike is unauthorized, that the picket lines must be ignored and that if necessary the other trades shall supply men to maintain continuous operations on this vital construction project." Gray complied with this request, and within a few hours most of the local union officers had received directions to ignore the picket lines of the laborers. President Moreschi of the laborers wired his local that the dispute "was submitted to arbitration with the consent of Local 818 and . . . the request of the men is being promptly and efficiently processed. Your local, its officers and members are therefore directed to man the job."

In spite of these prompt and vigorous efforts of the responsible union officials, the picket lines were not withdrawn. On Friday and Saturday, May 26 and 27, the walkout spread to the other crafts and all construction on the K–29—K–31 site was halted. A special representative of the laborers, Nicholas Stirone, arrived in Oak Ridge on Sunday and began discussion with the local officers and the men. By Monday, a few of the crafts began to trickle through the lines. Tuesday was a holiday, and both Stirone and other local AFL officers worked tirelessly to explain the facts to the men. On Wednesday, May 31, the picket lines were withdrawn and full activity was resumed.

CASE NO. 10—AEC INSTALLATION: *Knolls Atomic Power Laboratory*, Schenectady, N. Y.; PARTIES: General Electric Co.; United Association of Plumbers and Steamfitters, AFL.

Background of Case. The Steamfitters, AFL, represent the employees in their craft working in the Knolls Laboratory. Under the terms of the contract, the union requested modification of the wage rates on April 1, 1950. The company asked that negotiations be postponed until June, at which time, it said, more data would be available on a proposed revision of the existing pension plan.

An important consideration in this situation was the union election scheduled for May 25 affecting other employees in the Knolls Laboratory as well as the bulk of the General Electric employees throughout the country. The company was reluctant to negotiate any agreement with one small segment of its workers before the others could be represented. The steamfitters denied that this was a proper consideration, and pressed for an agreement covering the workers within its jurisdiction.

Toward the middle of May the union called a strike at Schenectady, and the steamfitters walked off the job in both the commercial plant as well as the atomic energy laboratory. At first, the work in the Laboratory was not seriously threatened, but on May 19, the Atomic Energy Commission sent a telegram to the Panel requesting that it take jurisdiction of the dispute.

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The following day the Panel sent telegrams to both parties which contained these sentences:

"Under the provisions of 5 (c) of Panel procedures we are calling upon the union to restore services at the laboratory, and we are calling upon General Electric to make no changes without agreement in the terms and conditions of employment that existed when the dispute arose, pending further Panel procedure. The Panel will investigate the nature of the dispute at once and within fifteen days will advise you further."

After a delay of several days, which were required to establish union acceptance of the need to separate the Knolls employees from those in the commercial plants for the purpose of following Panel procedures, the steamfitters returned to work at the Laboratory. On May 26, representatives of the union and the company met with the Panel in New York City.

At this meeting, it developed that the company was ready to resume negotiations with the steamfitters early in June. Accordingly, June 6 was established as the date for the next meeting. With the assurance that the company would then be prepared to discuss the terms of a new agreement with the union, the union representatives agreed to keep its atomic energy employees on the job. It was also agreed that further negotiations without the presence of Panel representatives would be fruitful. As of May 31, 1950, this case was still incomplete.

WILLIAM H. DAVIS, *Chairman.*
AARON HORVITZ, *Member.*
EDWIN E. WITTE, *Member.*

JOHN T. DUNLOP, *Consultant.*
DONALD B. STRAUS, *Executive Secretary.*
June 15, 1950.

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APPENDIX 10

Information Control Policy of U. S. Atomic Energy Commission

Secrecy is an important element of preparation for national defense. It is at the same time a strong deterrent to the free flow of scientific and technical information which is essential to progress. This condition is recognized by the Atomic Energy Act of 1946, which attempts to define a reasonable compromise and which puts the responsibility for further definition and administration upon the Atomic Energy Commission. This law gives to the Commission an unprecedented responsibility and authority because it recognizes fully the dilemma which exists in connection with atomic energy information. This dilemma is as follows:

a) On the one hand, rapid progress in basic science requires free interchange of information. Modern military technology depends upon basic science. Therefore, to achieve maximum military strength, there must be free interchange of information.

b) On the other hand, American military technology must, insofar as possible, surpass that of our potential enemies. New weapons developments on which millions of dollars and the time of thousands of men have been spent must not be given away. Yet these developments may depend upon discoveries in science. Therefore, there must be an area of secrecy in both science and technology.

To further complicate this dilemma, there must be taken into account all the evil effects of secrecy outside the fields of science and technology. In particular, it must be remembered that the whole American system of democratic government assumes that the people should be kept informed—that billions of dollars of the taxpayer's money should not be spent without telling him how or why. Yet, the American people certainly do not want either our war plans or the details of our armaments to be published. They know that 150 million people cannot keep a secret and that a certain amount of secrecy is important, even in a democracy.

A clear solution to this dilemma would only be possible if it were known exactly when the United States might have to defend itself in another war. If it were to be next year, there should be virtually complete secrecy; if it were certain that there would be no war for 30 years, virtually all secrecy should be abandoned.

In view of the current international situation, a middle course is evidently necessary—a course which will make it possible for the United States to defend itself with vigor and success if it is attacked within the next few years, and yet a course that can be followed for many years without seriously weakening our democracy or our science.

In attempting to make the most effective compromise, the Commission, in the light of consultations with other branches of the Government and of its own knowledge of the problems involved and basic policy set by the Atomic Energy Act, has laid down three fundamental principles as guides:

a) Weapons information, including design, production and stockpiles, should be kept secret.

b) Basic science should be free except where it is directly related to weapons.

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c) Until international control is attained, there shall be no information exchanged with other nations on the use of atomic energy for industrial purposes.

In addition to these three basic areas, there is also a twilight zone of information that does not fall automatically into these categories. In attempting to judge such information, the Commission uses a simple criterion; it asks the question, "Will the release of this information help the United States atomic energy program more than it will help the atomic energy program of a potential enemy?"

Although this is a simple criterion, it is very difficult to apply. In attempting to apply it, the Commission assumes, perhaps rightly, perhaps wrongly, that it makes a great deal of difference who is giving out information.

Essentially, there are six categories of people who might write or say something about atomic energy that would help a potential enemy:

a) Full-time employees of the Atomic Energy Commission or its contractors with access to classified data.

b) Scientists who have had access to classified data or still do on a part-time basis.

c) Scientists whose work is supported by the Atomic Energy Commission but without access to classified data.

d) Entirely independent research workers who have never had access to classified work but who may turn up ideas of military value.

e) Writers, lecturers, editors, columnists, or public officials who have had some access to classified data.

f) Similar men who have had no official access but are shrewd enough to pick up significant information by interviews with informed people or even by guessing from published materials.

There are three areas in which these people may happen to talk or write:

I

Detailed technical articles of limited scope.

II

General articles or speeches of professional or popular level discussing the work of the Atomic Energy Commission or related topics, often including estimates on rate or scale of effort or statements of problems and probabilities.

III

General articles or speeches primarily concerned with the political, moral or military aspects of the work of the Atomic Energy Commission. Again, these often contain estimates on rate or scale of effort or statements of problems and probabilities, and sometimes stockpile estimates.

Thus, there are 18 categories of articles and speeches which concern the Atomic Energy Commission in one way or another. Since there are practically no articles even vaguely related to atomic energy that do not fall into one of these categories, the Commission must rely upon common sense to limit its activities, realizing full well that it cannot guarantee that there may not be damaging information appearing in any one of the 18 categories.

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ARTICLES IN AREA I

If these are written by authors in category (*a*) the Atomic Energy Commis declassification system can be employed satisfactorily. This applies al equally well to authors in category (*b*) except that the Commission must upon the voluntary cooperation of the authors or of the editors of techr journals who submit for clearance those papers about which there may be s doubt. This intervention by editors is also helpful to the Commission articles prepared by the third category of authors, although in such cases the an additional aid provided by the one man on each project who has been cle and appointed to look out for discoveries that might need to be classified.

The number of authors of technical papers in category (*d*) is small. Here Commission must depend entirely upon the good sense of the authors and on cooperation of editors. Actually, the Commission is only interested in revie such articles when either the author or the editor has good reason to believe classifiable information has been developed and included.

Authors in categories (*e*) and (*f*) are not likely to write technical arti If they do write such articles and publish them in journals whose editors are alert, the Commission has no formal way of obtaining them for review. Actu as with authors in category (*d*), the Commission is interested in reviewing articles only when either the author or the editor has good reason to believe classifiable information has been developed and included.

ARTICLES AND SPEECHES IN AREAS II AND III

The Commission believes that the nontechnical parts of general articles, wri by authors who may be connected with the atomic energy project but who are full-time employees of the Commission or its contractors and whose pre connection with the project is not on a policy level, constitute an area w interference would clearly be unjustified—except with the writings of full- project people for administrative reasons. The Commission appreciates the evils of any limitation on freedom of speech and intends to avoid interfer in this area.

The Commission believes that public discussion of political or moral quest arising from development of atomic or hydrogen bombs is vital to wise decis in a democracy. The Commission neither has nor desires to have any auth to interfere with public discussion of such questions.

The Commission follows the policy of disregarding almost entirely the spee and writings of those who have had no access to classified information. Th done for two reasons: (1) the Commission wishes to restrict its activitie much as possible, and (2) as a security safeguard the Commission does not to become involved in the review of articles or speeches by outsiders.

The Commission has consistently refused to comment on articles and spee by outsiders because in the process of comment in detail—of requesting deletion of specific references—there would be revealed the very facts the C mission wished to withhold. By specifying what should be taken out of spe tive articles and talks, classified information would be underscored and reve to the authors who have had no previous access to classified information and presumably are not cleared to receive it. When random guesses happen t correctly on real secrets, it would appear that security is breached. This is necessarily true, however, so long as the writer and the reader do not k whether the guesser is right or not. Security is breached, however, if the C mission identifies those guesses which coincide with facts by insisting on t removal. As long as the Commission makes no comment on speculations of pe

who do not have access to restricted data, a competitor will not have help from an official source in his problem of differentiating fact from fancy.

In Areas II and III, the writings and speeches of people who have or have had access to classified data and are discussing topics related to classified programs are the most difficult to handle. The Commission believes that such men share with the Commission the responsibility for seeing to it that no significant information is revealed, and hopes that they will realize that they cannot always make a sound judgment on the significance of what they have written, however well acquainted they are with certain phases of the project. The Commission hopes they will realize that even if their information is extensive, it cannot be as extensive as the collective knowledge available to the Commission. If there is any possible doubt, the Commission strongly desires that such people would submit their articles or speeches for review well in advance of publication. The Commission will try in every way to work with them, realizing the value of public discussion.

The Commission recognizes the difficulties confronting the press as well as men working on science and technology, and welcomes consultation with them as groups or individually. Within the area of information free and open to the public, the Commission encourages contact between reporters, writers, and broadcasters, and responsible officials and scientists and members of the Commission.

Adopted May 17, 1950.

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