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HAZARDS AND SAFETY MEASURES
RELATED TO
NUCLEAR-POWERED MERCHANT SHIPS
AN ANNOTATED BIBLIOGRAPHY
OF DECLASSIFIED LITERATURE
ALI-51

MASTER

Compiled by M. K. White

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		<hr/> 640

TABLE OF CONTENTS

	<u>Item Number</u>	<u>Page</u>
ABSTRACT		1
INTRODUCTION		3
1. NUCLEAR REACTORS FOR MARINE USE	627-632	1-1
1.1 Reactors Applied to Marine Vessels	627-628	1-2
1.1.1 Merchant Shipping	627	1-2
1.1.2 Naval Reactors	628	1-2
1.2 Information on Reactors	629-632	1-3
1.2.1 General	629	1-3
1.2.2 Specific Reactors	630-632	1-4
2. PERMISSIBLE RADIATION EXPOSURE STANDARDS	633-663	2-1
2.1 Maximum Permissible Limits	633-635	2-2
2.1.1 Establishment and Validity of Maximum Permissible Limits	633-634	2-2
2.1.2 Maximum Permissible Exposure to Internal Radiation	635	2-2
2.2 Background Radiation	636-647	2-2
2.2.1 Natural Radioactivity	636-642	2-2
2.2.2 Man-Made Isotopes	643-647	2-5
2.3 Biological Effects Relevant to the Estab- lishment of Permissible Levels	648-663	2-6
2.3.1 General	648	2-6
2.3.2 Specific - Animal Data	649-658	2-6
2.3.3 Specific - Human Data	659-663	2-11

TABLE OF CONTENTS (Continued)

	<u>Item Number</u>	<u>Page</u>
3. NUCLEAR ACCIDENTS AND THEIR PROBABILITIES	664-692	3-1
3.1 General Discussions	664-671	3-2
3.1.1 Accident Theory	664-665	3-2
3.1.2 Criteria for Safety	666-668	3-2
3.1.3 Potential Accidents	669-670	3-3
3.1.4 Reactor-Program Progress Reports	671	3-4
3.2 Mechanisms of Primary Accident Initiation	672-685	3-5
3.2.1 Power Failure - Loss of Coolant Flow	672-673	3-5
3.2.2 Loss of Coolant	674	3-5
3.2.3 Bulk Boiling	675	3-6
3.2.4 Power Transients	676	3-7
3.2.5 Corrosion and Radiation Damage	677-678	3-7
3.2.6 Reactivity Insertion	679-681	3-8
3.2.7 Fuel Element Burn-Out	682-683	3-8
3.2.8 Temperature Coefficients	684	3-9
3.2.9 Emergency and Shutdown Cooling	685	3-9
3.3 Effects on Reactor and Surroundings	686-689	3-9
3.3.1 Secondary Accidents	686-688	3-9
3.3.1.1 Metal-Water Reactions	686-688	3-9
3.3.2 Structural Damage	689	3-10
3.4 Extent of Hazards	690-692	3-11
3.4.1 Possible Magnitude of Accidents	690-692	3-11

TABLE OF CONTENTS (Continued)

	<u>Item Number</u>	<u>Page</u>
4. CONSEQUENCES OF FISSION-PRODUCT RELEASE	693-739	4-1
4.1 Fission-Product Release to the Atmosphere	693-700	4-2
4.1.1 Meteorological Factors Affecting Dispersal	693-697	4-2
4.1.2 Rain-Out of Radioactivity	698	4-3
4.1.3 Fall-Out of Radioactivity	699	4-4
4.1.4 Specific Experimental Studies	700	4-4
4.2 Fission-Product Release to the Ocean	701-718	4-4
4.2.1 Relative Information	701-705	4-4
4.2.2 Distribution in the Ocean	706-707	4-6
4.2.3 Effects on Marine Life	708-710	4-7
4.2.4 Distribution and Effects in Fresh Water	711-718	4-8
4.3 Gross Effects on Man	719-736	4-11
4.3.1 Characteristics of Hazardous Material	719-720	4-11
4.3.2 Personnel Hazards from Radioactive Materials	721-725	4-12
4.3.3 Dosage Determinations	726	4-14
4.3.4 Effects on Man	727-730	4-14
4.3.5 Experimental Studies, Related	731-736	4-15
4.4 Post-Accident Reactor Hazards	737-739	4-19

TABLE OF CONTENTS (Continued)

	<u>Item Number</u>	<u>Page</u>
5. CONTROL MEASURES	740-829	5-1
5.1 Administrative Control	740-784	5-2
5.1.1 General Problems	740-744	5-2
5.1.2 Regulations	745-746	5-4
5.1.3 Health-Physics Procedures	747-749	5-4
5.1.4 Principles of Protection	750-751	5-5
5.1.5 Operation, Testing, and Inspection of Reactors	752-756	5-6
5.1.6 Hazards - Summary Reports	757-762	5-7
5.1.7 Health-Physics Activities	763-780	5-10
5.1.7.1 Radiation Measurement	763-767	5-10
5.1.7.2 Environmental Surveys	768-769	5-11
5.1.7.3 Air Monitoring	770-771	5-11
5.1.7.4 Analytical Procedures	772-773	5-12
5.1.7.5 Personnel Dosimetry	774-776	5-12
5.1.7.6 Miscellaneous Health- Physics Information	777-780	5-14
5.1.8 Training	781-784	5-15
5.2 Inherent Controls	785-810	5-16
5.2.1 Shielding	785-789	5-16
5.2.2 Control Systems	790-792	5-18
5.2.3 Ventilation	793-801	5-18
5.2.4 Reactor Design	802-803	5-21
5.2.5 Stack-Gas Treatment	804-810	5-22
5.3 Corrective Measures	811-820	5-24
5.3.1 Decontamination	811-820	5-24
5.4 Waste Disposal	821-829	5-27
5.4.1 General Problems	821-822	5-27
5.4.2 Specific Waste-Treatment Problems	823-829	5-28
SUBJECT INDEX		A-1
AUTHOR INDEX		B-1
NUMERICAL INDEX		C-1

ABSTRACT

This compilation contains 202 abstracts of reports and documents on subjects related to maritime reactor safety; the abstracts are indexed in the AEC "Abstracts of Classified Reports" (ACR). These ACR references were listed as unclassified or declassified in TID-4021, TID-4035, and TID-4035, Supplement 1. The abstracts were selected as a part of the preparation of the classified bibliography (ALI-50, printed August 30, 1958) on this same subject. (See also SO-6200, September 15, 1957, unclassified.)

The abstracts are grouped according to the category of information they present; within each category, the most recent abstracts are given first. Subject, author, and report number indices are provided. A report number code key is not included. The report numbers used by the AEC Technical Information Service can be found in TID-85 (1st Rev.).

The abstracts are those indexed through ACR Vol. 13 (1957). Because of the lag in abstracting, reports issued in late 1957 are not likely to be included.

INTRODUCTION

PURPOSE

This compilation is a continuation of the literature search presented in SO-6200, an annotated bibliography of the unclassified literature, published September 15, 1957, and ALI-50, published August 30, 1958 (SECRET). The search was sponsored and encouraged by the Maritime Reactors Branch, Division of Reactor Development, U. S. Atomic Energy Commission, as part of its program leading toward the launching of the nuclear merchant ship Savannah.

SCOPE

The operation of nuclear-powered ships by civilians raises many questions. Because of the possible hazards, central station power reactors are located somewhat remotely from power consumers. Nuclear ships, on the other hand, when they enter harbors will be near large populations. The probability of a reactor accident and the potential hazard therefore are of great interest.

If a nuclear-powered ship collided with another ship in a harbor, could the reactor be protected from damage? What effect would the ship's attitude and environment have on criticality and decay-heat removal? If the fission products were released to the sea, how would they disperse and what would be their immediate and ultimate fate? Can control measures to reduce the probability of collisions or the potential seriousness of the consequences be devised? Such questions as these guided the selection of titles in this bibliography. Because of the complexity of the subject and its newness to many who will be called upon to make decisions, the titles represent both general and specific coverage of the subject. The coverage is far from exhaustive, however, because much information has yet to be developed and much is reported in the classified literature. This volume includes only references that were originally issued with a security classification.

The references include information on the inherent and administrative controls required for the safe operation of nuclear-powered merchant vessels. They also point out potential hazards for which controls are in the early stages of development or have not yet been devised. The references should be useful for the revision of codes and regulations pertaining to the design, construction, maintenance, inspection, and

salvage of such vessels. In addition, they provide information on: the environment of a marine nuclear reactor; the status of nuclear-reactor types; and the hazard to man from ionizing radiations.

Ideally, a compilation of reports on a limited subject area would contain only final, summary, and complete reports, and such has been the goal of this and prior compilations; however, for reactors under development or construction, comprehensive summary reports, except for hazard-summary reports, were lacking. Since considerable pertinent information is given in progress and quarterly reports, typical examples of each such report series are included herein; where particularly useful information appears, it is abstracted.

1. Nuclear Reactors for Marine Use

The references in Section 1 describe reactors that have been evaluated or that are under design or construction for naval or merchant-marine application. Background on the development of power reactor systems is also provided.

The references in 1.2 were selected as examples of reports containing both hazard information and useful background information, or because they give pertinent data on a particular reactor.¹ While interim reports are available, few worthwhile summary reports on reactor development were found.

Section 1 represents only a fraction of the background, historical, and descriptive information available in the literature, principally because such information is not essential to the objectives of this compilation. All useful reports on merchant-ship propulsion by nuclear power, however, are included.

A comprehensive discussion of the hazards presented by a nuclear merchant ship was not found, although the potential hazards are discussed^{627, 631*}.

2. Permissible Radiation Exposure Standards

Section 2.1 contains information on criteria for maximum permissible: exposure levels; exposure to external radiation; concentrations of radioisotopes in food, water, and air; and amounts of radioisotopes in the body.

*Superscripts refer to specific items in the bibliography.

Section 2.2 describes background radiation as found in the soil, air, fresh and ocean water, and man.

Background activity increases as weapons tests progress. The effect of a single explosion can be detected for months⁶⁴⁶, and the distribution of the fission products by no means occurs homogeneously in the atmosphere. Rain water contains nuclear debris⁶⁴⁴.

Hundreds of stations are accumulating data on ground-source, cosmic, and man-made background radiation. Work on sea-water radioactivity is not at a comparable level. Power reactor operations also contribute to background radioactivity through the inert gases released and the activity induced in ventilation air. The increase in background is of the same order of magnitude as diurnal fluctuations in some areas^{636, 637}.

Section 2.3 contains references describing experimentally observed effects of radiation; human tolerances can be estimated from these^{648, 649}. Several references indicate the need for further evaluation of the relative biological effectiveness of the various ionizing radiations⁶⁵⁷. The cancer-producing dose in animals is said to be related to the harmless daily dose as is the ratio for these two conditions in man⁶⁴⁹.

The extrapolation of plant and animal data to man is indicated to be unreliable until more data on animals approaching man in size⁶⁴⁸ is obtained. Recently measured biological effects of neutrons exceed predicted values, particularly in the energy range greater than 1 Mev⁶⁵¹. A few studies are reported for radiation effects on marine life⁶⁵⁸.

References containing data on low-level radiation effects on humans are not numerous^{659, 660}. Strontium tolerances appear to have been chosen on a more conservative basis than those for nonbone-seeking isotopes⁶⁵⁰.

3. Nuclear Accidents and Their Probabilities

Section 3.1 presents references to: theoretical or before-the-fact discussions of reactor accidents and preliminary information from progress reports on naval propulsion units.

The theory of accidents and criteria for safe operation are receiving continuing attention⁶⁶⁹. There is no indication that unknown or obscure reactor physics principles could be the basis for accident

initiation. Reactor accidents are more likely to occur through human error in operation or through simultaneous failure of mechanical or electrical components in the reactor or control system⁶⁶⁴. Accidents of varying degrees of credibility are being proposed⁶⁷¹ and investigated; reactor designs and control-system interlocks are being revised to reduce the probability of harmful results from human errors⁶⁶⁵.

Adequate cooling of marine reactors under extreme conditions of attitude or if the ship is sunk is not discussed. Credible accidents appear likely to result in damage only to the reactor and within the containment vessel⁶⁶⁴.

Section 3.2 presents references on the mechanism of primary accident initiation. Nine categories of accident causes are covered. Other categories are reported in other sections. A given abstract may refer to a different category from the one under which it is listed.

The mechanisms presented include some whose consequences may penetrate the containment vessels. The loss-of-coolant accident⁶⁷⁴, rapid reactivity insertion⁶⁸⁰, the metal-water reaction⁶⁷⁴, and the occurrence of poison transients appear to be incidents against which the reactor designer can provide no intrinsic self-regulating safety mechanism. Other accidents may result in fuel-element meltdown and possibly core collapse as a result of energy accumulating within the core more rapidly than it can be removed by the cooling system. Studies on the events following core meltdown are not included.

Section 3.3 gives references that describe the effects on the reactor or its surroundings following a primary accident. Secondary accidents, distinct from but initiated by the primary accidents, are usually more severe and cause more extensive damage. They are generally uncontrollable. No references are presented on core meltdown, which, with the metal-water reaction, requires a power transient and insufficient cooling for its initiation. The extent of these two accidents is not completely predictable on the basis of present knowledge. Severe temperature gradients across structural materials in the reactor core can result in physical damage to the structural material. Proper design procedures appear to be capable of handling any credible thermal shock stresses that may be generated⁶⁸⁹.

Damage to the reactor pressure vessel or containment as a result of pressure surges or missiles produced from an explosion are not reported.

Section 3.4 discusses hazards, including the probability of incidents, the possible energy released in an accident, and the fraction of fission-product inventory that could be released.

Little information is available regarding the probability of accidents in reactor operation. Summary articles providing insight on the magnitude of the energy released from a reactor that might be used in a marine vessel are not available. Information of this sort can be found scattered through the contractor reports on naval reactor developments. Estimates have been made of the fraction of total fission-product activity that might be released accidentally^{691, 692}.

4. Consequences of Fission-Product Release

The consequences of fission-product release are: dispersion of fission products in the atmosphere and in the ocean and other bodies of water; irradiation of man; and contamination of the reactor ancillaries.

Section 4.1 presents references to the dispersal of radioactivity in the atmosphere and the routes the radioactivity follows in leaving the atmosphere.

Fall-out patterns, approximately predictable from meteorological information, show cloud radiation dosages but do not estimate deposition of radioactivity⁶⁹³. Radiation hazards from airborne radioactivity may persist for several hundred miles⁶⁹⁸. Radiation from the cloud is considerably more hazardous than material deposited in the lungs from inhalation of the cloud. Deposition via precipitation may present a local hazard. Rainfall, however, is not an effective means of scavenging radioactivity from the atmosphere.

Section 4.2 gives references to the distribution and effects of fission products in the ocean. In the absence of extensive specific information, related subjects are discussed, principally contamination of fresh water with fission products. Harbor circulation studies are preliminary⁷⁰³.

The fate of fission products in the ocean has been studied sporadically; information on the dispersal or concentration of fall-out⁷⁰⁴ and of small amounts of liquid wastes⁷⁰⁶ is limited. No reference is made to the effect on bottom currents of the decay heat generated by sizable quantities of reactor debris or other nuclear wastes. A proposal for penetration of bottom mud with waste-weighted projectiles is made⁷⁰².

Bomb fall-out debris disappears from sea water but becomes concentrated in bottom fauna and fish^{707, 710}. Hazards may arise from human consumption of contaminated fish or seaweed or from radiation deposited on beach sand. The biological hazards are largely defined by isotopes of P, Sr, and I^{710, 711}.

Section 4.3 describes the hazards from radioactive materials and reports biological effects of fairly high radiation doses.

Section 4.4 presents reports of hazardous situations that might occur following a reactor accident of any magnitude.

5. Control Measures

Control measures are divided into: (1) those imposed on reactor design and operation by administration officials, regulatory bodies, and health-physics groups; and (2) those built into the reactor plant by design. The latter are called inherent controls and, as such, should be differentiated from the self-regulating features possessed by certain reactor designs. These latter features are covered most adequately in the hazard summary reports of Section 5.1.6.

Section 5.1 presents a wide range of material of interest to persons administering nuclear-energy propulsion applications. Certain aspects, such as insurance coverage and legislation, are not reported. A summary of reactor start-up procedure is presented⁷⁵⁶. Guides to the precautions required for nuclear safety are also given⁷⁴⁵⁻⁷⁴⁹.

Hazards discussed are principally those outlined in Section 3.2. No credible accidents are postulated for which interlocks, procedures, control systems, and containment do not cumulatively provide some measure of prevention.

Inadvertent bypassing of such preventive measures by negligence, sabotage, enemy action, or act of God is considered^{757, 759, 760, 761}. The quality and training of personnel employed in reactor operations cannot be overemphasized⁷⁶².

Section 5.2 provides references to equipment, structures, systems, and methods designed to provide inherent control of the hazards of operating nuclear power plants. Information on shielding is abundant⁷⁸⁵⁻⁷⁸⁹, but references to containment were absent. No direct references to the problem of optimizing the shipboard nuclear reactor location or to protecting it from the effects of collisions were found.

Section 5.3, on corrective measures, includes references to the action required after fission-product release--decontamination, maintenance, and repair. Decontamination of materials has been studied extensively.

Section 5.4, on waste disposal, treats fuel-reprocessing plant wastes and laundry wastes⁸²⁷, decontamination wastes, and laboratory wastes⁸²³. Incineration of active wastes is also covered⁸²⁴⁻⁸²⁶. Ultimate disposal to the ground^{822, 829} is discussed; sea disposal is not mentioned. Comprehensive articles on ultimate waste-disposal problems were not found.

1. NUCLEAR REACTORS FOR MARINE USE

1.1 REACTORS APPLIED TO MARINE VESSELS

1.1.1 Merchant Shipping

627 NNSD-15
NUCLEAR SHIP PROPULSION STUDY.

Interim Technical Report No. 3, covering period July 1, 1954, to November 1, 1954. J. B. Woodward, III. Newport News Shipbuilding and Dry Dock Co., Newport News, Va. November 1, 1954. 33 pp.

This report covers work done under a study agreement with the AEC dated November 4, 1953.

The operation of the reference-design nuclear-ship propulsion plant was studied in all situations likely to arise in merchant service. Comparisons were made between oil-fired and nuclear plants in steady-steaming performance, normal maneuvering performance, start-up and shutdown, refueling procedures, drydocking procedures, primary system maintenance, and engine-department crew requirements. The effect of fission-product transients on maneuverability and operation under emergency conditions is also discussed. (For preceding period see NNSD-9.)

1.1.2 Naval Reactors

628 M-4167
GAS-COOLED POWER PILE FOR
NAVAL APPLICATION. W. T. Moore.

Clinton Laboratories, Oak Ridge, Tenn. October 23, 1947. 15 pp.

This is a report on a four-week preliminary investigation of the suitability of a helium-cooled pile as a drive for a naval vessel. The study was based on:

- (1) Space requirements of the hull.
- (2) Power requirements listed in report A-4208 (GE) GE-KAK-1, "Survey of Atomic Power Plants for Naval Ship Propulsion," Knolls Atomic Power Laboratory.

The conclusions of the study were:

- (1) A helium-cooled pile appears feasible for naval application, providing a satisfactory method can be developed for canning fissionable material in beryllium metal; such a method will probably be found soon.
- (2) A unit to deliver 15,000 shp weighs about 527 tons and can be located in a cylindrical space 15 ft 10 in. in diameter and 43 ft long. This space includes shielding (except that a 3-ft thickness is located outside the pressure hull immediately above the pile) but does not include the boiler feed pump and two turboalternators, which are required to deliver variable-frequency current to the helium blower motors.
- (3) Using helium at 60 atm pressure with a temperature rise in the pile from 450F to 1300F, this unit has an over-all thermal efficiency of 19.5%.

(4) By using helium coolant with canned fuel, the heat of the pile can be delivered to a heat exchanger in a coolant essentially free of radioactivity. This makes it possible to eliminate

shielding except around the pile. Other coolants become radioactive in the pile and would require further shielding after leaving it.

(5) In an evaluation of the applicability of a gas under pressure as a pile coolant, consideration must be given to the possibility of radioactive contamination of the gas and to the hazards that this contamination introduces if a leak or rupture takes place in the system. Hazards due to gas coolant are not considered excessive in this design because of the following precautions:

(a) Helium-circulation blowers and control rods are completely canned motors that are electrically driven; thus, there are no seals or packing glands around movable parts.

(b) The only valves in the helium system are two check valves--one in the discharge line of each helium blower. Both valves can be welded externally, since no moving parts pass through the pressure shell.

(c) The only nonwelded joint in the helium system is located at the top of the pile shell; it is provided for reactor removal. It is of the breech-block type, having a bolted gasket similar to those used in high-pressure heat exchangers. It is hoped that a method for seal-welding this joint can be found.

(d) It is contemplated that the entire helium system, including the pile and the boiler, will be located in a pressure-tight compartment that personnel will not normally enter during pile operation.

(e) It is assumed that an efficient fuel canning system will be used and that there will be no radioactivity in the helium gas, except for that induced in impurities initially present in the helium.

1.2 INFORMATION ON REACTORS

1.2.1 General

629 DR-20
THE CHALK RIVER APPROACH TO
ATOMIC POWER. W. B. Lewis.
Atomic Energy Project (Canada).
January 22, 1952. 13 pp.

Several approaches to obtaining useful power from nuclear energy at a price the user would be prepared to pay are discussed. In the large-scale approach, a survey of the known sources of power in the world and their potential is made. The success of the Pu-production approach depends on the cost of alternative methods developed for Pu production as well as the economics of Pu-breeding reactors. The mobile-reactor approach does not lead directly to any distinctive development of large-scale operation. The natural-U approach is based on obtaining as much power as possible out of natural U with a minimum of chemical processing.

1. 2. 2 Specific Reactors

630 KAPL-6
ATOMIC REACTOR FOR NAVAL SHIP
PROPULSION; PROGRESS REPORT
TO NOVEMBER 1, 1947. D. R. Miller.
Knolls Atomic Power Laboratory,
Schenectady, N. Y. November 17,
1957. 11 pp.

Results of calculations are given for critical masses as a function of reflector thickness, uranium enrichment, xenon-135 absorption of neutrons at various specific power levels, xenon-absorption cross section at various temperatures, and coolant composition. Bismuth is found to be nearly ideal as a coolant from the standpoint of critical mass.

631 CF-54-6-194
PRELIMINARY STUDY OF A HOMO-
GENEOUS REACTOR FOR SHIP PRO-
PULSION. P. R. Clark. Oak Ridge
National Laboratory. June 25,
1954. 7 pp.

Homogeneous reactors were selected as the subject of an investigation of the application of nuclear power to a "Mariner" class cargo ship. A 100-Mw-heat-output reactor size was chosen. A reactor of this size offers safety, because of its high negative temperature coefficient and the continuous removal of long-lived fission products. The main disadvantages are radiation hazards resulting from leaks or the activation of equipment. The basis for the choice of the ship type, the reactor power-level selection, and other parameters are discussed.

632 M-3564
RADIOACTIVITY TO BE EXPECTED
IN THE STEAM FROM A NUCLEAR
POWER SYSTEM. H. G. Rickover.
U. S. Navy. September 10, 1947.
31 pp.

The amount of radioactivity that can be expected in the steam end of a nuclear-pile steam-power system is estimated. The conclusion is that if the fuel elements are suitably canned, there will be no problem arising in the steam system from radioactivity, but that if the fuel elements permit rapid diffusion of fission products into the primary coolant stream, appreciable radioactivity may exist in the steam and condensate systems, rendering close approach inadvisable except for brief periods. Because of the present meager knowledge of the diffusion of fission products, these estimates may be pessimistic by a factor of 100.

The need for the development of satisfactory high-temperature canning or cladding material is emphasized, and schematic diagrams of a nuclear power system using both canned and uncanned fuel elements are included. Discussions and tabulations of pertinent calculations and data are appended.

2. PERMISSIBLE RADIATION EXPOSURE STANDARDS

Environmental radioactivity in the NTA flight-path and test area was measured during the period from

November, 1954, through September, 1955, by means of six sampling series. The data reflect adequately the long half-life beta radioactivity in the air, soil, and water. Short half-life activity was not estimated. An additional radio assay of vegetation samples is required to complete the picture.

Following a weapons test, the maximum airborne activity observed was 448 micro microcuries/m³. This activity came from fission products that were approximately two days old. NBS Handbook No. 52 shows the permissible concentration to be 1000 micro microcuries for unknown beta emitters or 200 micro microcuries/m³ for Sr⁹⁰. The average beta activity of surface soil samples was 21 micro microcuries/g. Subsurface soil samples were approximately 50% lower in beta activity.

637 NRL-4118
THE RADIOACTIVITY OF THE ATMOSPHERE. I. H. Blifford. Naval Research Laboratory, Electron Optics Branch, Optics Division, Washington, D. C. April 15, 1953. 41 pp.

A historical review of investigations of atmospheric radioactivity is given; it includes discussions of the occurrence of radioactivity, experimental methods of observation, and original measurements. A bibliography of 416 references is included.

The level of radioactivity is shown to fluctuate diurnally and to increase at ground level under low-altitude temperature inversions. Variations in the radioactive content of air of the order of 10-1 are not uncommon over short periods.

638 NRL-3862
GEOGRAPHICAL DISTRIBUTION OF THE RADIOACTIVITY OF THE ATMOSPHERE. I. H. Blifford. Naval Research Laboratory, Washington, D. C. October 11, 1951. 5 pp.

Air samples taken at widely separated geographical locations in the United States and in the Pacific area show that temperature, humidity, topography, and the quantity of dust in the air have a strong influence on the radioactivity in the air. Radium and thorium are widely distributed and constitute 50-90% of the total activity. An estimate of the normal amount of radioactive matter in the air is 1.2×10^{-12} curie/m³.

639 UCRL-1437
MEDICAL AND HEALTH PHYSICS, QUARTERLY REPORT (APRIL, MAY, AND JUNE, 1951) OF THE RADIATION LABORATORY.

University of California Radiation Laboratory, Berkeley, California. August 14, 1951. 59 pp.

According to C. A. Tobias, the cosmic radiation near the top of the atmosphere is in the neighborhood of the accepted "safe" dose level and largely in the form of nuclei heavier than helium. Thus, with such high velocity, this radiation is expected to have little biological effect, although such effect is hard to predict. While it seems unlikely that there would be a provocation of carcinoma, leukemia, deterioration of nervous tissue, or radiation cataracts, these specific effects cannot

be ruled out. A table shows that a 24-hour dose of all cosmic rays at the top of the atmosphere would be near 10 mrep and 71 mrem. The Health Chemistry Group, under N. Garden, has worked on remote-control equipment for special laboratory handling of highly active material and has designed a new decontamination chamber (details not given). Waste from this laboratory is towed to sea for dumping. The laboratory makes routine tests on airborne activity using mercury-vapor surveys. It has obtained CWS No. 6 filters for face masks for its personnel. The Health Physics Group, under B. J. Moyer, has worked with Ilford nuclear plates for measuring fast-neutron fluxes; on a fast-neutron scintillation counter, it has taken routine exposure tests and reported 35 weekly exposures over 0.3 r at the linear accelerator, 16 in the chemistry section, and 10 in the 60-in. area. There were only three weekly exposures of 1.0 r, and these were in the chemistry section.

This report gives information about progress on: (1) the effectiveness of a chelation in vivo (EDTA) to aid elimination of heavy-metal active particles; (2) the role of heparin in reduction of cholesterol in blood vessels; and (3) the chemical reactions provoked by radiation of dilute aqueous solutions in the cyclotron.

640 NYO-1521
SOIL AND WATER URANIUM AND RADI-
UM SURVEY. D. E. Lynch. New
York Operations Office, AEC.
June, 1950. 43 pp.

This report presents the results of a survey to determine the soil and water contamination around several plants that process uranium and related elements. The natural radium content of soil is reported to be $9 - 15 \times 10^{-13}$ g/g, and the natural uranium content is $3 - 9 \times 10^{-6}$ g/g. These values are nearly in radioactive equilibrium by proportion.

641 KAPL-312
PROGRESS REPORT NO. 43 (FEBRUARY
1950); SECTION VI: HEALTH PHYSICS.
KAPL Staff. Knolls Atomic Power
Laboratory, Schenectady, N. Y.
1950.

The continuous beta-gamma monitor indicated daily maximum concentrations of natural radioactivity ranging from 6×10^{-12} to 7.8×10^{-10} curies/m³. The higher value occurred during an atmospheric inversion.

642 ORNL-495
HEALTH PHYSICS DIVISION, QUAR-
TERLY PROGRESS REPORT FOR
PERIOD ENDING OCTOBER 15, 1949.
K. Z. Morgan and F. Western.
Oak Ridge National Laboratory.
November 29, 1949. 20 pp.

Measurements of background radiation show the typical condition to be represented by a concentration of 1.5×10^{-10} curie/m³ of radon during the day and an accumulation during the normal nighttime temperature inversion to five times that value. A tentative maximum permissible concentration of C¹⁴O₂ in plant atmospheres is given as 10^{-7} curie/m³ of air.

2.2.2 Man-Made Isotopes

643 LP-176
DOSAGE DUE TO COSMIC RADIATION,
REPORT NO. 176.

B. T. Feld. Lexington Project,
Massachusetts Institute of Tech-
nology. September 15, 1948.
1 pp.

Cosmic rays are described in two classes: the hard, penetrating type; and the soft rays that are readily absorbed in lead. The following figures come from an M. I. T. publication, "Interpretation of Cosmic Ray Phenomena," by Bruno Rossi. At zero altitude, the dosage of both classes is calculated at 0.06×10^{-3} r/day, corresponding to a 50-year dosage at sea level of about 1 r. The great increase in intensity for both kinds of rays is between 10,000 ft and 32,500 ft. Above 70,000 ft, the soft-ray intensity falls.

644 ORNL-1081
FALL-OUT IN SOUTHEASTERN
UNITED STATES DURING JANUARY
AND FEBRUARY 1951, FROM THE
NEVADA ATOMIC TESTS; HEALTH
PHYSICS DIVISION. F. J. Davis.

Oak Ridge National Laboratory.
November 27, 1951. 39 pp.

Air-filter and rain-water collec-
tions of atmospheric fall-out were made
at Atlanta, Ga.; Urbana, Ill.; Topeka,
Kan.; Fort Worth, Texas; and Nashville,
Tenn. The air filters showed activity
as high as 1400 counts per minute, com-
pared with an average thorium back-
ground of 7; the precipitate from rain-
water collections showed that activity

increased as much as 400 times.
Radioautographs proved the particulate
nature of the activity, and radiochem-
ical analyses identified the activity as
recent fission products. Observed ac-
tivity peaks correlate well with the
meteorological positioning of radioac-
tive clouds from the Nevada tests.

645 UCLA-143
INDUSTRIAL HYGIENE DIVISION;
QUARTERLY PROGRESS REPORT
FOR THE PERIOD ENDING JUNE 30,
1951 (pp. 59-81). F. A. Bryan.

Atomic Energy Project, University
of California at Los Angeles.
July 10, 1951. 230 pp.

A study of airborne activity before
and after the Nevada bomb tests shows
 2.24×10^{-3} alpha disintegrations/hour/
ft³ of air sampled; after the test peaks,
activities ranged as high as 17.1×10^{-3}
and 14.5×10^{-3} alpha disintegrations/
hour/ft³.

646 UCLA-140
THE 1949 AND 1950 RADIOLOGICAL
SOIL SURVEY OF FISSION-PRODUCT
CONTAMINATION AND SOME SOIL-
PLANT INTERRELATIONSHIPS OF
AREAS IN NEW MEXICO AFFECTED
BY THE FIRST ATOMIC-BOMB DETO-
NATION. K. H. Larson, J. H. Olafson,
J. W. Neel, W. F. Dunn, S. H.
Gordon, and B. Gillooly. Atomic
Energy Project, University of
California at Los Angeles. June 12,
1951. 84 pp.

This report summarizes the fourth-
and fifth-year results of the radiolog-
ical surveys and assays of soils and

plants from the areas contaminated by fall-out from the first atomic-bomb detonation in New Mexico.

647 UCLA-78
METHODS AND BACKGROUND VALUES
FOR BETA-GAMMA RADIOACTIVITY
IN SOME PLANTS FROM NEW MEXICO
AND CALIFORNIA. D. B. Dunn,
Margaret R. Lewis, and S. H.
Gordon. Atomic Energy Project,
University of California at Los
Angeles. June 9, 1950. 25 pp.

This publication reports on observations of material collected from the first atomic-bomb detonation site in order to indicate the role low-level contamination of the soil plays in the metabolic and life cycles of the plants in that area. The fact that the site was in an alkaline desert area and that the contamination by radioactivity in the main was of a very low order made the survey slow and cumbersome. The uptake of natural and artificially radioactive minerals by plants was exceedingly variable for certain herbs, shrubs, and the few crop plants examined. Tentative maximum-normal-control background values for native grasses, weeds, and juniper bark have been established.

2.3 BIOLOGICAL EFFECTS RELEVANT TO THE ESTABLISHMENT OF PERMISSIBLE LEVELS

2.3.1 General

648 ANL-AMB-2
TOLERANCE TO Sr^{89} AND RADIUM.
A. M. Brues. Argonne National
Laboratory. July 22, 1946. 4 pp.

A reference to recent animal data is used to suggest a means of extrapolating radioactive tolerances to man of agents irradiating bone over long periods. Two general principles that may be used to further this hypothesis are: (1) a linear relation exists between dose, time after latency, and tumor expectancy; and (2) a logarithmic, or at least gradual, change in latent time with dose may be expressed.

2.3.2 Specific - Animal Data

649 HW-42403
RADIOLOGICAL SCIENCES DEPARTMENT. QUARTERLY PROGRESS REPORT ON RESEARCH AND DEVELOPMENT ACTIVITIES.

H. M. Parker. Hanford Works, Richland, Washington. April, 1956. 34 pp.

The high incidence of tumors in the thyroid glands of sheep fed 5 micro-curies of I^{131} per day for four years or more suggests that there may be short cuts in biological research. The ratio of the daily dose that is without demonstrable deleterious effect and the daily dose that is likely to produce a tumor in middle age or later for this isotope in sheep is comparable with the ratio for these two conditions for radium in man. If this ratio is more or less constant for other isotopes and other cases, determining the cancer-producing dose would reduce the biological research effort by over 90%.

Advances in the technology of measurement of the actual rate of underground water movement have now

confirmed that some radioactive wastes can travel as much as 10 times as fast as has been previously estimated; rates exceeding 2 miles per year have been measured at Hanford. The mobile isotopes are Cs^{137} as a nitrate and Co^{60} as a cyanide complex.

650 UCRL-2823
RADIOSTRONTIUM STUDIES. MEDICAL PHYSICS QUARTERLY PROGRESS REPORT FOR JULY, AUGUST, AND SEPTEMBER, 1954. Joseph G.

Hamilton, Patricia W. Durbin, and Muriel Johnston. University of California Radiation Laboratory, Berkeley, California. January 13, 1955. 5 pp.

This report describes attempts to determine the Sr^{90} - Y^{90} content of a baby monkey born three months after the intravenous administration of 50 microns of Sr^{90} and 150 microns of Ca^{45} to the mother. A large, shielded, thallium-activated sodium iodide crystal counter was employed to measure bremsstrahlung; results indicate a maternal transfer of 1% or 2% of the injected Sr^{90} to the fetus.

651 WT-820
GENETIC EFFECTS OF FAST NEUTRONS FROM NUCLEAR DETONATIONS. H. H. Plough and C. W.

Sheppard. Division of Biology and Medicine, AEC. January, 1954. 66 pp.

A series of genetics test-objects were exposed to fast-neutron irradiation at Operation Upshot-Knothole. The specimens were placed inside 7-in. -thick lead hemispheres set at

appropriate distances from ground zero to cover the dosage ranges required. Plant materials used included spores of several fungi, *Tradescantia* pollen, and seeds of *Datura* and corn. *Drosophila* flies, *Mormoniella* wasps, and several mouse strains constituted the animal specimens used. Analysis of data from breeding studies led to the conclusion that the relative biological effectiveness (RBE) for genetic effects from detonation neutrons compared with X or gamma irradiation is high, observed values ranging from about 2 to 15 or more. The RBE for chromosome breakage from detonation neutrons is not significantly higher than that from cyclotron neutrons; the RBE for the production of simple mutations by fast neutrons compared with X rays tends to be low, but the values are higher for gross chromosome aberrations. The genetic tests are of some value as biological dosimeters supplementary to physical dosimetry; and for equal doses, neutrons represent a greater potential genetic hazard than other forms of radiation from nuclear detonations.

652 UCLA-260
ADMINISTRATIVE AND BIOCHEMISTRY DIVISIONS; QUARTERLY PROGRESS REPORT FOR PERIOD ENDING JUNE 30, 1953 (pp. 5-26).

Atomic Energy Project, University of California at Los Angeles. July 1, 1953. 99 pp.

Under the conditions of experimental irradiation used, the LD_{50} of the cat was found to be 198 r. Alpha-tocopherol, a physiological antioxidant, was found to offer no protection against the lethal effects of irradiation.

653 LA-1309
THE RELATIVE PHYSIOLOGICAL AND
TOXICOLOGICAL PROPERTIES OF
AMERICUM AND PLUTONIUM.

W. Langham and R. E. Carter.
Los Alamos Scientific Laboratory.
November 15, 1951. 61 pp.

Urinary and fecal excretion of Am and its deposition in tissues and organs were similar to those of Pu. Liver and skeleton were the major sites of deposition. Zr citrate administered 15 minutes after injection of the Am increased the urinary excretion of Am and decreased the amount found in the liver and the skeleton at 4-16 days. LD₅₀ studies showed Am slightly less toxic than Pu when given in the acute toxic range. Survival studies, hematological observations, bone-marrow observations, comparison of tumor incidence, and the incidence of skeletal abnormalities indicated that Am and Pu have essentially the same chronic toxicity when given on an equal microcurie basis. Tolerance values for Am and Pu should be considered the same.

654 UCLA-143
DIVERSIFIED PROBLEMS DIVISION;
pp. 82-95 of QUARTERLY PROGRESS
REPORT FOR PERIOD ENDING JUNE
30, 1951. S. L. Warren. Atomic
Energy Project, University of
California at Los Angeles.
July 10, 1951. 14 pp.

A study of the embryos of paradise fish exposed to X rays at various developmental stages between fertilization and hatching shows exposures to 1000 r before gastrulation prevents

hatching in almost 100% of the embryos; exposure to as much as 4000 r after gastrulation has no demonstrable effect on the percent hatching. In most cases, irradiation increases the length of time before hatching occurs, but exposure within a few hours of hatching hastens the event. The radiosensitivity of the embryos varies inversely with their age; the life span of irradiated embryos is inversely proportional to the dose received. The responses immediately following irradiation are slight; but after the latent period, the embryos enter a critical period during which abnormalities begin to appear. Gross and microscopic changes of the developing embryo due to irradiation are discussed in detail.

655 ANL-4253
QUARTERLY REPORT, NOVEMBER
1948 TO FEBRUARY 1949. A. M.

Brues and H. Lisco. Biological
and Medical Division, Argonne
National Laboratory. February 1,
1949. 183 pp.

Studies of the role of the spleen in radiation injury indicate that: (1) severe anemia, leucopenia, and thrombocytopenia develop in mice after a single dosage of 600 r total-body X radiation; and (2) ectopic erythrocytopoiesis in the lead-protected spleens of mice given 600 r total-body X radiation (exclusive of spleens) compensates with such rapidity and so extensively for the destruction and interruption of this activity in the marrow spaces that no anemia of significance becomes apparent.

Cysteine administered intravenously to rats within one hour before X radiation in the nearly completely lethal range (800 r) greatly diminishes toxicity (5-week survival, 73% of 126 cysteine-treated; 13% of 134 irradiated controls). Injection of cysteine within five minutes after exposure fails to protect against X radiation. When cysteine-HCl is given at pH 1 prior to irradiation, rather similar protection is obtained with doses (expressed as cysteine) ranging from 175 to 575 mg/kg of body weight.

656 HW-12079
RADIOACTIVITY IN PEKIN DUCKS ON
THE COLUMBIA RIVER. K. E. Herde
and J. F. Cline. Hanford Works,
Richland, Washington. January 7,
1949. 11 pp.

Thirteen pekin ducks placed on the Columbia River for monitoring purposes were sacrificed after 1-15 months exposure to the slightly contaminated water of the stream. Eleven tissues or organs and feces samples of each fowl were assayed for beta radioactivity. Thyroids containing I^{131} from stack-gas contamination were highest of all tissues. Of other tissues, the pancreas was generally higher, averaging about 0.04 microcuries/kg. Values for bone, liver, spleen, gonads, and kidneys were of about the same order of magnitude, while muscle, lung, blood, and brain were usually lower by a factor of two. A decay study indicated that P^{32} was the dominant isotope present, although a longer-lived element presumed to be Fe^{59} was occasionally present. Yolks were found to be higher, by factors of 2-5, than albumen. The radiation dose to eggs was found to average only about 1/40 tolerance. The

highest level detected in bone, was less than 1/4 tolerance as most recently defined.

A graph shows comparative seasonal trends in radioactivity for three tissues and feces. A vernal and an autumnal peak of about equal magnitude occurred. These peaks were separated by a low, coincident with the crest of high river flow. An apparent low in late fall or winter was thought to be a plateau associated with lower temperatures and retarded algae growth. A supplementary study involving two ducks was made to show the differences in radioactivity associated with available food algae.

657 UCRL-73
SUMMARY OF RESEARCH PROGRESS
MEETING, MARCH 18, 1948. M. F.
Folden. University of California
Radiation Laboratory, Berkeley,
California. March 18, 1948.
7 pp.

In some animal experiments with 90 Mev neutrons the biological effectiveness of X rays was 3-14 times that of neutrons. Four graphs illustrate the effect of various dosages of X rays and neutrons on the red and white cell count and upon the weight of rats. In neutron irradiations, the animals were placed in a cage surrounded by paraffin 3 in. thick and about 15 ft from the source. Thimble chambers for physical measurements were imbedded in the paraffin. Photomicrographs of bone marrow irradiated with 3500 rep showed that the blood vessels are crowded with red cells and that the normal structure is destroyed. At dosage rates of 445 rep/

hour, no animals died; at 815 rep/hour, all of them died. The LD₅₀ is 670.

Yields of spallation products of antimony were studied. Data obtained from the deuteron bombardment of antimony are tabulated.

658 UWFL-5
LETHAL EFFECT OF X RAYS ON
FOUR MARINE MICROPLANKTON
ORGANISMS. Applied Fisheries Labo-
ratory, University of Washington.
November, 1946. 27 pp.

An exploratory series of experiments on marine microplankton was designed to determine the lethal effect of X rays on some representative types of marine plankton.

In the more heavily irradiated samples, the full effect of the treatment in reducing the number of organisms occurred a little more than a month after irradiation. Five months from the time of treatment, there was either little change (for three organisms) or recovery (for Nitzschia).

The X-ray dose that was lethal within 24 hours to 50% of the brown Mastigophora appeared to be about 50,000 r; a dose of 100,000 r was 100% lethal. No evidence of immediate death of Nitzschia Closterium was noted, and Chlorella did not seem to be affected quickly; thus, the immediately lethal doses for these organisms were not determined. Conclusions regarding later results are based upon a count made at irregular intervals until four months after exposure. Nitzschia Closterium exposed to 100,000 r was not present 20 days after treatment. The brown

Mastigophora, exposed to 25,000 r or more, were dead 23 days after treatment.

There are indications that for the first month, the counts of all organisms are inversely related to the amount of exposure above 1000 r. The counts of cultures exposed to 50,000 r and 100,000 r were appreciably lower than those in the other groups. Counts of cultures exposed to 1000 r were not unlike the control; in nine cases they were greater than the control, and in ten cases less. On the basis of 19 counts for each culture, the counts for the 10,000-r treatment exceeded the control twice; for the 25,000-r treatment once; for the 50,000-r treatment none; and for the 100,000-r treatment once. Tables suggest that for the first month the counts in the cultures subjected to higher irradiations, when compared with the mean of the controls, decreased with time, except in the case of the brown Mastigophora, which decreased in numbers more rapidly than the other groups.

Recovery was slow or practically nil up to the time the experiment was terminated in three of the groups, Chlorella, Carteriidae and the brown Mastigophora. Recovery was rapid for Nitzschia after the twenty-first day in groups irradiated with 25,000 r, 40,500 r, and 100,000 r, whereas the 1000-r and 10,000-r groups decreased in numbers after the twenty-first day and showed very little recovery for the duration of the experiment.

Not even in the 100,000-r groups of any of the organisms did the counts remain at zero.

661 CH-3841
A STUDY OF THE HANDS OF RADIOLOGISTS. M. Nickson. Argonne National Laboratory. June 1, 1947. 32 pp.

A group of radiologists' hands were studied for evidences of radiation damage to the skin. The techniques were the same as those used for routine hand studies of Argonne National Laboratory personnel; they consist of: (1) examination of wax impressions of the finger ridges and (2) examination of photographs of the vessels and papillae in the nail fold.

Of the 323 radiologists examined by the first method, 48% were found to have ridge abnormalities. The incidence of abnormality increased with the years of exposure to radiation, up to 100% after 35 years. The irregular use of lead gloves does not adequately protect the ridges from radiation.

Photographs of the nail fold of 152 radiologists were studied and compared with similar photographs of 101 laboratory workers and 41 persons over 63 years of age. Some abnormalities occurred in all three groups. The incidence of abnormality among the radiologists increased with years of exposure to radiation and exceeded the incidence of abnormality in the aged. No radiologist was unaffected after 30 years of exposure.

The most reliable criteria of damage seem to be: (1) distortion of the superficial vascular plexus; (2) branching of the vessels of the terminal row; and (3) distortion of the papillary border of the corium. These three things may

be induced by repeated low-dose exposure to radiation and, like other biological effects of radiation, cannot be distinguished from similar findings in very old persons.

It is concluded that abnormalities of the vessels and of the papillae in the nail fold are induced earlier in radiologists than in persons not exposed to radiation.

662 CH-3833
EFFECT OF A SINGLE X-RAY DOSE TO THE NAIL-FOLD AREA OF HUMAN SUBJECTS. M. Nickson. Argonne National Laboratory. June, 1947. 4 pp.

So that the nature of the changes occurring in the fingers of persons occupationally exposed to radiation could be further understood, the nail-fold area of 15 subjects was observed before and after a single radiation exposure. Fourteen subjects were undergoing X-ray or radium treatments for other purposes. None had received previous irradiation to the hands. The fifteenth was a staff member who occasionally prepared radium plaques used for treatments. He had been exposed intermittently over a period of seven years. For this study, he was observed before and after the preparation of a plaque containing 130 mg of radium. The patients having the X-ray treatments were given a single dose to the left fourth finger. This finger was chosen because, compared with the first, second, and third fingers, the skin is fairly thin there, and the vascular pattern is usually readily visible. Also, this finger is less likely to have been subjected to previous trauma.

The total dose ranged from 200 to 600 r. Microscopic observations were made immediately before treatment, immediately after treatment, and as frequently as possible thereafter.

From this brief and incomplete study, it appears that radiation exposures of 600 r or less, given as a single dose under the conditions described, produce no constant microscopic or macroscopic reaction. The transitory effects were most often microscopic, consisting of hyperemia of the small terminal vessels and dilatation of vessels in the superficial plexus. There was no change in the number of vessels visible in the area before and after radiation. It is proposed that test doses be given at higher levels.

Lymphocytes of the groups increased significantly after employment. The increase of the lymphocyte count in hazard groups is in excess of a light increase in the control group and is on the borderline of significance. Thus, it is possible that work in the presence of radiation or metal hazards somehow brings about slight lymphocytosis. Individual daily monitoring indicates that the average measured exposure is less than 0.1 r per day for all individuals in these groups.

663 CH-3865
CHANGES IN MEAN BLOOD LEVELS
OF METALLURGICAL LABORATORY
EMPLOYEES DURING THE FIRST
YEAR OF EMPLOYMENT AS RE-
LATED TO WORKING CONDITIONS.

N. Pearlman and G. A. Sacher.
Metallurgical Laboratory, Naval
Engineering Experiment Station,
Annapolis, Maryland. July, 1946.
9 pp.

The mean levels of several blood elements were investigated for a control group and for groups exposed to radiation and uranium toxicity hazards in the Metallurgical Laboratory at six months and one year after employment. No significant decrease in mean level was found for any blood element.

3. NUCLEAR ACCIDENTS AND THEIR PROBABILITIES

3.1 GENERAL DISCUSSIONS

3.1.1 Accident Theory

664 TID-5202
ATOMIC ENERGY COMMISSION SYM-
POSIUM ON REACTOR HAZARDS.
MINUTES OF MEETING AT THE NEW
YORK OPERATIONS OFFICE, APRIL
15, 1950. M M Mills Atomic
Energy Research Department, North
American Aviation, Inc. April, 1950.
18 pp.

This report does not deal with effects external to the reactor shield. In thermal reactors, a reactor runaway can be initiated by rapid control-rod movement. In thermal or fast-neutron reactors employing enriched material, transient thermal fluctuations may initiate a runaway as the result of Doppler broadening of the fission cross section. The cases of the reactor being delayed-super-critical and prompt-super-critical are considered. The E-folding times for the rate of power rise can vary for these two cases, between 0.05 sec and 20 micro sec. Although it may be anticipated that the runaway could be stopped by negative temperature coefficients or negative power coefficients, estimates of the actual values of these coefficients during a runaway are made difficult by the temperature gradient between the fuel and its surroundings. The need for increased knowledge of the resonance structure of U^{235} is discussed. Also discussed is the power coefficient associated with poisons and its possible auto-catalytic effects, fuel expansion, and loss of water. The effects of reactor accidents on the shielding and

containment structure are divided according to whether the accident produces a shock wave or a pressure wave. An upper-limit estimate of the maximum violence likely to be encountered with any reactor is equivalent to 465 lb of TNT, or 2.1×10^5 kg cal. The extra radioactivity caused by a runaway is estimated to be about 20% of the radioactivity following a normal shutdown.

665 WASH-10
REPORT ON TENTH MEETING OF
THE REACTOR SAFEGUARD COM-
MITTEE, U. S. ATOMIC ENERGY
COMMISSION BUILDING, WASHING-
TON, D C., MARCH 1, 2, AND 3,
1950. Reactor Safeguard Committee,
AEC. 7 pp.

3.1.2 Criteria for Safety

666 LA-1289
A STUDY OF AN ACCIDENTAL RADIA-
TION BURST. R. W. Paine, Jr.
Los Alamos Scientific Laboratory.
March, 1951. 30 pp.

This report analyzes a fission burst that occurred in a criticality-measuring apparatus. The incident produced no casualties and appeared to have been caused by the unforeseen effect of hydrodynamic forces on fissionable materials as they were being separated by a planned scram. Descriptions of the incident, the measures taken to approach the radioactive area, the techniques for determining the magnitude of the radiation and energy released, and the reconstructed incident are presented.

667 CF-50-9-37
 REVIEW OF ORNL HOMOGENEOUS
 REACTOR EXPERIMENT BY THE RE-
 ACTOR SAFEGUARD COMMITTEE.

C. E. Larson. Oak Ridge National
 Laboratory. September, 1950. 4 pp.

This report presents precautions taken to prevent equipment malfunction or failures that might lead to a nuclear incident. The problem conditions were: thinness of the diaphragm in the soup pump; corrosion by the reactor fluids; the effect of radiation on corrosion rate; the explosive recombination of dissociated water; the effect on reactivity of the introduction of cold soup; and the reliability of power control by means of regulation of power output.

668 CF-50-9-137
 HAZARDS AND ACCIDENTS ASSOCI-
 ATED WITH THE OPERATION OF THE
 X-10 REACTOR. Oak Ridge National
 Laboratory. September 25, 1950.
 5 pp.

The accidents or near-accidents that have been experienced as a result of the peculiarities of pile operation and other accidents or near-accidents of major proportions are briefly reported.

3.1.3 Potential Accidents

669 TID-10117
 REACTOR STUDIES, FINAL REPORT
 (PART I). Babcock and Wilcox Co.,
 Atomic Energy Division, Akron,
 Ohio. November, 1955. 169 pp.

Thorium-Converter Power-Reactor
Study: A study was made of a reactor

to operate at a 500-Mw power level. The fuel assemblies consist of U-bearing and Th-bearing flat plates clad with zircalloy. Reactor-core, reflector, and control-system designs are discussed. Preliminary critical-mass calculations were made using modified two-group theory and cylindrical geometry. The results of calculations of group constants, neutron-flux distributions, excess reactivity, Xe and Sm transients, the temperature coefficient of reactivity, neutron lifetime, and burn-out and isotope build-up are given. Results of the study indicate the feasibility of such a reactor.

Analysis of Flashing Cycles for
Pressurized Water-Package Power
Reactors: The possibilities of steam-
 power production by the flashing of hot,
 high-pressure-reactor coolant water
 are considered. Control and hazards
 are discussed and a schematic diagram
 of the cycle is given.

Heterogeneous Boiling Reactor:
 A design study was made for a package
 boiling reactor and an associated
 steam plant designed to produce 2.2
 Mw of electricity. The fuel plates,
 highly enriched UO_2 in a stainless-
 steel matrix, are stainless-steel clad.
 The core is cooled by vaporization and
 moderated with circulating light water.
 Saturated steam is extracted by cyclone
 separators and used to drive a turbo-
 generator. Burn-out poison in the form
 of a B^{10} compound is incorporated to
 reduce the reactivity variation with
 core life. The designs were made on
 the basis of reliability, maximum
 safety, and a minimum of development
 effort.

Shielding Studies: The emitted gamma spectrum and self-shielding properties of a given core design are derived, and a method of plotting fast- and slow-neutron and gamma fluxes through bulk shielding materials is discussed. Examples are shown.

Burn-Out Heat-Flux Studies: Available data on light H₂O burn-out data in the region of net steam generation are evaluated. Results show that burn-out heat flux: (1) increases with increased entrance subcooling; (2) increases with increased mass flow rate; and (3) decreases with increased pressure at the higher mass flow rates but reaches a maximum at about 1200 psia for lower flow rates.

670 K-1095
ANALYSIS OF A POSSIBLE RADIATION
BURST. L. Geller and H. F. Henry.
Carbide and Carbon Chemicals Co.
June 2, 1953. 25 pp.

Qualitative and quantitative aspects of an accidental critical reaction at the K-25 plant were calculated. Specific examples are considered to illustrate the effect of slight changes in geometry on the results.

3.1.4 Reactor-Program Progress Reports

671 ANL-5345 (Del. 2)
REACTOR ENGINEERING DIVISION
QUARTERLY REPORT, JULY 1, 1954,
THROUGH SEPTEMBER 30, 1954.
Argonne National Laboratory.
October, 1954. 127 pp.

The reactors discussed in this report are: (1) the BER (boiling experimental reactor); (2) the BORAX (boiling reactor experiment); (3) the PBR (power breeder reactor); and (4) the EBR-II (experimental breeder reactor II). The first two are thermal power reactors and the second two are fast power reactors. Naval reactors are discussed under advanced reactor design and evaluation. Several possible accidents and malfunctions of reactor components have been considered in connection with the submarine advanced reactor. The most serious type of accident occurs when all available excess reactivity is added slowly to the reactor at the point where the core has reached maximum excess reactivity and the average reactor temperature has been reduced to override transient xenon build-up. Shim and safety rods are completely withdrawn to override at the highest possible temperatures, and the reactor is operated at maximum power demand so that the xenon can be burned out and the reactor will reach full power in a minimum time.

If, for reasons of operator error, sabotage, or malfunction of control and equipment, no control-rod adjustment is made when full power is reached, the average temperature will continue to increase as the xenon burns out. At approximately 665F, the temperature coefficient of reactivity matches the maximum available reactivity from core life and complete rod withdrawal, and operation levels off. With no reduction in steam demand or boiler-feedwater flow, an increase in reactor power level of about 130% occurs. Bulk boiling around the axial center line would then take place; this incident is discussed in detail.

3.2 MECHANISMS OF PRIMARY ACCIDENT INITIATION

3.2.1 Power Failure - Loss of Coolant Flow

672 WAPD-MRP-63
PRESSURIZED WATER REACTOR PRO-
GRAM, TECHNICAL PROGRESS RE-
PORT FOR THE PERIOD JUNE 23, 1956,
TO AUGUST 23, 1956. Westinghouse
Atomic Power Division, Pittsburgh,
Pa. August 23, 1956. 93 pp.

A study of the loss-of-flow accident
was completed, and the conclusions are
listed.

673 WAPD-MRP-64
PRESSURIZED WATER REACTOR PRO-
GRAM, TECHNICAL PROGRESS RE-
PORT FOR THE PERIOD AUGUST 24,
1956, TO OCTOBER 23, 1956.
Westinghouse Atomic Power Divi-
sion, Pittsburgh, Pa. October 23,
1956. 94 pp.

Flow studies in the TWR pressure
vessel are discussed.

3.2.2 Loss of Coolant

674 ORNL-1794 (Vol. I)
THE OAK RIDGE NATIONAL LABORA-
TORY RESEARCH REACTOR SAFE-
GUARD REPORT. F. T. Binford.
Oak Ridge National Laboratory.
October, 1954. 94 pp.

The research reactor will operate
at power levels up to 10 Mw and will
deliver a maximum thermal flux of
 8×10^{13} neutrons/cm²/sec. The
shortest period occurring during a
start-up accident is calculated to be
approximately 60 millisec. The power
excursion from this situation would
have a maximum value of 3.5 times
full power. Sudden removal of coolant
concurrent with shutdown when the re-
actor is operating at 10 Mw would re-
sult in a fuel-element and core melt-
down time of about seven minutes.
Loss of coolant water is shown to be
improbable. The ultimate catastrophe
is postulated as a steam explosion and
an aluminum-water reaction following
core melt-down. A pulse of about 105
Mw-sec could melt the fuel assembly.
This pulse could not occur except
through sudden flooding of one or both
of the large engineering test facilities
that have previously been operated as
voids. A maximum of about 3% $\frac{\Delta K}{K}$
could be added in this fashion.

An estimate of the dispersion of
airborne activity from an ORR acci-
dent that melted some of the fuel plates
or produced a metal-water reaction is
given. In the first case, the maximum
permissible internal exposure is ex-
ceeded for a cold cloud out to about 38
miles. In the event of rain-out at the
time of the hot-cloud type of accident,
the radius of hazard in which the popu-
lace would be exposed to a total dose
of more than 50 r is 16 miles.

3.2.3 Bulk Boiling

675 ANL-WHZ-299
SUPPLEMENT TO A REPORT TO THE
ATOMIC ENERGY COMMISSION ON
THE PROPOSED ARGONNE RESEARCH
REACTOR (CP-5). J. M. West and J. T.
Weills. Argonne National Labora-
tory. May, 1951. 68 pp.

This report answers criticisms of the Reactor Safeguards Committee about the proposed Argonne Research Reactor (CP-5). Tabulated data and graphs are presented, and conclusions are drawn regarding the following four reactor safety conditions.

(1) Nucleate Boiling

A bubble of steam 5 cm in radius in the core center reduces the reactivity by about $0.9\% \frac{\Delta K}{K}$. Steam formation is shown to limit the power of an excursion to an easily tolerable level. At least $3\% \frac{\Delta K}{K}$ (a reactor period of 40 millisecc) can be automatically damped out in times of the order of 30 millisecc.

(2) Fission-Products Escape

The rate of diffusion of fission products out of the fuel elements following a loss of coolant is estimated for the maximum fuel-element surface temperature of 370C, which occurs about 30 minutes after shutdown. Probably less than 1% of the volatile fission products would be lost at fuel-element temperatures below 600C.

(3) Internally Contained Safety Device

Within the reactor, safety devices as fast as the ejection of water as steam would be difficult to devise. Such devices, however, could introduce larger ΔK 's than would be provided by natural safety features.

(4) Airborne and Water-Borne Hazards

Airborne hazards to the surrounding population are reduced if the reactor is enclosed in a gas-tight building provided with scrubbing facilities for the ventilation air. The reactor building is normally operated with its air pressure at less than that of ambient atmospheric by perhaps 1/2-inch of water. Escape of airborne fission products is not possible under these conditions unless physical damage to the reactor building occurs. Credible accident situations are described in terms of the airborne hazards to the population at distances up to 20 miles. The report gives detailed estimates of whole-body and thyroid exposures from a continuous release of waste fission products over a period of 10 hours in a puff cloud emitted within a 10-minute period and for the case in which part of the solid fission products are vaporized. The most pessimistic assumptions result in whole-body exposures of 120 r at a distance of one mile. No appreciable water-borne hazard is visualized for any conceivable accident situation.

3.2.4 Power Transients

676 MEMO-JRL-3
BURSTING OF FUEL PINS IN AN UN-
CONTROLLED REACTOR. J. R. Low, Jr.
Knolls Atomic Power Laboratory,
Schenectady, N. Y. July 18, 1951.
11 pp.

Events that may lead to the rupture of a stainless-steel fuel pin containing MgO-UO_2 when the power increases by a factor of e /millisec are examined. It is concluded that the major source of internal pressure leading to rupture will be the vapor pressure of UO_2 and that the rupture will occur in approximately 12 millisec under the conditions assumed. The pin wall can be expected to rupture at many points along its length, causing releases of the fuel mixture to the coolant, but not to shatter in the sense that a brittle material would.

3.2.5 Corrosion and Radiation Damage

677 APEX-172
RADIATION DAMAGE TO NONMETAL-
LIC MATERIALS. V. P. Calkins.
General Electric Co., Aircraft Nu-
clear Propulsion Department,
Cincinnati, Ohio. August, 1954. 51pp.

This article discusses the general mechanism by which radiation damage to materials occurs, the units used to measure the radiation received by a given material, and the specific types of radiation damage involved. Radiation damage to materials and components of nuclear power plants is reported. These

materials and components include aqueous solutions, organic compounds, lubricants, greases, fuels, elastomers, plastics, aircraft hoses, electrical components, paints, and thermal insulation.

678 WAPD-MRP-43 (Rev.)
PRESSURIZED WATER REACTOR
PROGRAM. TECHNICAL PROGRESS
REPORT FOR THE PERIOD JANUARY
1, 1954, TO MARCH 1, 1954.
Westinghouse Atomic Power Divi-
sion, Pittsburgh, Pa. 48 pp.

Fuel-element design studies of the pressurized water reactor (PWR) indicate the feasibility of using U-Mo fuel alloy in a rod configuration. Burn-out and mass-transfer tests have been completed. U-Mo-alloy preparation techniques are described as is the fabrication of reactor-plate, -rod, and -pellet fuel assemblies. Dynamic corrosion testing of PWR core materials and the characteristics of several corrosion inhibitors, including U-base fuel alloys, are reported. Data are presented on the corrosion rate of unclad U-Mo alloy in 575F H_2O . Accelerator irradiation experiments were performed on Zr in contact with H_2O flowing at 8.5 ft/sec by 2-Mev electrons. Univac calculations of ϵ and p for the PWR are reported. Further studies have been made on reactor control by Li_3BO_3 and the compatibility of this compound with other reactor materials. (For preceding period see WAPD-MRP-42.)

3.2.6 Reactivity Insertion

679 CF-55-5-115
EFFECT OF SLURRY-SETTLING ON
REACTIVITY IN A ONE-REGION
THORIUM BREEDER REACTOR.

H. C. Claiborne and T. B. Fowler.
Oak Ridge National Laboratory.
May 18, 1955. 7 pp.

The effect of uniform slurry-settling on reactivity in one-region thorium breeder reactors of economic interest was investigated. The fuel considered was a mixed slurry of UO_2 and ThO_2 suspended in D_2O . It was found that when settling occurred, thermal reactors of possible economic interest (10-12 ft in diameter and containing 200-300 g Th/l) became subcritical.

680 CF-54-6-16
DUMP TANKS FOR HRT BLANKET.

S. Visner. Oak Ridge National
Laboratory. June 3, 1954. 5 pp.

The criticality of blanket dump tanks associated with the HRT was investigated for the contingency that the fuel solution from the core becomes mixed with the blanket contents. The solution volume of 2000 l is estimated as necessary, but a 24-in. -diameter pipe 40 ft long, and with a capacity of 3500 l is recommended. A Cd coating at an end, to take care of a heavy fuel-loading caused by tilting of the pipe, is also recommended.

681 ORNL-54-6-40
THE RADIATION EXCURSION OF MAY
26, 1954: A PRELIMINARY REPORT.

Dixon Callihan. Oak Ridge National
Laboratory. June, 1954. 13 pp.

A mechanical failure in one of the experimental enriched uranium/water solution critical assemblies introduced a large excess reactivity and caused the assembly to rise on a prompt critical period. The total number of fissions during the transient has been estimated at 10^{17} ; there was no evidence of violent boiling or mechanical breakdown in the system. The safety system operated normally. The cause of the accident was a displacement of a poison rod to a region of less importance. An analysis of the incident and the associated radiation level is presented.

3.2.7 Fuel Element Burn-Out

682 STR-TOT-472
SIGNIFICANT PEAK RADIATION
LEVELS DURING INCIDENT WITH
ASSOCIATED DECAY. G.H. Conley.
Technical Information Service Ex-
tension, AEC. June 22, 1955. 2 pp.

After a fuel-plate rupture, there was excessive radiation at the control panel, behind the rod motor, at the center of the catwalk around the top hat, and in the scram hatch. For 12 hours, the after section of the lower reactor compartment showed high readings. The equipment gamma readings fell rapidly to fairly low levels during the 12 hours, but the airborne gamma took as much as 42 hours for the same degree of decline.

The airborne concentration exceeded 22.2 d/min/l, the level at which respirators are required. Direct radiation levels were 5-6 times above normal levels at shutdown.

683 WAPD-MRP-47 (Rev.)
PRESSURIZED WATER REACTOR PRO-
GRAM. TECHNICAL PROGRESS RE-
PORT FOR THE PERIOD JULY 15, 1954,
TO AUGUST 26, 1954. Westinghouse
Atomic Power Division, Pittsburgh,
Pa. 93 pp.

The thermal and hydraulic properties of PWR core designs are being investigated for several fuel-element assemblies. Tentative burn-out data at 2000 psia have been obtained for a typical tubular specimen.

3.2.8 Temperature Coefficients

684 NDA MEMO 14-38
TRANSIENT BEHAVIOR OF THE EBR.
W. H. Jens. Nuclear Development
Associates, Inc., White Plains, N. Y.
January, 1954. 4 pp.

This report criticizes ANL-5023 for its interpretation of a fuel temperature rise following a decrease in coolant flow. The author postulates that the positive temperature coefficient might be the result of a geometric change following the change in the flow rate. The differential heating of the fuel elements, caused by the shape of the flux distribution, produces bowing of the rods toward the center and adds reactivity.

3.2.9 Emergency and Shutdown Cooling

685 ORNL-120
HEAT DISSIPATION FROM FUEL AS-
SEMBLIES OF A HIGH-FLUX REACTOR
AFTER SHUTDOWN. W. K. Stromquist.
Oak Ridge National Laboratory.
August 2, 1948. 30 pp.

Experiments conducted with a mock fuel assembly channel show that natural convection of residual cooling water in the high-flux reactor furnishes adequate cooling capacity after shutdown following 20 days' operation at a 30,000-kw power level. Heat transfer by natural convection of air is not sufficient to prevent melting of fuel assemblies after shutdown following such operation. Theoretical investigations cited are consistent with the experimental data.

3.3 EFFECTS ON REACTOR AND SURROUNDINGS

3.3.1 Secondary Accidents

3.3.1.1 Metal-Water Reactions

686 KAPL-1495
METAL-WATER REACTIONS.

H. M. Saltsburg. Knolls Atomic
Power Laboratory, Schenectady,
N. Y. April, 1956. 28 pp.

This report presents an analytical examination of metal-water reaction characteristics. It is hypothesized that external hydrodynamical and heat-transfer considerations govern the rate of reaction rather than chemical considerations. Prior to the vaporization of the metal, the reaction rate is dependent upon the temperature and hence upon a prior nuclear runaway.

The report summarizes the experimental investigations that have been made to date. Experiments for testing the hypothesis are outlined.

In a nuclear runaway, the metal-water reaction potential does not become serious until vaporization of the metal occurs.

687 PPC-89
ALUMINUM-WATER REACTION EXPERIMENT: STATUS REPORT.

O.J. Elgert, T.J. Boland, and G.L. Smith. Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho. March 10, 1955. 4 pp.

Six Al-U samples in contact with water and contained in pressure capsules were irradiated in the reactor core for 6-12 sec. Three of the six samples melted at the face in contact with the water; no melting on this face was observed in the other samples. Cable noise eliminated any pressure readings in one of the melted samples. The other two samples in which melting occurred produced explosions with pressure transients of 8000 psi in one case and above 20,000 psi in the other. Visual observation of the samples after irradiation revealed that only a small portion of the material had probably reacted.

688 ANL-WMM-596
RADIATION HAZARDS. J. J. Katz and H. R. Hoekstra. Argonne National Laboratory. January, 1950. 4 pp.

This report describes the additional reactor hazards possible if the fuel or its cladding material should react at high temperature with an aqueous coolant or with oxygen from the air. The report concludes that the reaction of uranium, zirconium-uranium, and aluminum-uranium alloys does not

occur at a dangerous rate at 1000C in steam nor at 1150C with oxygen. Alloys are less sensitive than the pure metals. Dangerous contributions to reactor hazards can be anticipated only if the metals are very finely subdivided, such as by vaporization or liquid state dispersion, in the coolant.

3.3.2 Structural Damage

689 ANL-5461
REACTOR ENGINEERING DIVISION,
QUARTERLY REPORT ON THE
POWER REACTOR PROGRAM.
Argonne National Laboratory.
April, 1955. 123 pp.

This report describes a reactor pressure-vessel design and a building-shell design that can withstand the pressure build-up from a 25% reaction of the metal in the reactor core. An estimate of the structural damage to the vessel and surroundings is based upon a theoretical study of the shock wave, pressures, water velocity, and forces developed in the pressure vessel as the result of an explosive release of 0.8×10^9 cal.

Corrosion data in deionized water are presented for uranium alloys under irradiation conditions.

The reactivity change upon void production in a boiling reactor has some dependence upon the uniformity of distribution of the void. In BORAX-I, the reactivity change is negative regardless of the distribution; in BORAX-II, reactivity change is positive if voids are produced only near the center.

3.4 EXTENT OF HAZARDS

3.4.1 Possible Magnitude of Accidents

690 ANL-FWT-105
HAZARD EVALUATION REPORT ON
THE FAST-REACTOR ZERO-HOUR
EXPERIMENT. R. O. Brittan,
B. Zerutti, H. V. Lichtenberger,
R. Rice, and F. W. Thalgott.
Argonne National Laboratory.
April, 1955. 75 pp.

This report deals with the program in which U-235 is used in a reactor experiment planned to obtain neutron physics information for the design of fast-power reactors. A description of the physical and administrative safeguards provided is given. Eleven interlocks prevent or curtail operations that might lead to a hazard. The maximum credible accident described requires a failure of all of the safety restrictions. This accident results in 10^{20} fissions and the release of 1.1×10^9 cal of nuclear and chemical energy.

691 WASH-169
REVIEW OF REACTOR EXCLUSION
RADIUS. J. Z. Holland. U.S. Weather
Bureau, Washington, D. C.
February, 1954. 26 pp.

Recently developed general formulas for maximum dry-weather deposition and maximum rain-out of particulate or gaseous matter from an airborne cloud near the ground are compared with the exclusion radius formulas in use by the U.S. AEC Advisory Committee on Reactor Safeguards. The mass deposition rate is assumed to be proportional to the contaminant concentration within a few

meters of the ground. The constant of proportionality is called the velocity of deposition; in simple cases, it is actually the mean fall velocity of the particles. For rain-out, the deposition depends upon the scrubbing efficiency of the rain and upon the integrated concentration in the vertical. The RSC formulas are shown to be conservative because of: (1) their choice of a low-limiting acceptable exposure; (2) their omission of the effects of surface deposition and rain-out; and (3) their assumption of source strength.

692 TID-227
TECHNICAL CO-OPERATION PRO-
GRAM: DISCUSSION ON SAFETY.
E. Teller (British). September,
1948. 5 pp.

The English believe that the main danger in the construction and operation of a pile arises from radioactive contamination rather than from the possibility of an explosion. They have considered the possible consequences of all of the radioactivity in the pile being distributed over the countryside. They all consider an air-cooled pile safer than a water-cooled one, since, in the latter, the vaporization of the water or sudden cutoff of the water supply may lead to a fast increase in reactivity. Safety devices and waste disposal are also commented upon.

4. CONSEQUENCES OF FISSION-PRODUCT RELEASE

4.1 FISSION-PRODUCT RELEASE TO THE ATMOSPHERE

4.1.1 Meteorological Factors Affect- ing Dispersal

693 HW-23601
PROBABLE TRAJECTORIES FOR
HYPOTHETICAL AIRBORNE WASTES
EMITTED IN THE HANFORD WORKS
AREA DURING SEPTEMBER, OCTO-
BER, AND NOVEMBER 1951. RE-
PORT NUMBER FOUR, A QUARTER-
LY SUMMARY. P. W. Nickola. Han-
ford Works, Richland, Washington.
February 20, 1952. 26 pp.

The probability that clouds from Hanford will pass over certain areas at various distances and directions from the source has been calculated for September, October, and November of 1951. The calculations are not presented, but the results are given in the form of aerial contour maps and tabulated probability functions. From data obtained in five years of balloon ascents at Hanford, a monthly distribution of wind direction at 4500 ft was determined. These monthly distributions are compared with the corresponding distributions for the months of 1951 under study as a means of deciding whether a given month of 1951 was representative of that same month in all years.

694 TID-399
AEC METEOROLOGICAL INFORMA-
TION MEETING FEBRUARY 1-2, 1951.
A. E. Gorman. Technical Informa-
tion Service Extension, AEC. Au-
gust 8, 1951. 107 pp.

This report has value as a manual of basic information on methods useful to the micrometeorologist in interpreting: (1) data on particles and their movement in the atmosphere; (2) the dispersion of particulate materials from stacks of different heights and different locations; (3) the significance of data obtained from wind-tunnel experiments; and (4) the instrumentation in place and proposed for the AEC-supervised records of air contamination. The programs at the several AEC operations are given briefly. Fourteen papers on specific problems are included.

695 HW-21415 and Supplement 1
A RECOMPUTATION AND EXTEN-
SION OF PARAMETERS INVOLVED
IN SUTTON'S DIFFUSION HYPOTH-
ESIS. M. L. Barad, and G. R.
Hilst. Hanford Works, Richland,
Washington. June, 1951. 36 pp.

By using the hypothesis presented by O. G. Sutton in 1947, workers in the field of atmospheric pollution have been using erroneous parameters to calculate the distribution of pollutants emitted from plant stacks. This report presents the corrected values, points out limitations in their use, and extends the computation to cases not covered by Sutton. Values for concentrations at various distances, maximum ground-level concentrations for various stack-height and wind-velocity values, and the influence of atmospheric stability on these values are shown graphically.

696 NP-4691
 AIR TRANSPORT REPORT NO. 2:
 QUARTERLY REPORT FOR THE
 PERIOD OCTOBER 1, 1950, TO
 JANUARY 1, 1951. W. W. Kellogg.
 Institute of Geophysics. January,
 1951. 21 pp.

An application of the Fickian theory of molecular diffusion to the cloud is described whereby it is possible to predict a cloud density at a given distance and at a given time from a point source. The effect of eddy movement is presented. This analysis may also apply to particulate material in a cloud.

697 NP-4692
 AIR TRANSPORT REPORT NO. 1:
 QUARTERLY REPORT FOR THE
 PERIOD JULY 1, 1950, TO OCTOBER 1, 1950. W. W. Kellogg. Institute of Geophysics. October 1, 1950. 6 pp.

Theodolite photographs of titanium tetrachloride smoke clouds are prepared for analysis so that the important parameters in the processes of free-air eddy diffusion and wind shear can be determined. These data are based on smoke-bomb detonations from 20,000 ft to 80,000 ft. Concurrent upper-atmosphere meteorological data were obtained.

4.1.2 Rain-Out of Radioactivity

698 KAPL-1572
 RADIOLOGICAL DEVELOPMENT
 ACTIVITIES IN THE HEALTH

PHYSICS UNIT: SEMI-ANNUAL
 PROGRESS REPORT FOR JULY
 THROUGH DECEMBER, 1955. L. J.
 Cherubin and J. J. FitzGerald.
 Knolls Atomic Power Laboratory,
 Schenectady, N.Y. December,
 1955. 52 pp.

A formula useful for estimating the cumulative dose from the maximum deposition of radioactivity from an atomic-bomb explosion or a critical-assembly incident is presented. For example, the integrated dose from the maximum deposition of radioactivity on the ground at a distance of 3000 miles from a 20-kiloton bomb explosion is 150 mr, if the radioactivity is deposited in that area after a period of 36 hours. This calculated result is compared with actual fall-out data. The formula is useful in estimating the upper limit of the rain-out hazard.

In general, the long-lived fission products released would not penetrate the upper atmosphere, where the particles would be the nuclei for rain-drops. The long-lived fission products would be washed out of the lower atmosphere. Washout brings down a smaller fraction of the total activity than does rain-out. During a heavy rainfall, the rate of washout is 0.5% per hour, and the radioactive deposition by this means is estimated by use of a formula presented. At a distance of 1 mile from a reactor incident containing 10^8 curies in the cloud, a ground concentration of 0.21 curies/m² could result from that rate of washout. This deposition is approximately 1/1000 of maximum deposition under the condition of rain-out.

4.1.3 Fall-out of Radioactivity

699 KAPL-997
SEMIANNUAL PROGRESS REPORT
OF RADIOLOGICAL DEVELOPMENT
ACTIVITIES IN THE HEALTH AND
SAFETY UNIT FOR JANUARY-JUNE,
1953. Knolls Atomic Power Labora-
tory, Schenectady, N. Y. July,
1953. 48 pp.

The collection efficiency as a function of particle size of air-cleaning and air-sampling filter media is reported for a face-velocity range of 0.5 to 100 cm/sec. The minimum collection efficiencies for the Whatman-40, Hollingsworth and Vose-70, and the Chemical Corps-6 were 59.3%, 97.0% and 98.2%, respectively, for the particle-size and face-velocity ranges investigated. The average absorptions of alpha and beta activity in the Hollingsworth and Vose-70 filter media for a series of analyses were 63% and 24%, respectively.

Formulas to determine the integrated dose resulting from the rain-out and fall-out of activity from a fission-product cloud have been developed and are discussed in this report. (For preceding period, see KAPL-863.)

4.1.4 Specific Experimental Studies

700 TID-5027
OBSERVATIONS ON FALL-OUT FROM
THE NEVADA TESTS, JANUARY 27 TO
FEBRUARY 6, 1951. M. M. Weiss
and J. B. H. Kuper. Technical Infor-
mation Service Extension, Atomic
Energy Commission, 1951. 19 pp.

Measurement stations were set up near Ithaca, N. Y., at Lexington, Mass., and Presque Isle, Me. None of the stations obtained information that would indicate there had been an explosion on February 6, 1951. The probable paths of the active clouds are traced in charts. Activity deposited on 10 square miles of the Brookhaven Laboratory site in one snowfall was estimated at 9.3 curies.

4.2 FISSION-PRODUCT RELEASE TO THE OCEAN

4.2.1 Relative Information

701 ANL-4999
THE EFFECT OF IONIZING PARTICLES
ON LIQUID WATER AND AQUEOUS
SOLUTIONS. Edwin J. Hart. Argonne
National Laboratory. March 6, 1953.
20 pp.

The principles underlying the interaction of ionizing radiations with water are discussed in detail; the radiation chemistry of water is explained by the concept of hydrogen and hydroxyl free radicals and their reactions with impurities. Neutron and gamma-ray dosimetry in aqueous solution are discussed as well as the decomposition of water in the Argonne Heavy-Water Reactor.

702 DP-5
DISPOSAL OF ACTIVE WASTES AT SEA.
J. E. Evans. Technical Information
Service, Atomic Energy Commission.
April 10, 1952. 14 pp.

If aged wastes could be cheaply reduced to a small volume, it might be possible to drop a 50-100 gal container onto

the ocean floor where the mud is suitably deep and life is absent. There are off-shore areas with mud deposits at least 100 ft thick. If the waste container (preferably made solid with concrete) had a density of 2.2, it could fall by gravity and penetrate the mud for 200 ft. Such a location has been found about 500 nautical miles east of Savanah in water 15,000 ft deep. International problems would probably result if prematurely released contamination came into contact with living organisms. Thermal currents generated by waste decay heat are not discussed.

703 NP-1134
ONR PROJECT SUMMARY, QUARTERLY SUPPLEMENT, OCTOBER 1, 1949.
W. H. Leahy. Office of Naval Research. October 1, 1949. 433 pp.

As of fiscal 1950, ONR research work is presented annually in a volume dated July 1. Material in the quarterly reports is repeated.

The work in oceanography has included: (1) soundings for determination of gravities of waters; (2) surveys of ocean-bottom formations around the Fiji Islands and in the Carribean; (3) hydrography of the North Atlantic; and (4) work on deep ocean currents.

A study of the circulation characteristics of several bays, ports, and other frequently navigated waters in the Puget Sound area is reportedly under way. The final results would be useful in an assessment of the effects of a nuclear detonation in a harbor.

704 UWFL-10
PRELIMINARY OUTLINE OF A PROGRAM FOR THE SECOND RADIOBIOLOGICAL SURVEY OF BIKINI ATOLL DURING THE SUMMER OF 1948.

Applied Fisheries Laboratory.
University of Washington. 7 pp.

A resurvey of Bikini Atoll during the summer of 1948 should be undertaken to further knowledge of the overall biological problems resulting from the release of energy of atomic bombs above or under water.

Biological studies are of necessity long and complex projects. The Bikini biological studies are so complicated that only continuous effort will reveal the basic principles they contain.

Fundamental data that need to be gathered at regular intervals for re-evaluation of the problems involved are: (1) The presence of radiation in the various types of marine organisms. (2) The distribution of radioactive substances in the marine plants and animals found at different geographical locations on the atoll. (3) The amounts of radioactive substances in certain tissues and organs.

705 ANL-4017
THE LETHAL ACTION OF X RADIATION, STABLE ISOTOPES OF FISSION ELEMENTS, Sr^{89} , and $(\text{Ba-La})^{140}$ UPON GOLDFISH. C. L. Prosser, C. R. Hagen, Jr., and W. Grundhauser. Argonne National Laboratory. July, 1947. 40 pp.

Solutions of stable barium at 1 ppm killed 50% of the goldfish within 30 days. Cerium was toxic at 10 ppm, and bromine at 1000 ppm. Solutions of strontium and iodine were nontoxic at least up to 1000 ppm.

Single doses of 850 r of X radiation killed 50% of the goldfish within 30 days. Half a group of goldfish receiving 100 r daily were dead at 26 days; half a group receiving 50 r daily were dead at 33 days. Half the controls and those receiving 25 r daily were dead at 40 days.

Calculations of radiation dosage show that in solutions containing fission products at 1 microgram/ml, the dose from external radiation is a small fraction of that from internal radiation. In solutions of Sr^{89} at an initial concentration of 0.4 microgram/ml, however, a significant number of deaths occurred. On the basis of measurements of accumulated Sr^{89} , the median total accumulated dose of internal beta radiation varied from 1580 to 27,550 rep at daily (24-hour) rates of 50-680 rep. Lethal doses for goldfish in aquaria in which Sr^{89} was replenished monthly were similar to those given in a single dosage. This similarity was also observed for lethal doses in a single experiment with (Ba-La)¹⁴⁰.

4.2.2 Distribution in the Ocean

706 HW-39624
RADIOLOGICAL SCIENCES DEPARTMENT, QUARTERLY PROGRESS REPORT ON RESEARCH AND DEVELOPMENT ACTIVITIES. H. M. Parker.
Hanford Works, Richland, Washington. October, 1955. 36 pp.

A comparison of the British method of disposal at sea with the local method of disposal into a major river has shown many features of interest. That of the most practical importance is the widely different order of concentration factors of the nuclides in the two systems. Plutonium uptake is quite significant in the marine system, whereas strontium, surprisingly, is not concentrated. This is almost the reverse of the river case. Since the Hanford system is also a method of ocean disposal, with the Columbia River as the pipeline, these comparisons stimulate another look at the marine case following a cursory examination years ago at considerably lower effluent activity levels.

Plutonium contamination of the Columbia River is zero; water contains natural uranium, however, and its activation, as in passing through the reactors, contributes to some plutonium concentration in the irradiated water. The new method of measuring Np^{239} leads to a reliable minimum value of 3×10^{-13} microcuries of Pu^{239} /ml in the river. This should establish an activity density of 10^{-10} - 10^{-9} microcuries of Pu^{239} /g in some marine systems.

Increased attention to the transfer of radioactive materials to birds is probably desirable in view of concentration factors of up to 1.5 million for P^{32} in duck eggs.

707 UWFL-11
CONCENTRATION OF ACTIVE MATERIALS BY HYDROIDS IN THE BIKINI LAGOON DURING THE SUMMER OF 1947. L. R. Donaldson, A. H. Seymour, A. D. Welander, and K. Bonham.

Applied Fisheries Laboratory, University of Washington. 1947. 8 pp.

Marine organisms active on ship bottoms and belonging to the family Plumularides were shown to be selective in concentrating radioactive elements. A sample organism accumulated soluble activity from sea water at the rate of 0.75 microcuries/kg in 44 days.

4.2.3 Effects on Marine Life

708 UWFL-19
ENIWETOK RADIOLOGICAL RESURVEY,
JULY, 1948. Applied Fisheries Laboratory, University of Washington.

Marine organisms, including fish, invertebrates, algae, and plankton, were collected at Eniwetok Atoll between July 22 and July 28, 1948. Except for plankton, practically all of the specimens were collected in the shallow waters of the reef. Plankton tows were made in the lagoon as time allowed. Samples were prepared in the field from fresh specimens and in the University of Washington Laboratory from frozen specimens. Counts of samples prepared from fresh specimens were similar to those of like samples from frozen specimens. Only beta-gamma counts were made. The counts were corrected for background, weight of sample, geometry, and counting date.

709 UWFL-18
RADIOLOGICAL ANALYSIS OF BIOLOGICAL SAMPLES COLLECTED AT ENIWETOK, MAY 16, 1948.

L. R. Donaldson, A. H. Seymour, and J. R. Donaldson. Applied Fisheries Laboratory, University of Washington. 1948. 12 pp.

Marine organisms were collected from the shallow waters of the reef about 1-1/4 miles north of Runit Island for the purpose of determining beta-gamma radiation. Samples of about 1g (wet weight) were reduced to an ash for counting. In the fish samples, the skin, muscle, bone, liver, gut, and gills were sampled. The entire organism for most invertebrates was used as a sample. A total of 118 samples were prepared and counted. The greatest concentration of active material was found in the gut, but some distribution of radioactive elements to the tissues had started in the short time (1-1/2 days) between fall-out and the time of collection. Decay studies on selected samples show a very rapid rate of initial change. A straight line fitted to the last three points in the decay curves, i.e., for November 27, 1948, January 1, 1949, and February 19, 1949, gives a half-life period of approximately 180 days.

710 UWFL-7
RADIOBIOLOGICAL RESURVEY OF BIKINI ATOLL DURING THE SUMMER OF 1947. Applied Fisheries Laboratory, University of Washington. 1947. 59 pp.

Fish and other organisms were taken from the Bikini lagoon for activity counting. Every section of the lagoon showed measurable activity. The organisms collected much of the radioactivity in the liver and in the spleen.

Bone deposition was comparatively low. Kidneys and gonads tended to concentrate activity. High counting rates were found in the coral heads around the atolls, especially those nearest the target area.

4.2.4 Distribution and Effects in Fresh Water

711 HW-25191
THE ABUNDANCE OF THE PRINCIPAL CRUSTACEA OF THE COLUMBIA RIVER AND THE RADIOACTIVITY THEY CONTAIN. R. W. Coopey.

Hanford Works, Richland, Washington. June 25, 1953. 15 pp.

The species and abundance of crustacea and the radioactivity they contained were traced for a 14-month period. Seasonal changes were found to influence the amount of radioactivity present in the organisms. Rapid growth favored high activity density. Unequal seasonal changes in radioactivity levels of body organs indicated functional differences in the utilization of the isotopes. A pronounced spring pulse and a smaller fall pulse were evident in the abundance of bottom cladocera. Radioactivity was highest during the fall pulse. Crayfish averaged 134 ± 22 g live weight and 39 ± 16 individuals/36 ft² of sampling area. Cladocera showed 2.6 g/ft² live weight and 260,000 individuals/ft² at maximum. No decrease could be found downstream from the Hanford operation. The principal isotope present in crustacea was P³², notwithstanding a variety of isotopes present in crustacean food and in the river water.

712 HW-26523
RADIOLOGICAL SCIENCES DEPARTMENT QUARTERLY PROGRESS REPORT OF RESEARCH AND DEVELOPMENT ACTIVITIES, OCTOBER-DECEMBER, 1952. H. M. Parker. Hanford Works, Richland, Washington. January 5, 1953. 29 pp.

Further contributions to the toxicities to plants, algae, animals, fish, and fish eggs of tritium, tritium oxide, deuterium oxide, protium, iodine 131, and plutonium were made during the period, in continuing work. Accompanying the investigations were modifications in analytical techniques and instrumentation. The evaluation of results must be sought in techniques and instrumentation. The evaluation of results must be sought in other, final reports. Activity density of river organisms decreased with falling water temperature.

Puff concentrations from a stack, measured over intervals of a few seconds to a few minutes, averaged about 30 times hourly average concentrations at distances of 500 feet; permissible stack emissions may have to be revised on this basis.

713 HW-23093
ACCUMULATION OF RADIOACTIVITY IN COLUMBIA RIVER FISH IN THE VICINITY OF THE HANFORD WORKS. P. A. Olson, Jr., and R. F. Foster. Hanford Works, Richland, Washington. July 1, 1952. 59 pp.

The data obtained from the radioassay of fish collected in the vicinity of the Hanford Works between April,

1948, and June, 1950, are presented. Most of the radioactivity in the fish resulted from concentrations of P^{32} in scales, bone, and certain visceral organs. The level of activity density in the fish was influenced by size, feeding habits, and metabolic rate, in addition to the activity density of the water. Changes in the operation of nuclear reactors have caused progressive increases in the activity densities of fish from one year to the next. The levels of radioactivity are not high enough to be hazardous to the fish or to the persons eating them.

714 HW-11344
A ONE-YEAR STUDY OF RADIOACTIVITY IN COLUMBIA RIVER FISH, K. E.

Herde. Hanford Works, Richland, Washington. October 25, 1948. 11 pp.

Over a one-year period, 194 fish weighing from 30 to 1700 g were collected from the Columbia River and assayed for beta-emitting materials. River algae activity was highest in late November, when it reached a maximum of 1 microcurie/kg (damp weight); the highest in fish tissue was in the bone of a sucker (Catostomus snyderi) collected on September 9, 1947. The level in fish was 0.9 microcurie/kg, compared with a high of 0.5 microcurie/kg found during the earlier survey ("Radioactivity in Various Species of Fish from the Columbia and Yakima Rivers," Document No. 3-5501, 5-14-47, K. E. Herde). Fish tissues reached a peak activity about October 1, which was approximately one month before algae activity reached its peak and at a time when the river flow rate was about

average. Most of the radioactivity was P^{32} , with Na^{24} representing over 10% of the total in about half of the 72 decay studies made of fish tissues. The presence of significant amounts of radio sodium was not evident from the earlier study. One squawfish was found to have a liver activity of about 0.06 microcurie/kg of very long-lived material. The bone of a sucker contained a lesser amount of an isotope of over a one-year half-life. Eggs and sperm were intermediate in activity level but definitely higher than the average for the entire fish. The contents of the gut were usually higher than those of the tissues but occasionally were exceeded by those of the liver, kidney, skin, or bone. Muscle was consistently lowest in activity, never being over 0.1 microcurie/kg. Maximum tissue radiation was about 40 mrep/day. Sufficient numbers of suckers, chiselmouths, and squawfish were collected to show a definite difference in the specific radioactivity of these species. Graphs are presented to show unusually slow decay in two specimens and to compare the activity levels in water, algae, and fish. Long-lived material showing no decay was shown to be closely correlated with tissues rather than with total radioactivity; this suggests that the material was K^{40} , a natural radioactive isotope of potassium.

715 M-4129
RADIOACTIVITY IN VARIOUS SPECIES OF FISH FROM THE COLUMBIA AND YAKIMA RIVERS, K. E. Herde.

Hanford Works, Richland, Washington. May 14, 1947. 17 pp.

Pile effluent water containing several radioactive elements has been discharged to the Columbia River since the beginning of operations. During the 5.5- to 6-hour cooling period of the water in retention basins, approximately 75% of the radio manganese (Mn^{56}) and 25% of the radio sodium (Na^{24}) were lost by decay. The Mn^{56} represents about 20%, Na^{24} 78-80%, and longer-lived elements only about 1% of the total radioactivity at the inlet to the river. This study is concerned principally with the accumulation of radioactive materials that make up the 1% of activity caused by elements with half-lives greater than that of Na^{24} . Fish were taken from four sites on the Columbia River and two on the Yakima River. Accumulated activity was highest in kidneys and livers. The maximum was found in the liver; skin (scales included), gills (arches included), bone (vertebrae), and muscle followed in that order. The concentration of active materials in tissues or organs ranged to a maximum of several thousand times that of an equal weight of river water. This concentration factor (fish-activity/water-activity) is several hundred times higher than factors previously reported for other materials. Activity levels seemed to vary with probable dosage (as determined by location, probable migration, and dilution of water) rather than with species or the feeding habits of fish.

716 M-4130
STUDIES IN THE ACCUMULATION OF
RADIOACTIVE ELEMENTS IN ON-
CORHYNCHUS TSCHAWYTSCHA
(CHINOOK SALMON) EXPOSED TO A
MEDIUM OF PILE EFFLUENT WATER.

K. E. Herde. Hanford Works,
Richland, Washington. October
14, 1946. 21 pp.

This paper presents data on the accumulation of radio sodium (Na^{24}) and other longer-lived elements in fish. The rate of increase of radioactive materials in the fish was greatest for the first six hours of exposure. A peak was reached at about 48 hours; after which a slight decline usually occurred for the next 24 hours, before a state of approximate equilibrium was reached. A variation of from 0.5 to 14.0 microcuries/kg accumulation was noted in specimens exposed 48 hours or more. Fingerlings in precooled effluent water showed a slightly, but fairly consistent, higher accumulation than those in refrigerated water. Fish that were weak or near death showed a very low comparative activity. Accumulation of longer-lived materials was comparatively low and variable. Water temperature and length of exposure were shown to be pertinent factors in the absorption of these materials. Graphs included show the presence of two or more materials having half-lives considerably longer than Na^{24} . Several specimens indicated two rates of long life decay. The most abundant material had a half-life of 14 days. Others appeared to have half-lives of more than 50 days.

717 HW-3-3442
ACCUMULATION OF RADIOACTIVE
ELEMENTS IN FISH IMMERSED IN
PILE EFFLUENT WATER. J. W.
Healy. Hanford Works, Richland,
Washington. February 27, 1946.
9 pp.

Pile water activity is mainly Na^{24} and Mn^{56} with about 1% miscellaneous longer-lived elements. With no discussion of fish health and welfare, the measurements were made to determine how much and when the fish showed activity. The fish did gain activity, probably the maximum in the first 24 hr, with concentration in liver, kidney, gill arches, and some in the bone, and at ratios considerably above the concentration of activity in the river water. There is evidence also that flocculent material in the water concentrates activity and that it is often in the upper layer rather than the deeper ones. Plutonium can be eaten and not excreted by the fish. Salmon eggs had not absorbed sodium or manganese, active or otherwise, through the egg shell.

718 M-4125
FISH IN WHITE OAK LAKE. H. J.
Curtis. Clinton Laboratories,
Oak Ridge, Tenn. April 23, 1945.
4 pp.

From time to time, fish in White Oak Lake have been examined, to make sure nothing being done at the laboratory seriously affects them, persons eating fish caught in the Clinch River, or persons living below on the Clinch River and drinking the water.

The usual analyses made are simply on the beta activity found in the tissues of the fish. The first fish analyzed was caught on May 3, 1944, and the activity in its tissues was fairly high. Since then the activity found in fish has been very much lower.

The highest specific activity in the first fish was in the heart. If one assumes that this activity had an average energy of 0.5 Mev, this organ was receiving radiations at the rate of 2 r per day when it was caught. All other tissues were somewhat lower. Most of the fish caught since have been receiving radiations at about 5×10^{-3} r/day as a result of their ingested activity, which is well below tolerance. The conclusion is that fish do not concentrate fission products to any very marked extent in their tissues under the conditions prevailing in the lake now, and certainly the fish are not being harmed by the active waste from this laboratory. The authors assert that since the fish in White Oak Lake are not being harmed, the fish in the Clinch River are not accumulating any appreciable amount of activity and that persons eating the fish are not being subjected to any activity hazards.

4.3 GROSS EFFECTS ON MAN

4.3.1 Characteristics of Hazardous Materials

719 ORNL-419
CAPTURE GAMMA RAYS. E. P.
Blizard. Oak Ridge National Laboratory. December, 1949. 24 pp.

For shielding purposes, the general shape of gamma spectra is sufficient, and spectrometer data are useful. For none of the measurements to date has there been reported an absolute calibration of the apparatus in the sense

that the number of photons in an energy interval per neutron capture is known. So long as the whole spectrum, including the low-energy end, is not measured, this calibration is of serious importance to shielding. Spectra for 10 elements are given.

720 ORNL-420
GAMMA RAYS FROM FISSION AND
FISSION PRODUCTS (ORNL SUMMER
SHIELDING SESSIONS). G. Young and
E. P. Blizard. Oak Ridge National
Laboratory. November 17, 1949.
11 pp.

A survey of the known information on fission and fission-product radiation is presented. Tables show total prompt-fission gamma energy, energy distribution (gamma emission) as a function of time after fission, radiation (gamma) emitted within given energy bands from 10 minutes after fission to a given time t , and hard fission-product gamma rays.

4.3.2 Personnel Hazards from Radio- active Materials

721 K-1071
THE INHALATION OF RADIOACTIVE
MATERIALS AS RELATED TO HAND
CONTAMINATION. J. C. Bailey and
R. C. Rohr. Carbide and Carbon
Chemicals Co., Oak Ridge, Tenn.
September 15, 1953. 18 pp.

Tests to determine the hazard of inhaling radioactive material as the result of smoking while the hands are contaminated indicate that for dry U-compounds adhering to the palmar surfaces of the hands, approximately 1.0% of the material

may be transferred to a cigarette; of this, approximately 0.2% may appear in the smoke inhaled. Most of the contamination originally placed in a cigarette was found in the ash, and only 11% of the material was not recovered following burning. Approximately half of this loss may be attributed to normal losses inherent in the analytical process, the recovery efficiency for which was found by supplementary experiments to be 95%.

722 M-4381
SUMMARY OF METABOLIC PROPER-
TIES OF RADIO ELEMENTS PRO-
DUCED IN URANIUM BY FISSION.

Radiation Laboratory, University of California. Technical Information Service, AEC. September 9, 1949. 3 pp.

A table presents the half-lives of 18 isotopes comprising 99.7% of the total radiation (energy remaining after 60 days' cooling of 100-day-irradiated uranium) from the fission of uranium; the half-lives range 40 hours for La^{140} to 2×10^6 years for Np^{237} . Hazards by bone absorption and retention of dust in the lung are listed. The critical feature is a high rate of deposition in the bone, very slow excretion of many of the isotopes, and a high fraction retention in the lungs after at least 18 days.

723 AD-95 (H)
AN ESTIMATE OF THE RELATIVE
HAZARD OF BETA AND GAMMA
RADIATION FROM FISSION PROD-
UCTS (Final Report). R. I. Condit,
J. P. Dyson, and W. A. S. Lamb.
Physics Branch, Naval Radiologi-
cal Defense Laboratory. April,
1949. 19 pp.

An exploratory study was made of the relative amounts of beta and gamma radiation reaching different parts of the body under the hypothetical case of a man standing erect on an infinite plane contaminated with fission products. The expressions for various calculations are given. Measurements were also made of the absorption of both types of radiation by different kinds of textiles and fibers. Ordinary clothing is seen to offer little protection to beta rays, and it would take some 300 layers of fairly heavy cotton or wool textile to cut down the gamma radiation to the body by 50%. The problems of inhalation are not considered. It is concluded that in a fission-product radiation field, both beta and gamma radiation must be measured.

724 M-1961
SUMMARY OF PROGRESS IN THE
PHARMACOLOGY DIVISION. H. C.
Hodge. University of Rochester,
Rochester, N. Y. 1947. 35 pp.

Inhalation experiments have demonstrated that $\text{BeSO}_4 \cdot 4\text{H}_2\text{O}$ is not immediately toxic to guinea pigs exposed for two weeks to atmospheres containing amounts of the order of 80 mg/m^3 . In a paired feeding experiment, the growth reduction in rats has been shown to be attributable to the beryllium in the diet rather than to the amount of food eaten. Rats fed 2.3% beryllium carbonate show no growth depression, whereas rats fed 5% beryllium carbonate show a marked growth depression. Five beryllium compounds (including beryllium metal) have been injected intratracheally into five species of animals. Results to date are inconclusive.

An attempt to sensitize animals to beryllium compounds by long exposure has thus far given only ambiguous results. Rats fed 10% thorium nitrate mixed in the diet have shown a severe weight depression. When radioactive thorium is directly administered into the blood stream of rabbits, it moves only slowly out of the blood; as much as 25% of the original dose may still be present in six hours. From these preliminary experiments, it appears that about one-third of the dose has been deposited in the skeleton in a six-hour period and that another third has been deposited in the liver. Only 0.3% appeared in the urine. Thorium has a strong tendency to absorb on glassware, and special precautions are necessary in the quantitative handling of minute amounts.

725 M-1878
COMPARATIVE INTRAVENOUS
LETHAL-DOSE PILOT STUDIES FOR
POLONIUM, RADIUM, AND PLUTONIUM
IN RATS. G. A. Boyd and R.
M. Fink. University of Rochester,
Rochester, N. Y. June 1, 1946.
248 pp.

Pilot studies on polonium, plutonium, and radium to determine the 20-day LD_{50} have been completed. Polonium dosages ranged from 50 to 170 microcuries/kg; plutonium dosage ranged from 18.5 to 185 microcuries/kg; and radium dosages ranged from 17 to 8000 microcuries/kg. In general, there were two or three animals at each dosage level. The values for polonium, plutonium, and purified radium (polonium at approximately 0.07% of equilibrium value) were

approximately 50, 130, and 4000 microcuries/kg, respectively.

Pathology studies were made on some of the animals at death. Polonium showed changes in the hematopoietic system at all dosage levels used. Radium caused changes in the hematopoietic system, liver kidneys, bowels, bone, testes, aorta, and coronary arteries. The changes in the hematopoietic system, bone, testes, and bowel were compatible with X-radiation effect. Liver, renal, and vascular effects were unlike those of X-radiation. Plutonium showed damage similar to that of X-radiation to the hematopoietic system, bone, liver, testes, and kidneys. In comparison with other tissues, testes may be less sensitive in high-voltage X-radiation experiments.

4.3.3 Dosage Determinations

726 Y-897
POTENTIAL HAZARDS OF CRITICAL-
ITY ACCIDENTS. C. L. Schuske.
Carbide and Carbon Chemicals Co.,
Oak Ridge, Tenn. August 5, 1952.
10 pp.

Accidental accumulations of supercritical masses of fissionable materials have resulted in radiation bursts ranging from a little less than 0.1 to more than 15 Mw. The lethal radii for bursts of 0.1, 3, and 15 Mw are calculated to be approximately 1.5, 9.5, and 22 ft, respectively. These calculations are based on the assumption that 400 r of gamma or gamma-equivalent radiation is lethal to 50% of the population. Although the residual

radiation from the fission fragments is large, operating personnel outside the lethal circle can remain in the contaminated area for as long as 20-30 sec without adding significantly to their over-all exposure. For an accident of about 0.1 Mw, probably less than 7 additional r will be received by those remaining in the contaminated area for 20 sec. The additional radiation would be proportionally higher for bursts of from 3 to 15 Mw. These approximations do not include the health hazard of ingested beta- and alpha-active contaminants that might be present in the air after a burst. When placed on 100-ft centers, process monitors with a sensitivity of 0.014 r/hour are more than adequate for full coverage of all likely bursts.

4.3.4 Effects on Man

727 NYO-4464
EFFECTS OF RADIATION ON HUMAN
DENTITION: PRELIMINARY REPORT.
T. Teraski and K. Shiota (Atomic
Bomb Casualty Commission). Na-
tional Research Council, Washington,
D. C. June 30, 1953. 13 pp. (Bibliog-
raphy and 29 References.)

This preliminary report does not give a clear picture of the possible effects on dentition in children exposed to harmful radiation before their second teeth have erupted. Hypoplasia of the enamel of teeth forming at the time of the explosion exceeded that observed in a similar control group. The 1267 exposed children were examined at Hiroshima during

the two years following January 1, 1951. Figures from the adult examinations of 1983 exposed people and 2297 nonexposed people as part of the total physical examination may indicate that: (1) the irradiation promoted onset of periodontal troubles common to middle age; (2) these troubles were not different from those of the nonexposed people; and (3) they might very likely have been hastened by the original mouth injuries from the incident.

728 TID-5033
UNIVERSITY OF CHICAGO TOXICITY
LABORATORY; QUARTERLY PROGRESS
REPORT (NO. 10A). Toxicity
Laboratory, University of Chicago.
July, 1951. 105 pp.

This report summarizes work performed under Contract AT (11-1)-37 and ending June 30, 1951. Of particular interest is the study on the effects of whole-body irradiation extended to man. Other studies cover toxicity of metals, the effect of radiation on animals, and the retention of aerosols in human subjects. Data are presented for the variation in physiological effects as a function of time and intensity factors; the biological effect relative to depth-dose and iron density; evacuation, militarily acceptable, and militarily effective doses; and the doses for varying degrees of injury. This report does not deal with genetic effects.

729 LAMS-808
A REPORT TO THE CHAIRMAN OF
THE NEPA PROJECT'S SUBCOMMITTEE
ON AVAILABLE DATA OF RADIATION
BIOLOGY. A SUMMARY OF
AVAILABLE DATA AT THE LOS
ALAMOS LABORATORY. W. H. Langham.

Los Alamos Scientific Laboratory.
November 18, 1948. 12 pp.

No text.

730 LP-67
BIOLOGICAL EFFECTS OF RADIATION.
F. L. Friedman. Lexington Project,
Massachusetts Institute of Technology.
June, 1948. 2 pp.

This Lexington Project report lists the extent of knowledge on the effect of radiation--gamma rays and neutrons--on human beings in doses in the range of 25 r/day. The text describes the variable dose required for the onset of nausea; the variable response to a given dose, depending upon the length of time over which it is administered; the measurability of the physiological effects as a function of the dose and the duration of exposure; genetic effects; and the relative biological effects of fast and thermal neutrons as compared with those of gamma rays.

4.3.5 Experimental Studies, Related

731 UCLA-250
PATHOLOGY, HEMATOLOGY, AND
BIOCHEMISTRY; QUARTERLY PROGRESS
REPORT FOR PERIOD ENDING
MARCH 31, 1953. Atomic Energy
Project, University of California at
Los Angeles. April 1, 1953. 19 pp.

The LD₅₀ for cats was roughly established to be between 140 and 275 r.

732 WASH-95
THE BIOPHYSICAL AND BIOLOGICAL
EFFECTS OF NEUTRONS (A Symposium
held March 17-18, 1952, in Washington,
D. C.).

Division of Biology and Medicine,
Atomic Energy Commission. 1952.
30 pp.

The need for further data on the relative biological effectiveness of fast neutrons as a function of the dose rate is expressed. Ten papers dealing with the biological effects as determined from studies with mice, tradescantia, rats, rabbits, dogs, and persons exposed at Hiroshima are abstracted.

There are no experimental physical or biological data available for the neutron energy range of 0.4 to 3 Mev. Conclusions regarding biological effects of neutrons in this energy range are classified.

One rem dose is delivered by 1.6×10^{10} thermal neutrons. The threshold cataract-inducing dose of thermal neutrons was found to be 16 r or less for mice.

733 UWFL-14
LETHAL EFFECTS OF X RAYS ON
MARINE AMPHIPODS. K. Bonham.
Applied Fisheries Laboratory,
University of Washington. 1947.
19 pp.

This publication describes two consecutive experiments to determine the lethal effects of various whole-body, single doses of X ray upon eulittoral marine amphipods. The X rays generated at 200 kv and 20 ma were filtered through copper and aluminum and administered in the first experiment to six groups of 20 amphipods each in doses of 150, 900, 6400, 16,000, 32,000,

or 82,000 r; in the second experiment, the X rays were administered to six groups of 30 amphipods each in doses of 200, 500, 2500, 5000, or 10,000 r. The dosage rate was 340 r/minute. In both experiments, six groups similar to those irradiated were kept as controls. The cultures were held in 1-gal glass jars of salt water sitting in a trough of tap water. The amphipods were removed from the jars to petri dishes with a syringe and the living and dead were counted. The first experiment showed that the dose producing significantly greater mortality than that suffered by the controls lay between 900 and 6400 r. The numbers of living young amphipods liberated by the ovigerous females were noticeably reduced by doses of 900 r or more. In the second experiment, 21 days after irradiation, the mortality of only the 500- and 10,000-r groups was greater than that in the control groups. In the second experiment, the rate of increase in numbers of young amphipods liberated was significantly less than that of the controls in the case of cultures receiving 1250 r; it was not quite significant (about the 10% level of probability) in the case of the 500-r group. It is concluded that under the conditions of the experiments, the dose necessary to increase the mortality rate above that of the controls was between 2500 and 5000r and that the rate of increase of numbers of young is a more sensitive criterion of X-ray injury, since it indicates results after doses of between 500 and 1250 r.

734 UCLA-111
SUMMARY OF THE RADIOLOGICAL
FINDINGS IN ANIMALS FROM THE BIOLOGICAL SURVEYS OF 1947 THROUGH 1950. James L. Leitch. Atomic Energy

Project, University of California
at Los Angeles. February, 1951.
34 pp.

Radiation hazards in the New Mexico areas affected by the first atomic-bomb detonation are reported here. Deposition of radioactive materials in animals was not definitely found during the first two years, although such a pickup was noted in plants. The first deposition in animals was noted in the fourth year and established beyond doubt in pack rats 29 miles northeast of the detonation site. Similar contamination appearing five miles west indicates the complex interrelation between meteorology, topography, soil chemistry, and the food chain available to animals in the area.

735 CH-3893
AN INTERSPECIES COMPARISON OF
THE RADIO TOXICITIES OF X RAY,
Sr⁸⁹, AND Pu²³⁹. C. L. Prosser
and Marguerite N. Swift. June,
1949. 10 pp.

On the basis of injected dose, the 30-day LD₅₀ for Sr⁸⁹ decreases with increasing animal size, from the mouse (7.8 microcuries/g) through the rat, rabbit and dog (0.8 microcurie/g). It then increases to 1.3 microcuries/g for the goat. The order is similar when computed on the basis of the dose retained at time of death. Radiation lost outside the body is greater in small mammals than in large ones, but measurements in mice show such loss to be not more than 3% of total emitted radiation from Sr⁸⁹. The LD₅₀ for X rays follows a different order from

Sr⁸⁹ sensitivity; it is highest in the rabbit, least in the dog, and intermediate in the mouse and rat.

The calculation of Sr⁸⁹ LD₅₀ on the basis of skeletal weight increases the species differences. When the 30-day LD₅₀ of Sr⁸⁹ is corrected for retention and relative radiosensitivity (with the radiosensitivity of mice used as a unit), the following series is obtained in microcuries/g: mouse 3.5, rat 2.48, rabbit 0.57, and goat 0.98. By extrapolation from this series, the 30-day LD₅₀ of Sr⁸⁹ for man would be between 1.0 and 1.5 microcuries/g. The strontium is deposited in bone and has a range (50% of the beta rays absorbed) of 0.72 mm in soft tissue. The species differences in LD₅₀ are interpreted on the assumption that some volume of marrow needs to be irradiated to cause death. The species series for Pu²³⁹, the alpha particles of which have a range of only about 40 microns in soft tissue, shows little variation in toxicity with size. The 30-day LD₅₀ on the basis of retained dose in microcuries/g and corrections for relative radiosensitivity is: mouse 0.0412, rat 0.0399, and dog 0.0375. If the relative radiosensitivity is known, it is possible to extrapolate from one species to another for alpha-particle dosage but not for lethal beta-particle dosage.

736 ANL-4001
THE EFFECTS OF TOTAL BODY X
IRRADIATION ON THE PERIPHERAL
BLOOD AND BLOOD-FORMING TIS-
SUES OF THE RAT. S. P. Stearner,

E. L. Simmons, and L. O. Jacobson. Argonne National Laboratory. April 7, 1947. 66 pp.

Following exposure to single doses of 300 and 600 r, a maximum anemia developed after 14-16 days. Recovery was complete at 30 days following the 300-r dose, but a significant difference persisted until 94 days between control animals and those exposed to 600 r. Histological study of the bone marrow after exposure to 600 r revealed a completely aplastic condition for 7-9 days following irradiation, but by 14 days, a hyperplastic condition was present. The relatively long life of the red cell (20-30 days) may explain the delayed appearance of the effects of irradiation on the circulating erythrocytes.

A macrocytic anemia was demonstrated by the presence of an increased mean corpuscular volume and a mean erythrocyte diameter. The white blood elements showed a maximum depression three days after X irradiation. Recovery began 10 days after exposure to 300 r and 600 r and was essentially complete at 30 days. After 25 r, there was a very small decrease in the number of circulating leucocytes, and recovery was complete by 14 days. Exposure at 300 r and 600 r produced drastic effects on heterophils as well as lymphocytes. Damage was seen in the lymphatic tissue as early as one-half hour following 600 r of X irradiation. The completely aplastic condition present at two days persisted until about the ninth day, at which time regeneration began. This corresponds to the first increase in the number of circulating cells. A large amount of

regenerating lymphatic tissue was present two weeks following irradiation, and active nodules were seen. At 35 days, regeneration was complete; but it appeared that compared with the controls, fewer cells were present per unit area. The time of degeneration and regeneration of granulopoietic tissue corresponded closely with the decrease and increase in the number of circulating cells. The relation between the number of leucocytes in the circulating blood and the condition of the tissue in which they are indicated a short life span for these cells. This is in accord with previous estimates.

Exposure to daily X-ray doses of 33.5 r resulted in a total of 3080 r and a maximum survival of three months. This dose rate produced only a slight depression in hemoglobin and erythrocyte values and a small decrease in the number of circulating heterophils. However, lymphocytes were reduced after one week of treatment and fell continually until the death of the animals. A dose rate of 7.7 r per day was not shown to shorten the life span of the rats and had a doubtful effect on the circulating erythrocytes. A number of circulating heterophils were not decreased, but lymphocytes were reduced after one month of daily exposure and remained at a low level. Exposure to 7.7 r for over eight months could not be shown to produce any change in the blood-forming organs.

A comparison of the effects of X irradiation on the peripheral blood of rats and rabbits showed that the pattern of

response was very similar in the two species and that only minor differences were present. The response of the peripheral blood cells to daily doses of X rays indicated that the effects upon lymphopoietic tissue were much greater than those upon the elements (heterophils and erythrocytes) formed in the bone marrow.

4.4. POST-ACCIDENT REACTOR HAZARDS

737 Y-1137A
FINAL REPORT OF THE EXPLOSION
IN OAK RIDGE, TENN., Y-12 SAL-
VAGE YARD ADJACENT TO BUILDING
9929-1. Union Carbide Nuclear Co.,
Oak Ridge, Tenn. July 20, 1956.
38 pp.

The explosion during the handling of Zr scrap at Y-12, May, 1956, is described. It was concluded by the Investigating Committee that the explosion was caused by finely divided Zr metal. Maximum explosion pressure and temperature for Zr-H₂O mixtures were calculated. Recommendations for the storage and handling of Zr are presented.

738 CRC-542
ANALYSIS OF THE RESIDUE IN DRIP
CANS BENEATH THE REACTOR
AFTER DECEMBER 12, 1952. N. Moss
and K. H. Vogel. Chalk River,
Canada. 14 pp.

Garbage cans were placed in the space under the NRX reactor on December 12, 1952, to catch light-water drips. After the accident on that date, it was thought these cans might have caught some fuel-rod material and that analysis might indicate what type of fuel rods had been involved in the accident. The garbage cans were emptied and removed to the disposal area. Samples of their

contents were analyzed for CM²⁴², Pu²³⁹ + Pu²⁴⁰, Am²⁴¹ + Pu²³⁸, and U. The ratios were very similar to those normally found at the center of U fuel rods irradiated to 3000 MWD/t. It was concluded that some fuel-rod material from highly irradiated rods had reached these cans.

739 HRAC-56
EXTERNAL RADIATION HAZARDS
FROM BETA AND GAMMA EMITTERS
IN THE ATMOSPHERE. W. B. Lewis.
Chalk River, Canada. January 26,
1948. 2 pp.

When there is widespread atmospheric pollution, the permissible exposure to external radiation should be expressed as 0.05 r in 24 hours. This will, of course, be measured by the normal beta- and gamma-ray monitoring instruments and may be considered quite separately from the inhalation hazard. Normally, this external radiation hazard need be taken into consideration only in the design of the ventilation systems of large plants. The hazard is one associated with normal operating conditions as well as with the high levels that might occur in a temporary emergency. In a temporary emergency, there is often a large safety factor that arises from the localized distribution of the activity; i. e., abnormally high local concentrations of gamma-ray emitters will not yield the radiation intensity associated with a widespread distribution of the same concentration. In an emergency condition, safety should be sought in a small space that is well shielded (e. g., an air raid shelter), since the hazard may exceed the inhalation hazard. For normal operating conditions, tolerance conditions are supplied for beta and gamma emitters.

5. CONTROL MEASURES

5.1 ADMINISTRATIVE CONTROL

5.1.1 General Problems

740 K-1088
AIRBORNE CONTAMINATION
RESULTING FROM TRANSFERABLE
CONTAMINATION ON SURFACES.

J. C. Bailey and R. C. Rohr.
Carbide and Carbon Chemicals
Co., Oak Ridge, Tenn. Novem-
ber 24, 1953. 12 pp.

A comparison of airborne activity with transferable surface activity in two contaminated plant locations during normal operation indicates that the ratio is in the range of about 0.25-1.9 d/min/m³ of air activity to d/min/cm² of surface activity. The 1.9 is considered the maximum value that might exist for long, continuous operations at K-25. However, a test designed to indicate the maximum activity that might result from plant operations included the combined action of air-circulating fans and equipment vibrations; this test gave a ratio of about 20 for short periods.

741 KAPL-580
PROGRESS REPORT FOR APRIL,
MAY, AND JUNE, 1951. HEALTH
PHYSICS. KAPL Staff. Knolls Atomic
Power Laboratory, Schenectady,
N. Y. 28 pp.

Operations of the separation pilot plant with Hanford level material produced record-high levels of radiation and contamination both inside and outside the plant. No radiation injury

was reported; however, there were 13 instances of total-body exposures exceeding 600 mrep for a 2-week period; in seven of these instances, the integrated dose exceeded 1000 mrep. The exposures were primarily beta-ray exposures, all encountered in high-level laboratory work. These instances of high exposure demonstrate the inadvisability of performing high-level work with equipment that has not been adequately operated first at lower levels of activity.

742 CF-50-7-147
SHIELDING OF NUCLEAR REACTORS,
LECTURE I: THE SOURCES OF RA-
DIATIONS. E. P. Blizard. Oak Ridge
National Laboratory. July 28, 1950.
8 pp.

The radiations in a reactor that present a shielding problem are the neutrons and gamma rays. This paper presents the energy spectra of these radiations produced by the following processes: neutrons accompanying fission, fission gammas, fission-product gammas, gammas from neutron capture in nuclei, gammas produced in neutron inelastic scattering, photoneutrons, delayed neutrons from fission products in circulating fuel, and gammas and/or X rays produced by neutron capture in coolants.

743 KAPL-384
SURVEY OF BASIC PRINCIPLES
AFFECTING THE DESIGN AND OPER-
ATION OF RADIOACTIVE-MATERIALS
LABORATORIES. H. H. Zornig.
Knolls Atomic Power Laboratory,
Schenectady, N. Y. July 1, 1950.
74 pp.

This publication gives pertinent information that has appeared in the literature, both classified and unclassified, concerning the effect of work with radioactive materials on the design of laboratory facilities and operating practices. The general features of the facilities and practices that have been developed in various laboratories are discussed. Persons who have designed and operated laboratories in which experimental work with radioactive materials is conducted are quoted whenever possible.

744 CH-3763
 PROTECTIVE MEASURES FOR PERSONNEL. J. J. Nickerson. Argonne National Laboratory. 1947. 59 pp.

Prevention of irradiation of the skin by beta rays is still a most important problem. Partial solutions are the training of the employee in proper techniques for handling beta-active substances and the development of devices for distant handling and remote control. Protection against gamma and X rays depend on training in: (1) the proper techniques for handling such substances; (2) the use of shielding; and (3) the use of remote control devices. Neutron radiation could be quite easily controlled by the use of shields composed of compounds containing a high percentage of hydrogen atmosphere plus a gamma-ray shield.

Control of radioactive materials that may get into the body and continue to irradiate an individual indefinitely is even more difficult than the control of radiation originating outside of the individual.

The greatest potential danger to the worker is the inhalation of radioactive materials. This hazard could be avoided or minimized if the worker has: (1) fresh, uncontaminated air supplied to him through a head hood or face-mask; and (2) a completely enclosed area (a dust box) designed for the handling of radioactive materials. The rate of air flow was periodically monitored in areas where radioactive materials were being handled in an effort to determine the concentration of radioactive material in the air inhaled by workers.

For the most part, the ingestion of radioactive materials has not presented a serious problem. Fortunately, many of the materials handled are very poorly absorbed by the gastrointestinal tract. It is important, however, to minimize the possibility of ingestion; thus, smoking, eating, and drinking in the work area were prohibited, and workers were required to keep their hands clean.

The absorption of radioactive materials through breaks in the skin must be prevented. Individuals with skin breaks were not permitted to work with radioactive materials until the breaks were healed. Contamination of internal structures through skin that was intact did not appear to be very probable except when workers used solutions of radioactive materials in organic solvents.

Experience has shown that work clothing should be provided all workers handling radioactive materials. If the clothing becomes contaminated, it should be washed in special laundries

so that public health problems can be avoided. A program of monitoring the clothing, shoes, masks, and gloves worn by the individual is essential.

The disposal of unwanted radioactive substances continues to be a major problem.

5.1.2 Regulations

745 M-4255
RULES GOVERNING THE HANDLING
OF FISSIONABLE MATERIAL ON THE
PLANT SITE. Clinton Laboratories,
Oak Ridge, Tenn. April 18, 1947.
14 pp.

In view of the dangers of handling fissionable materials extreme precautions must be exercised at all times. This publication sets up rules and regulations for safety, accountability, and security contingencies.

746 LAMS-456
PAJARITO SAFETY REGULATIONS.
R. E. Schrieber. Los Alamos
Scientific Laboratory. February,
1947. 12 pp.

Rules for handling fissionable material are given. Regulations are divided into three categories according to the degree of hazard involved. Design requirements for critical-assembly apparatus and procedures to be followed in case of an accident are outlined. The principles involved are stated in LAMS-452. The report lists equipment design features that are also applicable to reactor fail-safe operation.

5.1.3 Health-Physics Procedures

747 AD-218(OH)
HAZARD EVALUATION AND CONTROL
FOLLOWING A SPILL OF 40 MILLI-
GRAMS OF RADIUM. R. K. Skow,
S. R. Johns, F. L. Falgiano, and
F. R. Holden. Naval Radiological
Defense Laboratory. April 12,
1950. 21 pp.

During a laboratory exercise in the calibration of radiac instruments, 40.3 mg of Ra was accidentally spilled. The spill was undetected for approximately 30-60 minutes, during which time the Ra salt spread widely throughout the building. This report is an account of the evaluation and control of the health hazard from the accident. Attention is directed to AD-219(OE), which describes the procedures used and the results obtained in the reclamation of the school building.

748 ADL-72
HEALTH PHYSICS DURING PEACE
AND WAR. W. H. Sullivan. Naval
Radiological Defense Laboratory.
March 3, 1949. 13 pp.

The report covers wartime radiation hazards, functions of the health physicist, and health physics. The health physicist will play a prime role in setting operational standards for the practitioner of "atomic medicine." He will also serve as an important advisor to the tactician and strategist, who must always think in terms of calculated risks for the accomplishment of a given job. The health physicist's task will not be easy, but the basic principles that should guide his actions are clear, even though exact data are not always available.

749 M-2435
 RULES AND PROCEDURES FOR THE
 HANDLING OF ACTIVE MATERIALS.

L. B. Borst (Chairman, Activity Hazards Committee). Atomic Energy Commission, Washington, D. C. January 2, 1945. 79 pp.

This compilation is a revision of the manual dated June 16, 1944. The 19 general rules are briefly stated and then elaborated upon for application to different working areas and exact procedures. The manual describes: the duties of laboratory supervisors and the health officer; the responsibility of the individual worker; information reportable; and limits of exposure. The regulations had to be both stringent and broad enough that the worker could attain maximum protection from any absorption or release from the laboratory of all alpha emitters with half-lives between 10^3 and 10^5 years. Alpha emitters of shorter half-lives would require further regulations. Maximum exposures and times, methods of handling active materials (according to the degree of activity and work location), protective clothing and its cleaning, tool maintenance procedures and cleaning, waste disposal and continuous monitoring of sites, containers, and personnel, and shipping of active material are covered in the regulations written for a given AEC facility.

5.1.4. Principles of Protection

750 Y-A2-115
 CRITICALITY CONTROL AT THE
 Y-12 PLANT, OAK RIDGE, TENN.

Carbide and Carbon Chemicals Co. Technical Information Service Extension, AEC. 1955. 13 pp.

Although the total amount of criticality information is growing steadily, it is not yet large enough to answer all problems completely. Practical methods of ensuring nuclear safety are detailed, and rules for avoiding criticality or circumstances that could inadvertently lead to criticality are presented. The rules deal with enriched and natural uranium and with gaseous, liquid, and solid systems. Critical masses for several environments are given.

751 KAPL-675
 HEALTH PHYSICS PROGRESS REPORT
 FOR OCTOBER, NOVEMBER, AND
 DECEMBER, 1951. KAPL Staff.

Knolls Atomic Power Laboratory, Schenectady, N. Y. January 31, 1952. 27 pp.

Progress is reported in routine radiological services. Development of a proportional water sampler, a method for the spectrographic analysis of Be, modifications in I^{131} monitoring, and particle-size studies of stack effluent are reported. Four radiation-hazards incidents during the period, one of which represented an overexposure, resulted in a review of health-physics practices. It was concluded that existing recommendations were satisfactory but that current practices were devious. Activities at the Nevada test station produced increases in background-activity measurements at KAPL by factors of from 10 to 35.

5.1.5 Operation, Testing, and Inspection of Reactors

752 KT-178
CARRIER DESIGN OF IRRADIATED
APPR FUEL ELEMENTS. F. D.

Miraldi and A. D. Rossin. Massachusetts Institute of Technology, Oak Ridge, Tenn., Engineering Practice School. November 17, 1954. 34 pp.

Irradiation tests are to be run on APPR fuel elements in the STR at Arco. Evaluation of the tests will be made at ORNL. The design of a carrier for shipping fuel-element samples from Arco to ORNL is given. Both gamma shielding and heat dissipation are considered.

753 IDO-16073
A SURVEY OF THE MATERIALS-
TESTING REACTOR SHIELD. E. Fast,
J. P. Byron, and J. W. McCaslin.
Phillips Petroleum Co., Atomic
Energy Division, Idaho Falls, Idaho.
May 27, 1953. 38 pp.

A detailed survey of the MTR shield to determine its adequacy from a health-physics point of view has been completed. The survey was made with X-ray film and with survey instruments. In general, the bulk shield showed no radiation leaks attributable to faulty construction. However, beam intensities from the experimental plugs were greater than anticipated. Revisions were made in the keys so that the experimental plugs could be oriented, and in the outer shielding plugs so that these beam intensities could be

reduced to permissible values. No excess neutron intensities were found, except at the thermal column. The slow-neutron flux was originally at the biological maximum permissible level during full-power operation, but 1/4 in. of boral plate has effectively reduced it. Gamma intensities at this point remain near maximum permissible levels. The shield of the subpile room appears to be considerably better than the designers anticipated. A maximum intensity of 300 mr/hr was measured in the basement during the discharge of a fuel assembly through the subpile room. During normal operation, a reading of 1-2 mr/hr was observed in the subpile room.

754 CF-53-5-45
EXPERIMENTAL PROGRAM FOR HRE
AT HIGH POWER: PART 1, CORE-
MIXING, GAS COEFFICIENT OF RE-
ACTIVITY, AND CONCENTRATION
EFFECT IN CORE. Sidney Visner.
Oak Ridge National Laboratory.
May 7, 1953. 9 pp.

Reactivity changes associated with power, such as mixing in the core, gas residence, and the concentrating of the solution in the core, are discussed. Data are presented on the heat balance by steam flow, condensate flow, cooling of the turbine condenser, gas production, and determination of the ease of starting up the reactor by concentration of the fuel. Special operational procedures are given. Startup, operation with constant condensate holdup, rapid power decrease, rapid decrease in fuel-pressure operation at a constant outlet temperature and 1000 psi, and the effect of pulse-feeder flow-rate are discussed.

755 TID-5058
 PERSONNEL PROTECTION DURING
 REACTOR STARTUP. L. B. Borst.
 Technical Information Service Ex-
 tension, AEC. August 7, 1950.
 3 pp.

A set of rules given to the Radiation Safety Committee covers fuel loading, experiments at low levels, instrumentation for locations in the pile at significant neutron densities (over 10^8 neutrons/cm²/sec), the state of the reactor before personnel can enter the plenum, and removal of material from the reactor.

756 TID-5047
 SEQUENCE OF START-UP OPERA-
 TIONS. L. B. Borst. Brookhaven
 National Laboratory. August, 1950.
 7 pp.

This report is in the form of a check list of 52 operations that must be carried out as a part of the cold startup of the Brookhaven reactor. Initially, fuel channels are charged, so that the reactor can be brought to criticality while calibrating. The procedure includes flux-mapping, barometric-coefficient determination, measurement of flux transients during control-rod movements, and operation at several temperature levels.

5.1.6 Hazards-Summary Reports

757 ORNL-1853
 HOMOGENEOUS REACTOR PROJECT;
 QUARTERLY PROGRESS REPORT
 FOR THE PERIOD ENDING JANU-
 ARY 31, 1955. H. F. McDuffie

and D. C. Kelly, comps. Oak Ridge National Laboratory. March 23, 1955. 4 pp.

Possible blast effects from a rupture of the pressure vessel were considered sufficient to justify the 1.5-2.0 in. - thick blast shield around the pressure vessel. A maximum pressure of 29 psi is expected in the reactor equipment cell in the event of an instantaneous release of core and pressure-vessel liquids and the release of heat-exchanger liquids through 6-in. steam lines. The danger of UO₄ precipitation in the cooled dump and sampler lines was investigated. If the reactor is operating at 10 Mw, the fuel solution cannot immediately be cooled below 70C after it is removed from the main circulating loop. Designs for the reactor pressure vessel and core tank were completed, and stresses in the carbon-steel wall of the pressure vessel were calculated. A parametric study of core pressure rise as a function of reactivity addition was conducted on the ORACLE. Parameters included the temperature coefficient of reactivity, the length of piping between core and pressurizer, the friction coefficient, fluid compressibility, the volume of pressurizing fluid, and the lifetime of prompt neutrons. The phenomenon of "walk-away," a slow reactivity rise due to fuel concentration, was investigated. Fuel concentration results when water is removed from the core by radiolysis faster than it is returned after recombination.

758 ORNL-1794
 THE OAK RIDGE NATIONAL LABORATORY RESEARCH REACTOR SAFEGUARD REPORT (VOLUME II, APPENDIX). F. T. Binford. Oak Ridge National Laboratory. October, 1954. 98 pp.

This volume includes reports on the design of the ORR; it is also a reference volume for the hazard evaluation of reactors of similar design. Information is given on operational review committees, the dispersion of airborne waste in the X-10 area, selected radiation hazards of ORR, shielding design, activity present in the cooling system, and radiation-intensity estimates.

759 KAPL-ADM-867 (Supplement)
 SAFEGUARD ANALYSIS OF THE PROOF-TEST REACTOR: SUPPLEMENT I, FISSION DISPERSAL ANALYSIS FOR THE PROOF-TEST REACTOR. J. J. Fitzgerald, H. Hurwitz, Jr., and L. Tonks. Knolls Atomic Power Laboratory, Schenectady, N. Y. September 11, 1953. 34 pp.

The personal hazard from a nuclear accident varies with proximity, meteorological conditions, topographical conditions, and concentrations of radioactivity. An incident that releases 2.5×10^{-8} (t - 1.2) curie of 0.5-Mev gamma rays and the corresponding beta activity is assumed. Dispersion is described with Sutton's formula for a puff cloud. The beta hazard is quite low, is reduced by a factor of 2 by the skin, and is not the principal inhalation hazard. Beta particles do not penetrate the blood-forming organs. The

gamma radiation is lethal 50 m from the cloud origin but is below the permissible limits at 300 m. Inhalation hazard derives from the uranium particles and from the fission products, but at no time do these exceed the emergency permissible dose (1000 rep) to the lung. Equations show the dose rate resulting from rain-out and fall-out. Calculations show that the dose rate is reduced by continuous fall-out from the traveling cloud. At 200 m, the total integrated dose from fall-out is 46 r; but if a person remains for only five minutes after the cloud reaches this position (80 seconds after the accident in the inversion case), he will receive only 23% of this dose, or 10.6 r.

Radioactivity in the Stony Creek Reservoir from rain-out and fall-out would give activities far below those set up as the permissible emergency concentrations for drinking for one day. Permissible emergency concentrations for one day are:

Fission Products	1.0 millicurie/l
Sr ⁸⁹	0.14 millicurie/l
I ¹³¹	0.01 millicurie/l
U ²³⁵	265 milligrams/l

760 ANL-WHZ-252
 A REPORT TO THE ATOMIC ENERGY COMMISSION ON THE PROPOSED ARGONNE RESEARCH REACTOR. W. H. Zinn. Argonne National Laboratory. June 15, 1950. 57 pp.

The hazards of the new Argonne pile (CP-5, D₂O-moderated and -cooled and developing 2000 kw at 5×10^{13}

neutrons/cm²/sec) are discussed. The reactor design, the proposed operation, and the control features are given in detail. The possible reactor hazards are: the misuse of pneumatic experimental facilities; improper fuel charging or recharging; quick insertion of poison or fissionable material into large experimental holes; failure to detect a large loss of reactivity during startup; the release of fission products from stored spent fuel; nonoperation of safety rods; nonfunction or malfunction of instruments and circuits; an increased reactivity from chilled D₂O; overdose from neutron beams; the escape of radioactive gases; a leak of D₂O in the reactor tank; entry into thimbles of water (light or heavy); the mixture of ordinary water with D₂O; an excess level of D₂O in the tank; fracture of the shim rod; bunching of fuel elements; overheating of fuel elements during shutdown; warping or plugging of fuel assemblies; the release of large amounts of energy from exothermic reactions; failure of fuel cladding; failure of the D₂O pump; xenon and temperature-coefficient transients; leakage of radioactive water; the presence of radioactive particles; fire; problems associated with the methods of fuel transportation and storage; bombing; sabotage; and earthquakes.

761 ANL-SM-516
HAZARDS OF THE MATERIALS-
TESTING FACTOR. S. McLain.
Argonne National Laboratory.

This report describes the proposed MTR core and its operational, nuclear, and heat-transfer characteristics. The reactor will contain 19% excess

reactivity at startup. The control system is designed to control a period as short as 0.1 sec, but periods shorter than 1 sec are avoided by the control system.

Experiment changes will occur at 15-day intervals during refueling shutdowns. Safety is the only restriction imposed by the reactor administration on experiment design. Conditions activating scram circuits are described. The danger from prompt critical conditions are said to be slight, because the energy release would be slower than shock-wave propagation. The melting of fuel elements and the extent of damage and hazards from accidents of different size are described; details are not given. Other aspects described are location, meteorology of the site, water drainage, and earthquake liability.

762 ANL-WHZ-250
A REPORT TO THE ATOMIC ENERGY
COMMISSION ON THE PROPOSED
CP 3' REACTOR. Argonne National
Laboratory. June 15, 1950. 96 pp.

This report describes potential hazards from the operation of the CP-3'. This reactor differs from CP-3 in that its fuel rods contain enriched (93%) uranium. The reactor and its experimental facilities are described. Fifteen reactor hazards are discussed in detail.

5. 1. 7 Health-Physics Activities

5. 1. 7. 1 Radiation Measurement

763 KAPL-1118
A REMOTELY OPERATED RADIATION
SURVEY METER. L. C. Cooper.

Knolls Atomic Power Laboratory,
Schenectady, N. Y. May 20, 1954.
12 pp.

An illustrated description is presented of a remotely operated beta-gamma-radiation survey meter covering the range from 0.01 to 100,000 r/hr.

764 Y-836
HEALTH PHYSICS PROGRESS REPORT: JANUARY 1, 1951, TO JUNE 30, 1951. E. G. Struxness.
Carbide and Carbon Chemicals Co.,
Oak Ridge, Tenn. December 15, 1951. 39 pp.

An account of the rupture of a Po-Be neutron-source container and the contamination resulting from the accident are described. Control methods and decontamination procedures are discussed. Shielding data for the 86-in. cyclotron are given. A plastic ring containing film for the monitoring of beta radiation in the presence of weak gamma radiation is described. These plastic rings can be changed weekly; ease of identification is an aid in keeping accurate exposure records. Contents of catastrophe kits are listed, and a photograph of a kit and contents is included. A fixed isokinetic sampler for installation in the discharge pipe for monitoring effluent air is described.

765 CF-51-5-74
CALIBRATION OF THE FAST-NEUTRON DOSIMETER USED AT THE BULK-SHIELDING FACILITY. R. G. Cochran. Oak Ridge National Laboratory. May 11, 1951. 8 pp.

A brief description is given of the fast-neutron dosimeter used for measuring fast-neutron dosage at the bulk-shielding facility. The method of calibrating the dosimeter is described, and an estimate is made of errors that might be expected through the use of this instrument.

766 K-757
PRELIMINARY REPORT ON A HIGH-SENSITIVITY GAMMA PROBE FOR USE WITH THE SAMSON SURVEY METER. R. W. Schede. Carbide and Carbon Chemicals Co. May 1, 1951. 14 pp.

A high-sensitivity gamma extension probe has been developed for use with the Samson survey meter. The probe has a sensitivity of 0.02 mr/hr full scale; it weighs 4.5 lb and is 19 in. long and 2.5 in. in diameter. The primary function of this probe is to locate deposits of U²³⁵ in process equipment.

767 NP-1341
ON THE USEFULNESS OF DIFFERENT RADIATION DETECTION METHODS FOR ROENTGEN MEASUREMENT PURPOSES. W. Ramm. Evans Signal Laboratory. September 30, 1949. 28 pp.

The following features of radiation detection devices are discussed: (1) usefulness for measuring dose or dose rate; (2) sensitivity and range in

intensity that can be covered; (3) volume and size; (4) materials employed; (5) method of use and kind of reading; (6) necessary equipment; and (7) temperature dependence and applicability for neutron detection.

5. 1. 7. 2 Environmental Surveys

768 KAPL-1160
HEALTH PHYSICS REPORT FOR
APRIL, MAY, JUNE, 1954. Knolls
Atomic Power Laboratory, Schenectady, N. Y. 35 pp.

This report summarizes personnel, in-plant, and environmental radiation-monitoring procedures during the period. (For preceding period see KAPL-1116.)

769 ORNL-873
PROGRESS REPORT OF THE RADIO-ACTIVE WASTE-DISPOSAL RESEARCH AND DEVELOPMENT SECTION OF THE HEALTH PHYSICS DIVISION: JULY 1 TO SEPTEMBER 30, 1950. R. J. Morton. Oak Ridge National Laboratory. November 21, 1950. 42 pp.

The objectives of the ecological survey of White Oak Creek are stated as follows:

(1) A biological survey of all surrounding flora, fauna, and animal life.

(2) An analysis of all specimens taken for gross radioactivity.

(3) The establishment of records for the long-term ecological study of all the forms of life in the area.

(4) The study of alpha, beta, and gamma levels in water, muds, and shores will be undertaken to determine any relationships between such activity and that found in the flora, fauna, and animal life.

These objectives form the base for a long series of subsequent reports.

5. 1. 7. 3 Air Monitoring

770 CR-HP-577
THE ANNULAR IMPACTOR. G. W. C. Tait. Chalk River, Canada. 1952. 13 pp.

An air-sampling device based on the impaction principle is described. It differs from previous instruments, since it can sample at very high rates, of the order of 700 l/minute. This capability is achieved by the use of a very simple arrangement of the impactor parts with the jet in the form of an annular ribbon. The device appears to be particularly useful for the sampling of dusts containing long-lived alpha emitters. Heretofore, such dusts had been difficult to assess because of the presence of appreciable concentrations of natural radon decay products. The impaction device differentiates sharply between most coarse industrial dusts and the finer, natural dusts, since it separates particles

greater than and less than 0.5 micron in diameter. Good discrimination is achieved, since dusts arising from most technical processes have a mass median well over 1 micron, whereas radon decay products have been found elsewhere to be 0.04 micron in diameter. Results of field testing are included.

771 KAPL-324
HEALTH PHYSICS PROGRESS
REPORT NO. 44, SECTION VI:
MARCH, 1950. KAPL Staff. Knolls
Atomic Power Laboratory, Schenectady, N. Y. April 21, 1950.
18 pp.

The air-sparging (agitation) of uranium solutions in the engineering laboratory produced general atmospheric contamination levels of 6 micrograms of uranium/m³. The total activity discharged to the Mohawk River from March 3, 1949, to March 15, 1950, was estimated at 0.47 curie of predominantly beta activity.

5.1.7.4 Analytical Procedures

772 HW-20136
HEALTH INSTRUMENT CONTROL
LABORATORY: ROUTINE CHEMICAL
PROCEDURES. J. W. Healy, R. C.
Thorburn, and Z. E. Carey.
Hanford Works, Richland, Wash.
July 15, 1951. 123 pp.

Procedures currently used in the Health Instrument Development Control Laboratory at the Hanford Works in the analysis of materials from the

environs for beta and alpha emitters are given in detail. Procedures for analysis of the following are included: water, vegetation, solids (soil, laundry lint, and algae), air samples, aqueous wastes, organic wastes, and air filters. Procedures are given for the determination of Sr-Ba, Zr, Ru, Cs, Ce, Y, total rare earths, Pu, U, and Po; methods of determining procedure efficiency are given.

773 KAPL-364
THE K-25 CONTINUOUS WATER
MONITOR; SECTION I-C OF THE
MEETING OF THE AEC WASTE-
PROCESSING COMMITTEE, JUNE 26-
28, 1950; PART III. W. G. S. Fort.
Knolls Atomic Power Laboratory,
Schenectady, N. Y. October 11,
1950. 2 pp.

The monitor is designed to provide a continuous record of the radioactivity of the sanitary water at the K-25 plant. It is fully automatic. The water passes three cylindrical Cu cups suspended beneath three thin-mica-window G-M tubes. The counts from these tubes are accumulated for a prearranged period (usually 10 minutes) on a pair of telephone-type stepping switches, and a type-S Micromax records the indicated total count. Operating characteristics are given.

5.1.7.5 Personnel Dosimetry

774 HW-7-4451
DETECTION OF I¹³¹ IN THE BODY.
J. W. Healy. Hanford Works, Richland, Wash. July 25, 1946. 5 pp.

The radioactive gases and vapors evolved from the dissolving process are vented to the atmosphere from the top of 200-ft stacks, where the fumes are diluted and dispersed by air currents. The most hazardous radioactive poison present in any large concentration is the eight-day iodine, which deposits in the thyroid glands of animals and bombards the surrounding tissue with beta particles.

The detection of iodine in the body is accomplished by measurement of the gamma radiation at the outside of the neck. Calculations of the tolerance amount of I^{131} in the body indicate that about 0.08 microcurie/g of thyroid will deliver a dose of 1 rep. Thus, for an adult human with a thyroid of 25 g, the tolerance amount of iodine would be 2 microcuries. Calibrations were made to enable the Health Instrument group to measure the amount of iodine deposited in the thyroid of personnel and animals exposed to I^{131} .

The small brass counters used for measuring the amount of iodine in the thyroid give 750 counts per minute for a tolerance amount of 2 microcuries in a human thyroid. Other types of counters give somewhat comparable rates.

The counter may be moved as much as 5 mm from the position of maximum sensitivity with a resulting error of only 2%. The depth of the thyroid changes the counting rate somewhat but does not become important until large depths (6-8 mm) are encountered.

775

CRM-315

SOME PROBLEMS ARISING IN THE DOSIMETRY OF ARTIFICIAL RADIOACTIVE SUBSTANCES AND HIGH ENERGY QUANTA. W. V. Mayneord. Chalk River, Canada. July, 1946. 23 pp.

The medical applications of artificial radioactive substances have brought a number of interesting physical problems. The dosimetry of these substances is discussed and certain of the more elementary mathematical and physical aspects are developed.

The main effort is directed to bridging the gap between the dosimetry of beams of radiation, as used in the classical techniques of radiation therapy, and the relatively new field of dosimetry of radiations emitted by radioactive substances extended throughout the body after injection or ingestion. It is shown that the recently developed theory of total energy absorption in the body from beams and point sources of radiation can be adapted to the dosimetry of artificial radioactive substances; and that in a few simple cases, the total energy absorbed by a living organism containing radioactive substances may be estimated. The use of absolute energy units makes it possible to deduce very general relationships between radioactive content and dosage-rate; and to sketch a common theory of dosimetry of gamma rays, beta rays, positrons, and neutrons. This common dosimetry may advantageously be applied to problems of protection and tolerance determination.

776 CF-43-12-322
SAFETY RULES ON ACTIVITY
HAZARDS ADOPTED BY THE CEN-
TRAL SAFETY COMMITTEE,
DECEMBER 11, 1943. Technical
Information Service Extension,
AEC. December 14, 1943. 4 pp.

This report describes the use of pocket meters, personnel responsibilities, requirements of the health officer's surveys, and conditions of entry into an overexposed area under the permissible level of 0.1 r/24 hr. This level is the total additive exposure from independent components of all radiations involved. Areas that are not to be entered are also listed.

5.1.7.6 Miscellaneous Health-
Physics Information

777 WT-12
PROTECTIVE CLOTHING AND PER-
SONNEL DECONTAMINATION. F. M.
Steadman. Office of the Quarter-
master General, Ft. Lee, Va., and
Quartermaster Research and De-
velopment Laboratories, Philadel-
phia, Pa. December, 1951. 150 pp.

Preliminary laundering decontam-
ination methods developed in a test
program at ORNL were tested in
Operation Greenhouse under conditions
of field contamination from atomic-
weapons bursts. Normal clothing ma-
terials showed little difference in con-
taminability, except that water-repel-
lent finishes appeared to pick up more
contamination and to resist its removal
to a greater degree than materials that

were not water-repellent. Contamina-
tion picked up by movement in fallout-
contaminated areas was removed as
readily as that picked up by surface
materials activated by the detonation.
Contaminated clothing was decontam-
inated satisfactorily if it was laundered
with synthetic detergents and then
washed with alkaline and acid chelating
agents in commercial, corrosion-
resistant-metal laundry equipment.
Commercial laundries can safely and
practically decontaminate launderable
clothing contaminated as a result of an
atomic-bomb detonation. Decontamina-
tion of launderable clothing contaminated
by laboratory spills may be accomplished
by the use of the long procedure:
formula 77. Personnel decontamination
was satisfactorily accomplished without
the use of special detergents, commer-
cial toilet soap proving as efficient as
specially formulated detergents in dis-
tilled water.

778 AD-219(OE)
DECONTAMINATION OF BUILDING
233, U. S. NAVAL STATION, TREAS-
URE ISLAND, CALIF., (MEMORAN-
DUM REPORT). Naval Radiological
Defense Laboratory. May 18, 1950.
18 pp.

As a result of the accidental loss of
40.3 mg of radium from an instrument
calibration capsule in a classroom
demonstration, a two-story building be-
came radiologically contaminated.
Procedures for isolation and decontam-
ination of the affected areas and per-
sonnel are reported.

779 M-1813
 REVIEW OF THE FIRST YEAR'S WORK
 ON U DUST INHALATION IN EXPERI-
 MENTAL ANIMALS. H. C. Hodge.
 University of Rochester, Rochester,
 N. Y. July, 1945. 60 pp.

As an aid in the selection of dust concentrations that could be used in the chronic studies, the various U compounds were suspended as dusts in the atmospheres of experimental chambers, and animals were observed therein for 30-day periods. So that a clear picture of acute U toxicity and the necessary criteria for the recognition of U poisoning could be established, one experiment on each compound was carried out at a fairly high dust concentration (approximately 20 mg of dust/m³). These high dust-concentration studies are described. As a guide to the order in which the various U compounds were studied, a list of toxicological priorities was established. The construction of exposure chambers is briefly described; some of the difficulties of providing a controlled dust concentration are pointed out; the methods of characterizing the dust cloud are described; and some of the tests on respiratory protective devices are summarized.

A table of inhalation mortalities of the various U compounds is included. The various U compounds are classified into three groups: (1) most toxic (UF₆, UCl₄, and UO₂F₂); (2) intermediate toxicity (UO₄, NH₄ salt, Na salt, UO₃, and U-nitrate); and (3) lowest toxicity (ore, UF₄, UO₂, and U₃O₈). Species variations in toxicities of the various compounds are discussed.

780 N-2275
 REPORT ON DUST SURVEY MADE
 AT BUFFALO. S. Laskin. Univer-
 sity of Rochester, Rochester, N. Y.
 May 10, 1945. 6 pp.

A preliminary dust survey was made at Buffalo, where samples were taken so that particle sizes, particle numbers, and U concentrations of dusts in and near areas where the greatest amounts of U dust prevailed could be determined. The methods used were the same as those employed in the exposure units at Rochester. The particle size of the U dusts in the industrial plants was smaller than that of the dusts in the exposure units. Average values for the size distribution were M_g (medium size) = 0.31 micron, and σ_g (standard deviation) = 2.8 for the industrial samples, compared with M_g = 0.58 micron, and σ_g = 2.1 for the exposure unit. Similar results were obtained for the calculated weight distributions--1.5 microns for industrial samples as against 1.9 microns for exposure units. Dust particles numbered from 5.0 to 25.2 million/ft³. Figures on concentration are given for areas in and near operations at the plant.

5.1.8 Training

781 LAMS-452
 PAJARITO SAFETY MANUAL. R. E.
 Schrieber. Los Alamos Scientific
 Laboratory. December 3, 1946.
 26 pp.

This manual preceded the writing and adoption of specific safety regulations to be followed in a facility. The general information and safety limits on radioactive materials and the human tolerances have since been republished in several public documents in more precise form. This manual, covering conditions at Pajarito, cites the need for detecting leaks in packaging and describes the use of gloves, determination of amounts of materials, and the relations of places of use to amounts of materials. A detailed discussion of nuclear safety and the laboratory philosophy on critical experiments is provided; this discussion covers the reasonable combinations of accidents that could lead to a critical condition.

782 M-4291
TABLE FOR REFERENCE IN DETERMINING TOLERANCE VALUES, K. Z. Morgan. Clinton Laboratories, Oak Ridge, Tenn. April 4, 1945. 2 pp.

A table of tolerance values and a table of conversion factors for mr/hour or mrep/hour to particles/time are given.

HEW-7184
783 AECD-2943
HEALTH-INSTRUMENT LECTURE SERIES, PART I. Hanford Works, Richland, Wash. July 1, 1947. 175 pp.

This report is essentially a training manual aimed at college-degree chemical engineers or chemists who would work with the medical department in the protection of employees from excess radiation exposure. It is broad

in scope and contains chapters on nuclear physics, ionization in gases, instruments for radiation detection, fission and fission products, effects of radiation on the body, radiation dosimetry, tolerance doses, and protection methods.

784 NP-1838 (Special Text 3-150)
RADIOLOGICAL-DEFENSE INDOCTRINATION COURSE FOR ARMED FORCES SCHOOLS. Chemical Corps School, Chemical and Radiological Laboratories, Army Chemical Center. February, 1950. 159 pp.

The course consists of eight 50-minute periods encompassing: An introduction to nuclear physics, including structure of the atom, structure of the atomic nucleus, and a comparison of the nuclei of different elements; types of radiation and nuclear fission; explosion phenomena; physiological effects of blast and radiation; instruments for detecting radiation; survey and decontamination procedures; organization and training for radiological defense; and the command problems of radiological warfare.

5.2 INHERENT CONTROLS

5.2.1 Shielding

785 NRL-4146
MEASUREMENTS OF PENETRATION AND SCATTERING OF RADIATION ABOARD THE USS RANDOLPH. L. A. Beach, R. B. Theus, and W. R. Faust. Naval Research Laboratory, Washington, D. C. April, 1953. 40 pp.

Measurements made aboard an aircraft carrier on the penetration of Co^{60} and Na^{24} gamma radiation through the deck and bulkhead agree with theoretically computed values. The scattering of radiation in the torpedo protection spaces was measured and is explained by a single scattering calculation. This information indicates the level of protection afforded the crew from radiation produced by a nuclear weapon and provides a design basis for the installation of a nuclear power plant aboard a naval vessel. Although this information may in theory be calculated, the problem of obtaining a solution to the transport equation satisfying the appropriate boundary values is mathematically hopeless.

786 BNL-1443
NEUTRON-STREAMING THROUGH
BOUNDARIES IN A MOCKUP OF THE
SIR ROTATING PLUG. H. J. C.

Kouts, W. W. Pratt, R. D. Schamberger, F. J. Shore, H. P. Sleeper, Jr., and H. Susskind.
Brookhaven National Laboratory.
March 25, 1953. 70 pp.

Neutron-attenuation data obtained at the Brookhaven shielding facility on a mockup of the fuel-rod unloading plug used in the SIR are summarized. The thermal-neutron flux, fast-neutron dose, and gamma-ray dose were measured in the water behind various components of the mockup. Details of the experimental mockup, radiation detectors, the calibration of instruments, and compilation of test data are appended.

787 CF-52-12-118
SOME CALCULATIONS FOR THE
BOILING REACTOR SHIELD. R. E.
Aven, A. R. Eckels, and P. N.
Haubenreich. Oak Ridge National
Laboratory. December 18, 1952.
24 pp.

788 ORNL-710
THEORETICAL AND PRACTICAL
ASPECTS OF SHIELDING. T. Rock-
well, III, and A. S. Kitzes. Oak
Ridge National Laboratory.
September 29, 1950. 334 pp.

Each of 22 papers that were intended to form a special "shielding issue" of Nucleonics but that could not be declassified as a unit covers a separate phase of reactor, laboratory, or shipment shielding. Experimental, theoretical, and design considerations in neutron and gamma attenuation are included.

789 M-3216
THE SHIELDING OF POWER PILES.
H. G. Rickover. U. S. Navy.
August 14, 1946. 8 pp.

The biological conditions that must be faced in the consideration of a nuclear power plant for marine use, where size and weight are more of a problem than with other installations, are set out concisely.

5.2.2 Control Systems

790 ORNL-1139
THE MTR SAFETY SYSTEM AND ITS COMPONENTS. T. E. Cole, E. E. St. John, and S. H. Hanauer. Oak Ridge National Laboratory. April, 1952. 32 pp.

Reactors built with large excess reactivity can conceivably reach prompt critical before accurate instruments are in the range to indicate the flux. Corrective action must come from a safety device, since the short period of the reactor precludes corrective action by the pile operator. Such a device will shut down the reactor in a time determined by the period of the reactor, by the delays in the safety system, and by the rate at which the safety system can decrease K. The magnets and control-rod armatures are shown to be the least satisfactory elements in the MTR safety system.

791 WAPD-IC-66
NEW INSTRUMENTATION LINEUP. M. A. Schultz. Westinghouse Atomic Power Division, Pittsburgh, Pa. January 17, 1952. 3 pp.

Changes in radiation-detection instrumentation for naval reactors are discussed. The use of ion chambers in ion tubes instead of thimble ion chambers is recommended in areas of high gamma intensity.

792 WAPD-21
SYMPOSIUM ON REACTOR INSTRUMENTATION: JUNE 5-6, 1950 (PART II). Westinghouse Atomic Power Division, Pittsburgh, Pa. 154 pp.

A symposium on reactor instrumentation is reported. Among the topics discussed were: the design and performance of ionization chambers; boron-coating processes; pile measurements with logarithmic amplifiers and counting-rate meters; fission chambers; amplifiers and power supplies; logarithmic counting-rate meters; logarithmic amplifiers; counting-rate-meter statistics; and the testing and comparison of pulse amplifiers.

5.2.3 Ventilation

793 KAPL-1268
SEMIANNUAL PROGRESS REPORT OF RADIOLOGICAL DEVELOPMENT ACTIVITIES IN THE HEALTH-PHYSICS UNIT. Knolls Atomic Power Laboratory, Schenectady, N. Y. June, 1954. 38 pp.

The filter-efficiency studies of the Whatman-41, the Hollingsworth and Vose-70, the Mine Safety Appliances 1106-B, and the AEC-1 filter media were extended to include collection efficiencies in the face velocity range of 100-250 cm/sec. The efficiencies or particles from 0.18 to 1.2 microns ranged from 60 to 99.9%. In general, all exceeded 90% with the exception of the Whatman-41.

794 HW-30142
COMPARATIVE STUDY OF ALTERNATIVE FIBROUS-GLASS-AND-SAND EXHAUST VENTILATION AIR-FILTER INSTALLATIONS FOR PUREX. L. L. Zahn, Jr. Hanford Works, Richland, Wash. December 14, 1953. 22 pp.

Fibrous glass filters were designed for the Redox Purex plants after it was found that radioactive aerosols were issuing from the process stacks of bismuth phosphate separations. This latter problem has been corrected with sand filters, which are about three times more costly than the glass filters and are also less efficient. At least two filter systems are required--each of a different size and of a different density of glass-fiber packing. The fore filter was calculated to be 92.0% efficient at 50 ft/minute superficial velocity (84-in. depth) with a pressure drop of 2.8 in. of water. The composite clean-up filter operates at 99.9% efficiency at a superficial velocity of 20 ft/minute (1-in. depth) with a pressure drop of 4.0 in. of water. Ventilation filters have to be thrown out rather than reclaimed; a minimum life of five years was expected. The formulas for calculating the performance and the geometry of the filters are included. Owens-Corning Fiberglas C was used in the fore-filter; the Deep-Bed filter unit of American Air Filter Co., was used for the clean-up filter of fine fiber.

795 KAPL-603
DETERMINATION OF FACE-MASK
FILTER-PAPER EFFICIENCIES FOR
MSA AND ASSAULT-MASK FILTERS.

C. G. Detwiler. Knolls Atomic
Power Laboratory, Schenectady,
N. Y. September 19, 1951. 22 pp.

In tests on filter papers used in the MSA Comfo Metal Fume Filter (CR-17034), the MSA Comfo Ultra-Filter (CR-72433), and the Assault-Mask Canister Filter, the Goetz molecular filter and the Houston duralumin aerosol were used as standards (the Houston duralumin aerosol resembles that used in

shops processing pile equipment), at flow rates near 21 l/minute--the normal breathing rate. The counting system and the use of data to calculate filter efficiencies are described. When corrections for the background count (158 particles/mm²) were made, the filter efficiencies were reported as 98.4%, 99.3%, and 99.0%, respectively.

796 CRLR-14
FILTER-MATERIAL EFFICIENCY
AGAINST HIGH LEVELS OF AIRBORNE
RADIOACTIVE CONTAMINATION.

J. J. Mahoney, E. H. Engquist, and
R. B. Price. Chemical Corps
School, Chemical and Radiological
Laboratories, Army Chemical
Center. August 13, 1951. 28 pp.

A test method involving the use of ¹³¹I particulates of 0.48-micron diameter was used to demonstrate that the type-6 filter material would allow penetration of 0.020-0.45% of the aerosol blown against it, up to activity levels of 20 microcuries/l. At activity levels of 60 and 4000 microcuries/l, the efficiency increased and the penetration was only 0.005-0.007%. This type of filter offers protection against airborne radioactive particulates of the radioactivity level anticipated in a cloud in the vicinity of an atomic detonation. Details of the test procedure and three appendixes with data on several aspects of handling aerosols are included.

797 NYO-1580
A PRELIMINARY FIELD SURVEY OF
AIR-CLEANING ACTIVITIES AT
ATOMIC ENERGY COMMISSION FACILITIES. August T. Rossano, Jr., Leslie Silverman, and Melvin W. First. Harvard University School of Public Health, Boston, Mass. February, 1951. 45 pp.

This report describes the air-cleaning facilities at seven national laboratories, a chemical works, an industrial laboratory, a university, and the Hanford Works. Comments on possible improvements to these facilities are made, and a comparison of the types of equipment used is given. A description of activities under way that will reduce the volume of radioactive wastes to be stored by incineration is made.

The recommendations suggest that a variable gradient filter can be used to prolong the life of highly efficient final filters in an air-cleaning system. Also recommended are: segregating air streams according to their activity level; operation of blowers under negative pressure; provision for final discharge of cleaned gases through tall stacks; and precleaning of air that is likely to be contaminated.

798 HDC-743
STACK CONTAMINATION: THE 200
AREA. C. E. Lapple. Hanford Works,
Richland, Wash. October 11, 1948.
26 pp.

Sand filters to eliminate contamination of the atmosphere by the exhaust from ventilation air stacks were previously recommended. This report summarizes the status and findings of the project.

799 CF-48-9-165
PRELIMINARY CALCULATIONS CONCERNING THE PARTICLE PROBLEM.
L. T. Newman. September 28,
1948. 8 pp.

Recent health-physics work (ORNL-146) has shown that considerable numbers of radioactive particles are being deposited in the Oak Ridge National Laboratory area; the chief source of these particles appears to be the pile stack, although there may be other sources. If these particles are inhaled and deposited in the lungs, the radiation in their immediate neighborhood will be rather high, even though the total amount of material (and radiation) might be well within tolerance limits. Particle size and distribution, probability of the inhalation of particles, comparison with other toxic dusts, behavior of cyclones and filters, and the efficiency of collecting devices are discussed.

800 HDC-611
STACK CONTAMINATION: THE 200
AREA; INTERIM REPORT, JUNE 22
TO AUGUST 2, 1948. C. E. Lapple.
Hanford Works, Richland, Wash.
August 6, 1948. 29 pp.

As a result of a paper study and confirming field tests, a sand filter has been recommended and accepted for substantially eliminating the continuous emanation of active particles from the 200-Area stacks. A detailed description of this filter installation is given. The filter is intended to eliminate active particles (dust or mist) but not vapors. It will not solve any particle emanation resulting from an already contaminated stack. This problem can be investigated and rectified after the sand filter has been installed to prevent further contamination. A sand filter has been found to be superior to a packed scrubber.

801 MLM-188
THE APPLICATION OF TYPE-6
FILTER PAPER FOR THE REMOVAL
OF AIRBORNE ALPHA-EMITTING
CONTAMINATION. R. Endebrook.

Mound Laboratory. April 18, 1947.
35 pp.

This report discusses the problem of determining the efficiency of paper filters in removing airborne alpha-emitting contamination at various levels of contamination. The operational pressure differential and the pressure differential build-up of type-6 filter paper were determined. Other pertinent data collected included: (1) the efficiencies and pressure differentials at various rates of air flow; (2) the pressure differential of a filter unit with perforated aluminum protective plates removed; (3) the efficiency and pressure differential of multiple filters in series; (4) the evaluation of inherent inaccuracies of the test methods; (5) the causes of pressure differential buildup; and (6) the verification of data supplied for the type-6 filter paper and filter units.

5.2.4 Reactor Design

802 CF-54-3-164
SAFETY OF THE HOMOGENEOUS
REACTOR TEST. P. R. Kasten and
V. K. Pare. Oak Ridge National
Laboratory. March 25, 1955. 10 pp.

Equations for pressure rise in the aqueous core as a function of instantaneous reactivity increase have been set up on the following parameters: (1) the

length of piping between the core and pressurizer, and (2) the compressibility of the core fluid. The maximum credible pressure rise is estimated to be of the order of 600 psi.

803 KAPL-1450
REVIEW OF SIR PROJECT MODEL
STEAM GENERATOR INTEGRITY.

R. W. Lockhart, R. S. Kukfa,
D. R. Miller, and W. L. Robb.
Knolls Atomic Power Laboratory,
Schenectady, N. Y. November 1,
1955. 133 pp.

This report reviews and correlates the operating conditions and post-operational examination of 26 new and rebuilt components that were arranged and operated as 11 SIR Project model, liquid-metal-heated steam generators and heat exchangers. Particular attention was directed toward operational damage to the units that either caused a leak or could have caused a leak if they had been operated longer.

The data available are not very satisfactory for a statistical analysis, since almost every unit had a different design, operating program, and construction material. For this reason, the choice of construction material is difficult to make. Types 304 and 347 stainless steel were equally satisfactory against liquid-metal corrosion. Types A-280 and 304 had more water-side failures than did Type 347 operating under the various water treatments and with the various component designs. All tests were nonirradiated.

5.2.5 Stack-Gas Treatment

804 HW-28065
A STUDY OF THE EFFICIENCIES AND
PRESSURE-DROP CHARACTERISTICS
OF AIR-FILTERING MEDIA. F. E.
Adley, R. N. Scott, and W. E. Gill.
Hanford Works, Richland, Wash.
August 10, 1953. 17 pp.

With a fume of uranium oxide having a median particle size of 0.07 micron by count, 11 filters were tested. Of those suitable for air cleaning, efficiencies varied from 96 to 99.9%. Efficiency tended to decrease with increasing velocity through the filter media. A threefold increase in the original drop resulted from fume loads varying from 11 mg/ft² for low-capacity filters to 2800 mg/ft² for high-capacity filters.

805 NYO-1572
HANDBOOK ON AIR CLEANING
(PARTICULATE REMOVAL). S. K.
Friedlander, L. Silverman, P.
Drinker, and M. W. First. Har-
vard University.

This handbook is a collection of current information on methods of removing particulate matter from gases and criteria for judging the effectiveness of the methods. It is divided into four chapters: "Behavior of Aerosols in Air Cleaning"; "Air-Cleaning Equipment"; "Performance and Evaluation of Air-Cleaning Equipment"; and "Special Problems Involved in the Cleaning of Radioactive Aerosols."

806 ALI-13
INVESTIGATION OF STACK-GAS
FILTERING REQUIREMENTS AND
THE DEVELOPMENT OF SUITABLE
FILTERS. Arthur D. Little, Inc.
Technical Information Service, AEC.
April 29, 1949. 44 pp.

During the development of a pleated paper filter for CWS and the design of a full-scale model for 1000-1200 ft³/minute capacity, information on the collection of atmospheric dust by various densities and sizes of glass fiber, by a glass-fiber fabric (Glastex), by loose wool fiber and a hard wool bag fabric, and by foam glass was obtained. The filter units offer low cost and ease of handling.

807 ORNL-310
SURVEY OF ELECTROSTATIC PRE-
CIPITATORS FOR SEPARATION OF
RADIOACTIVE PARTICLES. F. C.
McCullough, J. A. Lane, and F. L.
Culler. Oak Ridge National Labo-
ratory. February 16, 1949. 90 pp.

The discharge of radioactive particles from the pile cooling-air stack and from the chemical processing and experimental facilities at Oak Ridge National Laboratory presents a serious health hazard to laboratory personnel. Facilities for cleaning the exhaust gas have been investigated, and the efficiencies of various types of cleaners, such as filters, cyclones, and electrostatic precipitators, have been reviewed. The cleaning of these gases presents a most difficult problem because of the extremely high efficiencies

required (99.9% or better removal of all particles down to 0.1 micron in diameter) and because of the low dust loading. Commercial electrostatic precipitators have been studied but none offers high efficiencies on a sound economic basis. The general requirements for a satisfactory electrostatic precipitator are formulated. An experimental precipitator and a program of investigation are proposed.

808 HDC-969
DISSOLVER OFF-GASES IN THE 200
AREA. C. E. Lapple. Hanford Works,
Richland, Wash. January 18, 1949.
3 pp.

Since the installation of large sand filters in some operating areas, the problem of recontamination of the cleared air has come up. Tests indicate that a great part of the recontamination originates from the dissolver off-gases that are now bled into the base of the stack. The following methods of decontamination of these gases are considered:

(1) The dissolver off-gases could be discharged directly into the existing large sand filter. The main objection is the presence of large amounts of nitric oxide vapors, particularly if the present scrubbers are removed. These vapors will constitute a potential hazard to the mechanical strength of the large sand filter.

(2) Although results were not entirely conclusive, previous tests indicated that an Ottawa sand filter removes over 95% of the iodine activity leaving the scrubber. Thus, since collection was obtained with Ottawa sand and since recent test data indicated marked advantages of fine Fiberglas over sand, it would seem logical to consider Fiberglas packing.

(3) Recent tests have indicated that silver-coated sand has a high collection efficiency for iodine. This type of unit can best be considered separately after the simpler-type filter has been evaluated.

809 CF-49-1-49
THE PARTICLE PROBLEM AT OAK
RIDGE NATIONAL LABORATORY: AN
HISTORICAL SUMMARY. Oak Ridge
National Laboratory. December 30,
1948. 22 pp.

This early summary of the plans for coping with the radioactive particles released into the air and onto the grounds near a pile does not offer definite hazard data, instrumental information, or health procedures such as those found in later Oak Ridge health-physics manuals. Preliminary surveys indicated that chief sources of contamination were the uranium separation area and the gases given off from the reactor, especially at rupture of a fuel slug. A bibliography of the 1948 interim and discussion reports is included under ORNL Central file numbers.

810 CF-48-9-126
RECOMMENDATION FOR IMMEDIATE
SOLUTION TO AIRBORNE HAZARDS
FROM THE PILE STACK. M. D.
Paterson and J. W. Gost. AEC.
Oak Ridge National Laboratory.
September 8, 1948. 3 pp.

Type-6 Chemical Corps Filters were recommended as mechanical filters for the pile stack, with or without cyclones and precipitators, to give longer life to the paper filters. To handle 120,000 ft³/minute, the stack would require 200 of these filters in the framework, at a cost of \$14,000, less than that of two comparable filters. The methylene blue test indicated an efficiency of 99.994% for smoke and dust from an air stream. Filter life was not established.

Arthur D. Little, Inc.

5.3 CORRECTIVE MEASURES

5.3.1 Decontamination

811 WAPD-MRP-55
TECHNICAL PROGRESS REPORT,
PRESSURIZED-WATER-REACTOR
PROGRAM, JUNE 17 TO JULY 28,
1955. Westinghouse Atomic Power
Division, Pittsburgh, Pa. July,
1955. 89 pp.

Decontamination of one loop of the reactor at full temperature and pressure is proposed by the technique of dissolving the UO_2 and causing it to release its fission product, which would be removed by the purification exchanger. A reagent that is selective to the UO_2 , noncorrosive to the system, and thermally stable is being sought.

812 IDO-26081
A GENERAL DECONTAMINATION
MANUAL FOR THE IDAHO CHEMICAL
PROCESSING PLANT. C. D. Watson.
Oak Ridge National Laboratory.
March 11, 1953. 18 pp.

Decontamination procedures are outlined for the removal of radioactive contamination from stainless-steel chemical processing equipment, stainless-steel laboratory surfaces, concrete surfaces, painted surfaces, asphalt floor tile, and Cu and brass surfaces. Two methods for the destruction of oxalic acid are included.

813 ORNL-1381
A REVIEW OF A POLONIUM CON-
TAMINATION PROBLEM. Dixon
Callihan and Don Ross. Oak Ridge
National Laboratory. August, 1952.
15 pp.

A source containing 250-325 mesh beryllium powder onto which polonium had been volatilized (with polonium activity of 6.9 curies) ruptured in use. Procedures used for the decontamination of equipment and personnel are described.

AD-337(C)
814 R6139
CHEMICAL DECONTAMINATION OF
STAINLESS STEEL AND 24S-T
ALCLAD ALUMINUM (FINAL REPORT)
W. Shelberg, R. Fuller, L. Gra-
ham, B. Lane, J. Mackin, and
L. Wentzler. Naval Radiological
Defense Laboratory. July 24, 1951.
24 pp.

Surface-active agents, complexing agents, commercial detergents, and mixtures of these materials were compared at room and steam-cleaning temperatures so that their ability to decontaminate stainless-steel and Alclad (24S-T Al) surfaces contaminated with neutral mixed-fission products (Sr, Y, Zr, and Nb) could be evaluated; 24 and 17 reagents with steel and Alclad, respectively, showed 90-99.9% decontamination efficiency at room temperature. A tendency for an increase in decontamination occurred with rising temperatures. Graphs show the dependency of decontamination upon pH as determined with NaOH and HCl.

815 AD-207(O)
FLAME DECONTAMINATION OF UN-
PAINTED CONCRETE AND WOOD.

R. C. Barry and V. V. Vandivert.
Naval Radiological Defense Labo-
ratory. March 14, 1950. 10 pp.

A hood was placed over the concrete area to be cleaned, and an oxyacetylene flame applied at an angle of approximately 45 degrees with the surface was directed toward the opening of the hood. A strip about 5 by 12 in. was burned (charred and dehydrated) before the hood was moved. It was found that the concrete was smoothly burned to a depth of about 1/64 in. and that brushing with the wire brush loosened all the burned material. The vacuum hose was detached from the hood and used for picking up the powdered concrete. For a wood surface, the burning equipment and procedures used were the same as for the concrete, except that a slightly hotter flame (a neutral flame) was used, and a faster cleaning rate was possible. The surfaces were undamaged in all cases and were suitable for painting after the cleaning was completed.

816 AD-205(E)
ADAPTATION OF NAVY STANDARD
FIRE-FIGHTING EQUIPMENT TO
DECONTAMINATION: INTERIM RE-
PORT. J. E. Howell, R. R. Soule,
V. V. Vandivert, and H. N. Well-
houser. Naval Radiological Defense
Laboratory. March 6, 1950. 30 pp.

Tests to determine the practicability of adapting existing fire-fighting equipment to radiological decontamination have been conducted. Two types of equipment were used in the evaluation:

(1) the standard fire hose with a general-purpose nozzle; and (2) mechanical foam fire-fighting equipment. The tests were carried out on contaminated painted steel plates under experimental conditions approximating those aboard ship. The fire hose was evaluated for its use in decontaminating by salt-water washing. The foam fire-fighting equipment was used as a field method of applying chemical agents to a contaminated surface. The function of the foam was to maintain, on the surface, a liquid film in which the desired action of the agent could be expected to occur.

The two methods were compared for decontaminating efficiency and for time and labor requirements. The experimental results were compared roughly with field results obtained at Crossroads, Test Baker. It was concluded that of the two methods studied, the salt-water (sea-water) wash is the more practicable method in both decontaminating efficiency and facility of application. The use of foam fire-fighting equipment showed no practical advantage over salt-water washing as a means of decontamination. The results obtained through the use of three complexing agents for 1-minute surface-contact periods showed little improvement over the salt-water wash alone. A maximum of 85% (a decontamination factor of 6.7) of the original contamination was removed from contaminated plates by salt-water washing under the experimental conditions. Because of the types and geometrical forms of exposed materials and surfaces in actual use, field results will fall somewhat short of this experimental figure. The control of exposed

materials, the redesign of weather surfaces, and attention to washing techniques can be expected to result in a considerable improvement over the 50% (decontamination factor of 2) removal that was accomplished by water washing at Bikini. Decontamination treatments described in this report were carried out on plates on which the contamination had dried. Tests on techniques of combating contamination before it has dried are described in NRDL Report No. AD-187(T).

817 AD-80(C)
NOTES CONCERNING THE USE OF
STRIP-COATS IN RADIOLOGICAL
DEFENSE. H. Matthiesen and J. Lai,
Naval Radiological Defense Laboratory. December 1, 1949. 46 pp.

The applicability of strip-coats to the problem of rapid and easy material decontamination has been examined. Criteria for determining the applicability of strip-coats are discussed, and the advantages and disadvantages of strip-coats in general and of a large number of commercially available strip-coats are stated. The very extensive bibliography includes abstracts of many references.

818 ADX-107
STUDIES CONCERNING THE CON-
TAMINATION AND DECONTAMINA-
TION OF PAINTED CONCRETE.
(FINAL REPORT). H. F. Matthiesen
and P. E. Zigman. Naval Radio-
logical Defense Laboratory. May 20,
1949. 80 pp.

The extent of radioactive contamination on painted concrete and the subsequent removal of the contamination

have been investigated. Samples were formerly part of a painted concrete barge that had been exposed to Tests Able and Baker. The investigation involved two phases: (1) the determination of the magnitude and distribution of contaminants by means of radioautographic and radiochemical techniques; and (2) the feasibility of decontamination by chemical reagents (water, citric acid, and ammonium fluoride) and physical means (wire brushing, sanding, steaming, washing with hot lye, burning, and sand-blasting). The details of the techniques utilized in acquiring this information, including conclusions and pertinent recommendations, are presented.

819 ORNL-158
SUMMARY OF SURFACE-DECON-
TAMINATION EXPERIENCE AT THE
OAK RIDGE NATIONAL LABORA-
TORY. F. N. Browder. Oak Ridge
National Laboratory. August 20,
1948. 39 pp.

Experience has shown that all impervious materials, such as stainless steel, mild steel, lead, glass, certain plastics, and certain surface coatings, can be decontaminated by means of vigorous washing with the proper reagents. Each decontamination operation is initiated with mild reagents (water); as the operation continues, the severity of the treatment is increased until the desired decontamination is obtained. Except by the physical removal of the contaminated portions, the satisfactory decontamination of such porous materials as bare concrete, wood, and plastics has been impossible.

The following decontamination reagents are considered: water and steam; acids and salts; bases and basic complexing agents; soaps and detergents; organic solvents and oils; and common ion solutions. Surface-decontamination methods are discussed in detail. An appendix includes discussions of the following: a condensation of the reports on experiments in surface decontamination, cell decontamination, pile fan decontamination, ORNL special decontamination service, decontamination of clothing (the ORNL laundry), and hand decontamination.

820 MUC-HG-1157
METHODS OF DECONTAMINATING
FISSION-PRODUCT ACTIVITY.

R. Gardner. Chicago Metallurgical Laboratory. 2 pp.

Optimum methods of decontamination are those that remove the activity with the least damage to the contaminated article. The extent of damage to the item depends upon its composition and the depth of penetration of the active material. Decontamination procedures usually involve removal of the layer of material carrying the activity, solution of the active material by acids or alkalies, or disposal of the contaminated item. Since this report deals only with fission products, nitric acid immediately becomes the major solvent because all of the fission products are readily soluble in nitric acid. Aqua regia and hydrochloric acid are useful in some cases. The types of surfaces encountered most frequently are natural softwood and hardwood, finished softwood and hardwood (i. e., that covered by a protective material, such

as paint, varnish, or shellac), finished and unfinished lead, black iron, steel, stone, concrete, and brick. Decontamination methods are suggested for each case.

5.4 WASTE DISPOSAL

5.4.1 General Problems

821 CF-48-9-158
OAK RIDGE NATIONAL LABORATORY
WASTE DISPOSAL. C. N. Rucker and
S. McLain. Oak Ridge National
Laboratory. September 20, 1946.
9 pp.

Hazards arise from solid particles carried by air from the pile, solid particles carried by air, dissolver gases around isotope operations, and liquid wastes run into White Oak Creek. It was proposed that the air from the piles be filtered through cyclones, glass wool, and electrostatic filters. The breakage of fuel elements was seen as the chief source of uranium dust. A program for reducing some of the prior contamination of the area included plans for vacuum removal of dust, dust-laying by black-topping, roof-washing, grass-planting, a tank farm for liquid-waste settling, and new ventilation for the isotope-processing building.

822 ORNL-163
MINUTES OF THE CONFERENCE ON
LIQUID-WASTE DISPOSAL: AUGUST 23-
25, 1948. Oak Ridge National Labora-
tory. November 2, 1948. 43 pp.

This report is divided into two main sections. The first, a general review of the facilities available for handling liquid-waste solutions, comments briefly on mud and water contamination in White Oak Creek and the Clinch River. The second part includes a flow chart and a more detailed description of the handling of liquid-waste solutions. Some of the topics discussed are: effectiveness of the present waste-disposal program; burial grounds for solid waste; related research in ion-exchange; rare-earth separation studies; precipitation and scavenger techniques; the Technical Division's liquid-waste disposal problems; ion-exchange development in the Technical Division; development and design of an evaporation system for liquid-waste disposal; the waste-disposal program undertaken by the Health Physics Division; and a proposal for a central burial ground.

5.4.2 Specific Waste-Treatment Problems

823 WAPD-MRP-50
PRESSURIZED-WATER-REACTOR
PROGRAM: TECHNICAL PROGRESS
REPORT FOR NOVEMBER 18
THROUGH DECEMBER 30, 1954.

Westinghouse Atomic Power Division,
Pittsburgh, Pa. December, 1954.
92 pp.

Liquid wastes at the PWR have the following sources: (1) decontamination solution from the primary loops; (2) purged loop-water resulting from slug rupture and warm-up periods; and (3) liquid resulting from continuous decontamination of the loop-system filter back flush. An exploratory program to evaluate processes for waste disposal is described.

824 LA-1691
INCINERATOR FOR RADIOACTIVE
RESIDUE. W. D. McNeese, W. J.
Maraman, and T. E. Chronister.
Los Alamos Scientific Laboratory.
March, 1954. 22 pp.

A batch-type incinerator that will dry and burn 12 l of wet packed rags (or the equivalent in other organic matter) in eight hours has been built. The material is ignited and burned in a stream of oxygen. Tars in the off-gas are trapped in a water bubbler; residual contaminated particles are caught by a CWS filter; and acid vapors are reacted in a caustic scrubber. The unit was designed to process plutonium residues; however, other radioactive materials could be handled by the use of appropriate shielding and manipulators.

825 KAPL-649
WASTE-DISPOSAL PROGRESS
REPORT FOR SEPTEMBER, OCTOBER,
AND NOVEMBER, 1951. Knolls
Atomic Power Laboratory, Schenectady, N. Y. 27 pp.

Experimental work on a pilot incinerator for contaminated combustible solids is reported, and design criteria for a production-type incinerator are summarized. The concentration of liquid waste by evaporation is reported and data on evaporation equipment and tests are given. Factors affecting the decontamination of nitric acid by distillation are discussed. The problem of high-level waste storage at KAPL is outlined briefly.

826 MLM-CF-50-11-44
 COMBUSTIBLE WASTE DISPOSAL AT
 MOUND LABORATORY. P. J. Schauer.
 Mound Laboratory. November 3,
 1950. 11 pp.

The basic decontamination factor and other considerations affecting the design of a radioactive-waste incineration process are listed, and data obtained from pilot-plant studies on the processing of active incinerator off-gases are given. The gas-process equipment and incinerator design are described and illustrated, and some remarks on incinerator operation are included.

827 KAPL-117
 LIQUID-WASTE DISPOSAL. J. A.
 Ayres, G. E. McCullough, and
 E. C. Pitzer. Knolls Atomic
 Power Laboratory, Schenectady,
 N. Y. January 24, 1949. 79 pp.

It is the policy of the Knolls Atomic Power Laboratory that no detectable amounts of activity will be released into the ground waters or air and that no activity will be buried. The waste streams to be treated include laboratory waste and the Redox waste streams. It has been estimated that the amount of laboratory waste is approximately 3000 gal/day and that this waste contains about 0.2% total solids. Laundry waste will be treated in the amount of 300-600 gal/day. Several means of waste disposal are considered, including ion-exchange, carrier precipitation, dilution, and evaporation.

Dilution was discarded, since it was at variance with the policy stated above. Ion-exchange of laboratory waste was not deemed suitable because of difficulties expected in the disposal of the spent resins and because of the lack of experience with solutions of such varying composition as are found in laboratory wastes. Carrier precipitation is not suitable because of the wide variety of precipitation pH values required for various ions found in the waste. The waste-disposal system to be installed in the Knolls Atomic Power Laboratory will consist of deionization of incoming laboratory and process water, evaporation of the laboratory and dilute plant wastes, and drying of the concentrated waste material and other process streams not requiring prior concentration. This report includes data on waste-disposal work accomplished at KAPL up to the design of equipment for installation in the Separations Process Research Unit.

828 CF-48-8-297
 OAK RIDGE NATIONAL LABORATORY
 LIQUID-WASTE DISPOSAL. C. N.
 Rucker. Oak Ridge National Laboratory, Operations Division. Technical Information Service Extension, AEC. Oak Ridge, Tenn. August 19, 1948. 7 pp. (Including 1 chart.)

For some five years the waste from the ORNL atomic facilities was stored in Gunit tanks with 5-in. -thick walls and 6 ft of earth over the covers, and in a gravel casing that gave a French type drain. Drainage was to a 200 ft²

pond 6 ft deep, and then to White Oak Creek at a low flow rate. Some chemical laboratory waste went directly to the settling basin. Uranium and plutonium waste solutions have been handled in a tank farm set up with a volume for 3-year use, but that age extended. Measures taken to reduce the volume of waste include concentration with 50% caustic solution; this produces a supernatant solution containing 0.005% uranium for drainage to the chemical settling tank.

829 CF-47-10-571
ECONOMIC STUDY OF THE WASTE
STORAGE-AND-DISPOSAL SYSTEM
IN THE 1200 AREA. F. L. Culler.
Oak Ridge National Laboratory.
October 22, 1947. 9 pp.

For the 5-year, 10-year, and permanent storage of active liquid wastes, stainless-steel tanks are recommended over lined-steel tanks or Gunitelined tanks. Evaporative reduction of waste volume makes storage for long periods in stainless-steel tanks the most economical alternative. The total cost per gallon stored for a 10-year period is in the \$1/gal range. Objections to other tank constructions are raised on the basis of factors not related to cost, such as thermal stresses and corrosion.

SUBJECT INDEX

	<u>Abstract No.</u>		<u>Abstract No.</u>
Accident Reports	726	Cats	
Air		radiation dosage	731
cleaning techniques	797	radiation-dosage	
filtration	801	determinations	652
decontamination	799	Chemical Radiation	
radiometric analysis	644, 772	detectors	701
Airborne Hazards Estimation	674	Clothing	
Alamogordo		decontamination	778, 819
animal ecology	734	Columbia River	
Alpha Particles		radiological monitoring	711, 713
detection and measurement	772	Concentration of Radio-	
tolerance	635	activity by Animals	706
Aluminum		Concretes, Decontamination	818
decontamination	814	Containment Buildings	688
Argonne Heavy Reactor		Contamination Control	744
safety	760	Conversion Factors	782
Atmosphere		Coolant Radioactivity	715
contamination	645	Corrosion Damage	803
radioactivity	637	Corrosion Inhibitors,	
Atmospheric Dispersion	695	Performance of	678
		Cosmic Radiation	639
		Cosmic Rays	643, 644
		Critical-Assembly Incident	681
Background Radiation	739, 647	Critical-Assembly Testing	746
Barite Concretes		Critical Mass	630
gamma attenuation	787	Criticality Control	750
Beta-Particle Meter	763	Criticality Studies	666
Beta-Ray Hazards	723	Criticality,	
Blood, Radiation Effect on	663	Accidental	670
Boiling Reactor, Loss of Pressure	689		
Brookhaven Reactor			
safety	755	Decontaminating Solutions	
start-up	756	evaluations	672, 673
		Decontamination	
		of areas	821
Cancer, Initiative Causes	660	of equipment	747, 778
Capture Gamma Radiation	719		815, 817
		of personnel	777, 813
		of PWR	823

	<u>Abstract No.</u>		<u>Abstract No.</u>
Disasters,		Fish	
Fission Dispersal from	759	isotope concentration by	710
Dogs		radiation effects on	654
radiosensitivity	735	radioactivity concentra-	
Doppler Accidents	664	tion by	714, 717
Dosimetry	775	radioactivity in	716, 718
man	649	radiometric analysis	713
Dusts,		toxicity studies	705
Sampling of Radioactive,		Fission-Product Release,	
and Annular Impactor for	770	Estimate of	675
		Fission Products	
		adsorption on river	
		sediment	793
Economics of Nuclear Power	629	plant metabolism	634
Eddy Diffusion, Atmospheric	696	toxicology	722
Electronic Equipment,		Fissionable Materials	
Radiation Damage to	677	Handling	745
Electrostatic Precipitators	807	Fuel Elements,	
Entrainment, Radioactivity in	632	Burn-Out	683
Environmental Dust	780	Fuel-Pin Rupture	676
Environs Monitoring	769	Fuel-Rod Bowing	684
Fall-Out		Gamma Radiation	
biological accumulation	633, 659	detection	786
distribution	724	detection and measurement	753
from high altitude	700	dosage determinations	728
integrated radiation dose			
from, and formulas for			
determining	699		
Fast Neutrons,		Hands	
Genetic Effects	651	contamination	721
Filter Materials	796	radiation effect on	661, 662
efficiency	699, 793	Harbor Circulation Charac-	
Filter Papers,		teristics	703
Efficiency	795	Hazard Summary Report	667
Filter Testing	794, 804	Hazards Summary Evaluations	665
Filters		Health Physics	741, 748
efficiency	810		751, 799
glass fiber	806	manual	749
performance	805	procedures	783

	<u>Abstract No.</u>		<u>Abstract No.</u>
Helium-Cooled Reactor	628	Marine Life	
Homogeneous Reactor	680	radiation effects	733
application to ship		radioactivity concentration by	709
propulsion	631	Marine Radiobiological Survey	708
hazards	757	Metal-Water Reaction	689
Homogeneous Reactor		Mice,	
Experiments,		Radiation Dosage Deter-	
Control	754	minations	736
Homogeneous Reactor Tests,		Monkeys,	
Safety	802	Sr ⁹⁰ in Skeleton	650
		MTR, Safety	761, 790
Incineration	797, 825		
Incinerators		Naval Reactors	671
design	826	Naval Vessels	
radioactive	824	nuclear power applied to	631
Inhalation Hazards	779	ranges of radiation in	785
Inversions	641	Neutron Spectrometers	786
Isotope Concentration by		Neutrons	
Marine Growth,		biological effects	732
Sea Contamination	707	Neutrons and X Rays, RBE's	657
KAPL,		NRX Reactor	738
Environs Monitoring	768	Nuclear-Ship Propulsion	627, 631
Liquid Waste, Storage of	828	Ocean Disposal	702
Loss of Coolant, Accidental	675, 686	ORNL Graphite Reactor,	
Lung, Effect of Nuclear		Safety	668
Metals on	724		
Man		Paints,	
radiation dosage	659	Decontamination	812
radiation effects on	789	Permissible Limits, C ¹⁴	642
tolerance to radiation	648	Physiological Effects of	
Manual, Nuclear Safety	781	Radiation	730
		Plutonium	
		lethal dosage determination	735
		physiological effects	653
		Possible Magnitude of Accidents	664

	Abstract No.		Abstract No.
Radiation		Shutdown Cooling	685
biological effects	655, 658, 725	Soils	
	729, 736, 829	contamination	640, 646
detection	765, 791	radioactivity in	636
detection instruments	773, 784	radiometric analysis	698
detection instruments		Solvents for Fission Products	820
(ion-current type)	766, 767	Stack Disposal	809
monitoring	743	meteorological findings	693, 694
permissible limits	751, 776	monitoring	695
spectra	720	Stack-Gas Diffusion	712
Radioactive Contamination	799, 816	Stainless Steel Decon-	
control	764	tamination	812, 814
monitoring	778	Submarine Intermediate	
Radiobiological Surveys	704	Reactor Shielding	786
Radio Iodine, Tolerance	774		
Radon-Thoron Occurrence	638		
Rain Water,			
Radiometric Analysis	644	Teeth, Radiation Effects on	727
Reactor		Tissue Concentration of I ¹³¹	656
control system, safety		Transferable Contamination	
studies of ARR	762	on Surfaces	740
coolant activity	758		
design, safety and waste			
disposal	674		
experiment, fast	690	Uranium,	
safety	792	Explosion During Irradiation	687
safety, exclusion-radius			
formulas	691		
slurries, critical behavior			
on settling	679	Burial of Waste	822
Reactors		Waste Disposal	793
burn-out heat flux	669	by liquid storage	825
radiation from	742	for PWR	811
Relative Biological Effect	728	policy	827
Rupture, Radiation from	682	underground	649
		Water, Contamination	771
		Wind-Shear Effects	697
Safety Devices	692		
Sand Filters	798, 800, 808		
Shielding	788	Zirconium Explosion	740
containers, design	752		

AUTHOR INDEX

A

Aven, R. E., 787

B

Bailey, J. C., 721, 740
 Barad, M. L., 695
 Beach, L. A., 785
 Binford, F. T., 674, 758
 Blifford, I. H., 637, 638
 Blizzard, E. P., 719, 720, 742
 Boland, T. J., 687
 Bonham, K., 707, 733
 Borst, L. B., 749, 755, 756
 Boyd, G. A., 725
 Brittan, R. O., 690
 Browder, F. N., 819
 Brues, A. M., 648, 655
 Bryan, F. A., 645
 Bryon, J. P., 753

C

Calkins, V. P., 677
 Callihan, D., 681
 Carey, Z. E., 772
 Carter, R. E., 653
 Cherubin, L. J., 698
 Chronister, T. E., 824
 Claiborne, H. C., 679
 Clark, P. R., 631
 Cline, J. F., 656
 Cochran, R. G., 765
 Cole, T. E., 790
 Condit, R. I., 723
 Conley, G. H., 682
 Cooper, L. C., 763
 Coopey, R. W., 711
 Culler, F. L., 807, 829

D

Davis, F. J., 644
 Detwiller, C. G., 795
 Donaldson, J. R., 709
 Donaldson, L. R., 709, 707
 Drinker, P., 805
 Dunn, D. B., 647
 Dunn, W. F., 646
 Durbin, P. W., 650
 Dyson, J. P., 723

E

Eckels, A. R., 787
 Elgert, O. J., 687
 Endebrock, R., 801
 Engquist, E. H., 796
 Evans, J. E., 702

F

Falgiano, F. L., 747
 Fast, E., 753
 Faust, W. R., 785
 Feld, B. T., 643
 Fink, R. M., 725
 First, Melwin, W., 797, 805
 Fitzgerald, J. J., 698, 759
 Folden, M. F., 657
 Fort, W. G. S., 773
 Foster, R. F., 713
 Fowler, T. B., 679
 Friedman, F. L., 730
 Fuller, R., 814

G

Gardner, R., 820
 Geller, L., 670

G

Gill, W. E., 804
 Gillooly, B., 646
 Gordon, S. H., 646, 647
 Gost, J. W., 810
 Graham, L., 814
 Grundhauser, W., 705

H

Hagen, C. W., Jr., 705
 Hamilton, J. G., 650
 Hanauer, S. H., 790
 Hart, E. J., 701
 Haubenreich, P. H., 787
 Healy, J. W., 772, 774
 Henry, H. F., 670
 Herde, K. E., 656, 714, 715, 716
 Hilst, G. R., 695
 Hodge, H. C., 724, 779
 Hoekstra, H. R., 688
 Holden, F. R., 747
 Holland, J. Z., 691
 Howell, J. E., 816
 Hurwitz, H., Jr., 759

J

Jacobson, L. O., 736
 Jens, W. H., 684
 Johns, S. R., 747
 Johnston, M., 650

K

Kasten, P. R., 802
 Katz, J. J., 688
 Kellogg, W. W., 696, 697
 Kelly, D. C., 757
 Kitzes, A. S., 788
 Kouts, H. J. C., 786
 Kukfa, R. S., 803
 Kuper, J. B. H., 700

L

Lai, J., 817
 Lamb, W. A. S., 723
 Lane, B., 814
 Lane, J. A., 807
 Langham, W., 653, 729
 Lapple, C. E., 798
 Larson, C. E., 667
 Laskin, S., 780
 Leahy, W. H., 703
 Leitch, J. L., 734
 Lewis, M. R., 647
 Lewis, W. B., 629, 739
 Lichtenberger, H. V., 689
 Lisco, H., 655
 Lockhart, R. W., 803
 Low, J. R., Jr., 676
 Lynch, D. E., 640

Mc

McCaslin, J. W., 753
 McCullough, F. C., 807
 McCullough, G. E., 827
 McDuffie, H. F., 757
 McLain, S., 821, 761
 McNeese, W. D., 824

M

Mackin, J., 814
 Mahoney, J. J., 796
 Maraman, W. J., 824
 Matthiesen, H. F., 818
 Mayneord, W. V., 775
 Miller, D. R., 630, 803
 Mills, M. M., 664
 Miraldi, F. D., 752
 Morgan, K. Z., 642, 782
 Moore, W. T., 628
 Morffit, J. W., 635
 Morton, R. J., 769
 Moshman, J., 660
 Moss, N., 738

N

Neel, J. W., 646
 Newman, L. T., 799
 Nickerson, J. J., 744
 Nickola, P. W., 693
 Nickson, M., 661, 662

O

Olafson, J. H., 646
 Olson, P. A., Jr., 713

P

Paine, R. W., Jr., 666
 Pare, V. K., 802
 Parker, H. M., 649, 706, 712
 Paterson, M. D., 810
 Pearlman, N., 663
 Pitzer, E. C., 827
 Plough, H. H., 651
 Pratt, W. W., 786
 Price, R. B., 796
 Prosser, C. L., 705, 735

R

Ramm, W., 767
 Rice, R., 689
 Rickover, H. G., 632, 789
 Robb, W. L., 803
 Rockwell, T., III, 788
 Rohr, R. C., 721, 740
 Ross, D., 813
 Rossano, A. T., Jr., 797
 Rossin, A. D., 752
 Rucker, C. N., 821, 828

S

Sacher, G. A., 663
 Saltsburg, H. M., 686
 Schamberger, R. D., 786
 Schauer, P. J., 826

S

Schede, R. W., 766
 Schrieber, R. E., 746, 781
 Schultz, M. A., 791
 Schuske, C. L., 726
 Scott, R. N., 804
 Seymour, A. H., 707, 709
 Shelberg, W., 814
 Sheppard, C. W., 651
 Shiota, K., 727
 Shockley, R. F., 636
 Shore, F. J., 786
 Simmons, E. L., 736
 Silverman, L., 797
 Skow, R. K., 747
 Sleeper, H. P., Jr., 786
 Smith, G. L., 687
 Soule, R. R., 816
 St. John, E. E., 790
 Steadman, F. M., 777
 Stearner, S. P., 736
 Stromquist, W. K., 685
 Struxness, E. G., 764
 Sullivan, W. H., 748
 Susskind, H., 786
 Swift, M. N., 735

T

Tait, G. W. C., 770
 Teller, E., 692
 Terasaki, T., 727
 Thalgott, F. W., 690
 Theus, R. B., 785
 Thorburn, R. C., 772
 Tonks, L., 759

V

Vandivert, V. V., 815, 816
 Visner, S., 680, 754
 Vogel, K. H., 738

W

Warren, S. L., 654
 Watson, C. D., 812
 Weills, J. T., 675
 Weiss, M. M., 700
 Welanders, A. D., 707
 Wellhouser, H. N., 816
 Wentzler, L., 814
 West, J. M., 675
 Western, F., 642
 Woodward, J. B., III, 627

Y

Young, G., 720

Z

Zahn, L. L., Jr., 794
 Zerutti, B., 689
 Zigman, P. E., 818
 Zinn, W. H., 760
 Zornig, H. H., 743

NUMERICAL INDEX OF REPORTS

<u>Report No.</u>	<u>Abstract No.</u>	<u>Report No.</u>	<u>Abstract No.</u>
<u>A</u> 7.390-29	635	<u>BNL</u> 1443	786
<u>AD</u> 80(C) 95(H) 205(E) 207(O) 218(OH) 219(OE) 337(C)	817 723 816 815 747 778 814	<u>CF</u> 43-12-322 47-10-571 48-8-297 48-9-126 48-9-158 48-9-165 49-1-49 50-7-147 50-9-37 50-9-137 51-5-74 52-12-118 53-5-45 54-3-164 54-6-16 54-6-194 55-5-115	776 829 828 810 821 799 809 742 667 668 765 787 754 802 680 631 679
<u>ADL</u> 72	748		
<u>ADX</u> 107	818		
<u>ALI</u> 13	806		
<u>ANL</u> 4001 4017 4253 4999 5345(Del. 2) 5461 AMB-2 FWT-105 SM-516 WHZ-252 WHZ-250 WHZ-299 WMM-596	736 705 655 701 671 689 648 690 761 762 760 675 688	<u>CH</u> 3763 3831 3833 3865 3893	744 661 662 663 735
		<u>CRC</u> 542	738
		<u>CR-HP</u> 577	770
<u>APEX</u> 172	677	<u>CRLR</u> 14	796

<u>Report No.</u>	<u>Abstract No.</u>	<u>Report No.</u>	<u>Abstract No.</u>
<u>CRM</u>		<u>K</u>	
<u>315</u>	775	<u>757</u>	766
		1071	721
<u>DP</u>		1088	740
<u>5</u>	702	1095	670
<u>DR</u>		<u>KAPL</u>	
<u>20</u>	629	<u>6</u>	630
		117	827
<u>HDC</u>		312	641
<u>611</u>	800	324	771
743	798	364 (Pt. 3)	773
969	808	384	743
		580	741
<u>HEW</u>		603	795
<u>7184</u>	783	649	825
		675	751
<u>HRAC</u>		997	699
<u>56</u>	739	1118	763
		1160	768
<u>HW</u>		1268	793
<u>3-3442</u>	717	1450	803
7-4451	774	1495	686
11344	714	1572	698
12079	656	ADM-867	759
20136	772		
21415 (Suppl. 1)	695	<u>KT</u>	
21415	696	<u>178</u>	752
23093	713		
23601	693	<u>LA</u>	
25191	711	<u>1289</u>	666
26523	712	1309	653
28065	804	1691	824
30142	794		
39624	706	<u>LAMS</u>	
42403	649	<u>452</u>	781
		456	746
<u>IDO</u>		808	729
<u>16073</u>	753		
26081	812		

<u>Report No.</u>	<u>Abstract No.</u>	<u>Report No.</u>	<u>Abstract No.</u>
<u>LP</u>		<u>NP</u>	
67	730	1134	703
176	643	1341	767
		1838	784
<u>M</u>		4691	696
1813	779	4692	697
1878	725		
1961	724	<u>NRL</u>	
2435	749	3862	638
3216	789	4118	637
3564	632	4146	785
4125	718		
4129	715	<u>NYO</u>	
4130	716	1521	640
4167	628	1572	805
4255	745	1580	797
4291	782	4464	727
4381	722		
<u>MEMO</u>		<u>ORNL</u>	
JRL-3	676	54-6-140	681
		120	685
<u>MLM</u>		163	822
188	801	158	819
CF-50-11-44	826	310	807
		419	719
<u>MUC</u>		420	720
HG-1157	820	495	642
		710	788
<u>N</u>		873	769
2275	780	1081	644
		1139	790
<u>NARF</u>		1381	813
55-34T	636	1794 (Vol. I)	674
		1794 (Vol. II)	758
<u>NDA</u>		1853	757
MEMO-14-38	684	<u>PPC</u>	
		89	687
<u>NNSD</u>		<u>STR</u>	
15	627	TOT-472	682

<u>Report No.</u>	<u>Abstract No.</u>	<u>Report No.</u>	<u>Abstract No.</u>
<u>TID</u>		<u>WAPD</u>	
77	660	21	792
227	692	IC-66	791
399	694	MRP-43 (Rev.)	678
5027	700	MRP-47 (Rev.)	683
5047	756	MRP-50	823
5033	728	MRP-55	811
5058	755	MRP-63	672
5202	664	MRP-64	673
10117	669		
		<u>WASH</u>	
<u>UCLA</u>		10	665
78	647	95	732
111	734	169	691
140	646		
143	645	<u>WT</u>	
143	654	12	777
250	731	820	651
260	652		
267	634	<u>Y</u>	
286	659	A2-115	750
320	633	836	764
		897	726
<u>UCRL</u>		1137A	737
73	657		
1437	639		
2823	650		
<u>UWFL</u>			
5	658		
7	710		
10	704		
11	707		
14	733		
18	709		
19	708		