300
2/14/69

UC-41
TID-25128

DR-887

MASTER

OPERATIONAL

ACCIDENTS

and RADIATION
EXPOSURE EXPERIENCE

Within the

UNITED STATES
ATOMIC ENERGY
COMMISSION

1943 - 1967

DIVISION OF OPERATIONAL SAFETY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

OPERATIONAL ACCIDENTS

and
RADIATION
EXPOSURE
EXPERIENCE

Within the

UNITED STATES ATOMIC ENERGY COMMISSION

DIVISION OF OPERATIONAL SAFETY
WASHINGTON, D. C. 20545

ISSUED DECEMBER 1968

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 60 cents

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

869

TABLE OF CONTENTS

	Page
PREFACE.....	v
PART I—ORGANIZATION.....	1
PART II—DEFINITIONS.....	3
PART III—AEC EXPERIENCE—PERSONNEL.....	5
Section 1—General.....	5
Chart I—Death Rates AEC-NSC 1943-1967.....	6
Chart II—Causes of Fatalities in AEC Programs 1943-1967.....	7
Chart III—Disabling Work Injuries (Operations) 1943-1967.....	8
Frequency.....	9
Chart IV—Injury Frequency Rates AEC-NSC 1943-1967.....	9
Severity.....	10
Chart V—Injury Severity Rates AEC-NSC 1943-1967.....	10
Section 2—Radiation Exposures.....	11
Chart VI—Radiation Exposure of AEC and AEC Contractor Personnel to Whole- Body Penetrating Radiation.....	11
Chart VII—Radiation Injuries AEC Operations 1943-1967.....	12
Chart VIII—Radiation Accidents Resulting in Lost-time Injuries.....	13
Chart IX—Time Lost from Radiation Injuries AEC Operations 1943-1967.....	14
PART IV—AEC EXPERIENCE—PROPERTY DAMAGE.....	15
Section 1—General.....	15
Chart X—AEC Incidents Causing Over \$50,000 Property Loss or Damage.....	17
Chart XI—AEC Property Damage Ratios 1947-1967.....	18
Chart XII—AEC Fire Loss Ratios 1947-1967.....	19
Chart XIII—Causes of AEC Property Damage by Contamination 1955-1967.....	20
Chart XIV—AEC Incidents Causing Over \$50,000 Property Damage or Loss 1943-1967.....	21
Section 2—Criticality Accidents.....	26
Chart XV—Criticality Accidents in USAEC Facilities.....	27
PART V—BEST NO-INJURY RECORDS KNOWN IN AEC ACTIVITIES.....	35
APPENDIX A—FATALITIES.....	37
APPENDIX B—RADIATION EXPOSURES OVER 15 REM.....	49

PREFACE

“Study the Past . . . What is Past is Prologue.” Although these words were penned many years before the establishment of the Atomic Energy Commission (AEC), we feel that they may be applied appropriately to the purpose of preparing this publication. It is only as we are fully aware of the history of the AEC’s accident and radiation exposure incident experience that we can profit thereby.

The protection of persons and property against potential hazards in AEC activities has been a fundamental concern of the AEC from the earliest developments in the use of atomic energy. We have simultaneously evolved a new technology and a safety program adapted to the AEC’s special purposes. Our continued goal is to develop and utilize this vital national resource to the maximum extent consistent with a high degree of safety.

The Atomic Energy Act of 1954, as amended, clearly demonstrates vital concern with the health and safety of the worker and the public. For example, in section 161(i) of the Act, Congress stipulated that, in the performance of its functions, the AEC is authorized to:

“prescribe such regulations or orders as it may deem necessary . . . (3) to govern any activity authorized pursuant to this Act, including standards and restrictions governing the design, location, and operation of facilities used in the conduct of such activity, in order to protect health and to minimize danger to life or property . . .”

Other examples include section 31(d) (Research Assistance):

“The arrangements made pursuant to this section shall contain such provisions (1) to protect health, (2) to minimize danger to life or property . . . as the Commission may determine.”

and section 41(b) (Production Facilities):

“. . . Any contract entered into under this section shall contain provisions . . . obligating the contractor . . . to comply with all safety and security regulations which may be prescribed by the Commission . . .”

From time to time, information has been disseminated pertaining to this subject in AEC publica-

tions. However, we have long believed that a publication such as this, centralizing as much experience as feasible, would be of help to those interested in the atomic energy program. Therefore, in 1965 we gathered available information, descriptions, and statistics regarding disabling injuries, radiation exposures, contaminations, criticalities, fatalities, and property damage accidents, and presented these and other relevant data under one cover entitled, “Operational Accidents and Radiation Exposure Experience within the United States Atomic Energy Commission 1943–1964.” The present publication updates the original by including the AEC’s additional experience from 1965–67.

As in any industrial organization, the AEC’s accident experience falls into two major classifications: (1) that which results in harm to people and (2) that which results in damage of property. However, because of the peculiar (or unique) nature of the atomic industry, both of these classifications must be subdivided into: (1) those occurrences which are not atomic energy-connected and (2) those occurrences which are atomic energy-connected.

In a 1956 publication, covering the period 1945–55, it was stated: “By far the most numerous (accidents) are those in no way related to atomic energy. Falls, electrocutions, motor vehicle accidents, and construction equipment accidents comprise the majority of accidents.” This was not a surprising statement at that time, since so much construction work was in progress during those years. However, it is interesting to note that it is still true, although in the past twelve years, while construction has decreased, the use of atomic energy has greatly increased, and along with this increase, of course, the number of employees in occupations involving potential radiation exposure.

In summary, while, because of the AEC’s singular involvement in radiation hazards, we are prone to emphasize those occurrences resulting in exposures, contaminations, and criticalities, these occurrences are in the minority in the overall picture. Actually, by far the majority of the occurrences within the AEC are comparable, in kind, to those occurring within any industrial organization.

PART I

ORGANIZATION

Since the establishment of the Atomic Energy Commission (AEC) by the Atomic Energy Act of 1946, the AEC has been responsible for the management of a complex of Government-owned nuclear energy facilities. Their design, construction, and operation is by contract with industrial, academic, and nonprofit organizations, rather than directly by Government employees. The operations at these facilities include the production and processing of special nuclear and radioactive materials, the development of nuclear reactors, the development of nuclear explosives, and research in the physical and biological sciences. The total investment in these facilities is over nine billion dollars.

A major part of the AEC's research is conducted at several national laboratories and three weapons development laboratories. Various production facilities are operated for the AEC and include nuclear feed materials plants, three uranium gaseous diffusion plants for producing enriched uranium, and two plutonium production complexes. Weapons testing is conducted at the Nevada Test Site. Similarly, various contractors operate test facilities at the National Reactor Testing Station in Idaho and at the Nuclear Rocket Development Station in Nevada.

The 1954 revision of the Atomic Energy Act established a comprehensive system of regulatory control over the private use of nuclear and radioactive by-product materials.

To implement these responsibilities of operation and regulation, there is a dual organization in which the regulatory activities are separated from promotional and developmental activities. The General Manager, with operational and promotional staffs, administers and directs operations being conducted for the AEC; the Director of Regulation, with his staff, carries out the regulatory program for licensed activities and assists the General Manager in the technical review of certain reactor proposals.

The AEC has field offices near its major sites to assist the General Manager in conducting the AEC's operations. Each office administers contracts within its area of jurisdiction with organizations operating the facilities or otherwise under contract with the AEC. The Director of Regulation has established regional offices in various parts of the United States from which licensee inspections and compliance activities are conducted. Through these contractual and regulatory systems, AEC undertakes to maintain Governmental control and direction in areas of health and safety.

The material included herein covers the experience of operational activities (not regulatory) during the period 1943-67, incorporating both information pertaining to the Manhattan Engineer District, predecessor to the AEC, as well as that of the AEC itself.

PART II

DEFINITIONS

Explanations of Terms Used in This Publication

ACCIDENT (INCIDENT)—The unexpected occurrence in a sequence of events which produces death, injury, radiation exposure, or property damage.

AEC—Atomic Energy Commission.

AEC CONSTRUCTION—Includes lump-sum, cost-plus, and architect-engineering contractors.

AEC FIELD OFFICES—See names and abbreviations listed in appendix A, page 47.

AEC OPERATIONAL ACTIVITIES—Includes AEC and AEC contractor personnel engaged in AEC operations and AEC construction.

AEC OPERATIONS—Includes production, research, and services contractors.

BODY BURDEN—The amount of radioactive material present in the body of man or animals.

CHAIN REACTION—A reaction that stimulates its own repetition. In a fission chain reaction, a fissionable nucleus absorbs a neutron and fissions, releasing more than one additional neutron. These in turn can be absorbed by other fissionable nuclei, releasing more neutrons. A fission chain reaction is self-sustaining when the number of neutrons released in a given time interval equals or exceeds the number of neutrons absorbed.

CONTAMINATION—The presence of unwanted radioactive particulate matter.

CRITICAL MASS—The smallest mass of fissionable materials that will support a self-sustaining chain reaction under stated conditions.

DEATH RATE—The number of deaths per 100,000 workers.

DISABLING (LOST-TIME) INJURY—A work injury which results in death, permanent total disability, permanent partial disability, or temporary total disability as defined in USAS Z16.1.

FIRE LOSS RATIO—Cents loss per \$100 of AEC property.

FISSIONABLE MATERIALS—Isotopes capable of being fissioned by neutrons.

FREQUENCY RATE—The number of disabling injuries per 1,000,000 man-hours worked.

GLOVEBOX (DRYBOX)—A sealed box in which workers, using gloves attached to and passing through openings in the box, can handle radioactive materials safely.

MAN-DAY—The equivalent of one man working one eight-hour day.

MAN-HOUR—The equivalent of one man working one hour.

MED—Manhattan Engineer District.

NSC—National Safety Council.

NUCLEAR CRITICALITY—The state in which the effective neutron multiplication constant (k_{eff}) of a system of fissionable material equals or exceeds unity.

NUCLEAR SAFETY (Bimonthly Technical Progress Review)—Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

PROPERTY DAMAGE RATIO—Cents loss per \$100 of AEC property.

REM—Roentgen equivalent man. A unit of absorbed dose in biological matter. It is equal to the absorbed dose in rads multiplied by the relative biological effectiveness of the radiation on the part of the body of concern.

ROENTGEN—A unit of exposure dose of ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying one electrostatic unit of electrical charge in one cubic centimeter of dry air under standard conditions.

SEVERITY RATE—The number of days charged per 1,000,000 man-hours worked.

TID (Technical Information Document)—Available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of

Standards, U.S. Department of Commerce, Springfield, Va. 22151. (Note: TID-5360, Suppl. 6. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

USAEC ACCIDENT AND FIRE PREVENTION ISSUE

USAEC HEALTH & SAFETY INFORMATION ISSUE

USAEC SERIOUS ACCIDENTS ISSUE

Available (if not out of print) from Division of Operational Safety, U.S. Atomic Energy Commission, Washington, D.C. 20545.

USASI-United States of America Standards Institute.

USAS Z16.1—Method of Recording and Measuring Work Injury Experience. Standard used by the AEC.

PART III

AEC EXPERIENCE—PERSONNEL

Section 1

GENERAL

The occupational injury and fatality experience, through 25 years of the development of the atomic energy industry under the guidance and direction of the Atomic Energy Commission (AEC) and its predecessor, the Manhattan Engineer District, demonstrates that when management vigorously promotes accident prevention programs, aimed at a specific type of injury, the occurrence of the injury can be practically eliminated.

The early unknown qualities and effects of nuclear energy provided the incentive to develop the most effective specialized injury prevention program ever devised, with the result that, during 25 years, there were only six deaths attributable to nuclear causes. Three of these occurred at Los Alamos (August 21, 1945, May 21, 1946, December 30, 1958) and were a direct result of exposure to a massive dose of nuclear radiation. The immediate causes of death in the three additional fatalities were the physical effects (i.e., blast, flying missiles, etc.) associated with the SL-1 reactor excursion of January 3, 1961; however, the radiation levels associated with that accident were extremely high and probably would have been fatal. It is also significant that during these 25 years there were only 35 workers involved in lost-time radiation nonfatal accidents.

These accidents, producing ionizing radiation exposures, were caused by human error, faulty manipulation of controls, deviation from standard operating procedures, faulty mechanical equipment, and other causes such as may be encountered in any other industry.

Fatalities from all causes totaled 276 during the 25-year period (see Charts I and II). Of this number, 166 occurred in construction, 98 in AEC operations (production, research and services), and 12 in Government functions. A list of fatalities occurring in AEC operational activities appears in Appendix A.

During this period, there were 16,978 lost-time injuries (as defined in USAS Z16.1) attributable to all accidental causes. This gives a 25-year frequency rate (number of injuries per million man-hours) of 3.11. Of the lost-time injuries (see Chart III) 50% (8,487) occurred in AEC operations. This was the experience of 465,976,037 man-days of potential accident exposure, which produced over three billion man-hours of work and a 25-year frequency rate of 2.28. As indicated above, only 38 of the 8,487 lost-time injuries, four-tenths of one percent (0.4%), were caused by nuclear radiation. This is equivalent to a frequency rate of 0.01. A list of radiation injuries occurring in AEC operations appears in Chart VIII.

CHART I

CHART II

In the AEC's construction activities, there were 7,697 injuries, resulting in a 25-year frequency rate of 5.46. This rate compares very favorably with the average frequency rate of the National Safety Council (NSC) of 17.21 for construction (1943-1967).

The 25-year Government (Federal employees) frequency rate was 2.52 (794 lost-time injuries). AEC Government experience won the President's Award, covering accident prevention among

Federal employees, in 1957, 1959, 1960, and 1962. The AEC earned these awards in the small-agency category.

The AEC's overall industrial accident experience has always been lower than the all-industry rate reported by 41 industries in the United States to the NSC. The average NSC 25-year rate of all industry is 8.67 compared to the 25-year AEC frequency rate of 3.11.

CHART III

Frequency

In 1945, and prior thereto, the pressures of war, such as heavy construction work, urgency, and shortages, all combined to produce relatively high accident frequency rates in AEC operations, although they were always below NSC rates. By 1950, the rate for work in operation had dropped to about 3.0 injuries per million man-hours. From then on, operation frequency rates were low by comparison with other industries. In 1947 through 1949, a renewed heavy construction program produced a construction injury rate of about 10.0.

This held the overall frequency rates of the AEC up in those years. A vigorous program concentrating on control of accidents in construction brought the frequency down again, and since 1958, the total frequency for all activities has been 2.2 or less. The proportion of construction work thereafter was small enough to be ineffective, in the overall, even though the construction rate was up in 1959. It is notable that the trend of AEC's injury frequency (see Chart IV) in all its operations throughout the years is roughly parallel to the national average, but from a fourth to a third of the national rate.

CHART IV

* NUMBER OF INJURIES PER MILLION MAN-HOURS

Severity

As stated regarding the AEC frequency rate, the AEC severity rate was affected adversely by the large amount of construction work during its early years.

In 1951, the AEC severity rate and the NSC severity rate were the same. Both have declined over the years; however, that of the AEC shows a greater decrease (see Chart V).

It is to be noted that a severity rate may fluctu-

ate markedly from year to year, depending upon the fatalities and types of disabilities occurring. Whereas the actual calendar days lost are charged for temporary total injuries, charges are based on 6,000 days for a death or permanent disability, with proportionately fewer days being charged for permanent partial disabilities of varying degrees of seriousness. Thus, fatalities and certain types of injuries can result in decided peaks in a severity rate.

CHART V

* NUMBER OF DAYS CHARGED PER MILLION MAN-HOURS

Section 2

RADIATION EXPOSURES

In accordance with its health and safety responsibilities, the AEC must conduct its activities in such a manner as to assure that employee radiation exposures are reduced to the lowest practical levels within established limits. To carry out this responsibility, it has been necessary for the AEC and its contractors to monitor routinely all employees who might receive a significant radiation dose.

AEC and AEC contractor employee exposures for the past 21 years are summarized in Chart VI. This chart shows that during this 21-year period over 99.8% of the employees received an annual dose of less than five rem and that over 94.6% received one rem or less. The majority of ex-

posures in excess of five rem in a year resulted from accidental situations. The more significant (15 rem and over) of these accidental exposures are briefly summarized in Appendix B.

During the 25 years of operation of the AEC and its predecessor, radiation resulted in a very small percentage (0.4) of the total lost-time injuries from all causes as indicated in Chart VII. These specific radiation exposures were classified as lost-time injuries as defined in the United States of America Standards Institute methods for reporting work injuries, USAS Z16.1-1967 (Rev. of Z16.1-1954) and AEC directives.

CHART VI

Radiation Exposure of AEC and AEC Contractor Personnel to Whole-Body Penetrating Radiation

Years	Rem Dose				
	0-1	1-5	5-10	10-25	>15
1947-54.....	130,128	5,311	284	32	6
1955.....	56,708	3,157	285	41	1
1956.....	38,225	2,312	100	4	3
1957.....	45,510	2,424	83	5	1
1958.....	59,455	6,271	159	10	12
1959.....	71,600	3,912	66	2	1
1960.....	77,522	4,629	41	2	1
1961.....	90,651	5,174	40	3	8
1962.....	122,437	5,707	113	0	8
1963.....	107,786	5,472	80	0	1
1964.....	122,711	6,157	86	11	0
1965.....	128,360	6,671	175	8	0
1966.....	130,552	7,218	167	0	2
1967.....	101,764	6,513	108	1	0
TOTAL.....	1,283,409	70,928	1,787	119	44

CHART VII

RADIATION INJURIES 1943-1967 AEC OPERATIONS

Of the 38 workers involved in lost-time radiation accidents, 3 died, 24 showed clinical manifestations attributable to radiation, and 11 were without evidence of radiation effects. Of the second group, 2 received permanent partial disabilities due to radiation, and 3 required removal of a digit because of deposition of plutonium in tissue.

Persons listed as having "lost-time injuries" but who actually had no evidence of clinical radiation effects were classified as lost-time injuries because they were removed from work and hospitalized

for diagnostic tests. Such tests were negative in these cases but loss of time was charged according to USAS standards for hospitalizations.

Additional information on these injuries concerning date and location of accident and nature and extent of injury are found on Chart VIII. Chart IX provides a comparison of total time lost from injuries due to radiation and to other causes. It is evident from the chart that radiation exposure was responsible for only a small part of the time lost due to injuries.

CHART VIII

RADIATION ACCIDENTS RESULTING IN LOST-TIME INJURIES

(As Defined in USA Standard Method of Recording and Measuring Work Injury Experience—USAS Z16.1-1967
(Revision of Z16.1-1964) and AEC Directives)

Date	Location	Number Involved	Source of Injury	Nature of Injury	Exposure		Days Lost
					80 KV X-Ray	GAMMA RAY	
8/21/45	Los Alamos	Two	Chain reaction in experimental critical assembly	(1) Fatality (2) No clinically diagnosed injury	(1) 480 r (2) 31 r	110 r 1 r	6000 60
5/21/46	Los Alamos	Eight	Chain reaction in experimental critical assembly	(1) Fatality (2) Skin rash, loss of hair and other symptoms (3) Skin rash and other symptoms (4) No clinically diagnosed injury (5) No clinically diagnosed injury (6) No clinically diagnosed injury (7) No clinically diagnosed injury (8) No clinically diagnosed injury	(1) 930 r (2) 390 r (3) NA (4) 185 r (5) 140 r (6) 55 r (7) 43 r (8) 33 r	114 r 26 r NA 10 7 r 8.7 r 4.4 r 3 r 2.41 r	6000 70 1/ 14 18 4 4 4
5/14/48	Eniwetok Proving Ground	Four	Improper handling of fission sample	Beta ray burns to hand	1.7 r <u>2/</u> 4.5 r <u>2/</u> 5.5 r <u>2/</u> 17 r <u>2/</u>		36 36 36 36
9/7/48	Los Alamos	One	Unpacking radioactive material	Beta ray burns to ankle	NA <u>3/</u>		36
6/2/52	Chicago	Four	Manual withdrawal of control rod from critical assembly	No clinically diagnosed injury	190 rem 160 rem 70 rem 12 rem		23 23 34 23
7/9/52	Los Alamos	One	Handling radioactive material with torn glove	Beta ray burns to hands	NA <u>4/</u>		3
3/1/55	Nevada Test	One	Entering exclusion area during test	No clinically diagnosed injury	39 r		19
7/27/55	National Reactor Testing Station	One	Radioactive particle entering ear canal	Partial loss of hearing	Not detectable		12
4/30/56	Los Alamos	One	Handling radioactive material with torn glove	Beta burns to hands	NA <u>5/</u>		14
6/18/56	Hanford	One	Escape of plutonium solution into control room	Contamination of exposed skin surfaces. No clinically diagnosed injury	0.4 μ /c Pu		4
6/14/57	Rocky Flats	One	Explosion in "dry box"	Plutonium lodged in finger, necessitating partial amputation	3.2 μ g Pu (0.2 μ /c)		50
6/16/58	Oak Ridge (Y-12 Plant)	Eight	Criticality incident caused by draining enriched uranium in drum of water	<u>6/</u>	461 rem 341 rem 428 rem 413 rem 298 rem 86 rem 86 rem 29 rem		83 83 83 83 83 34 65 41
12/30/58	Los Alamos	One	Criticality accident	Fatality	12000 $\pm$ 50% rem		6000
11/8/60	Albuquerque Sandia Base	One	Exposure from electronic beam	Multiple radiation burns middle section of face, abdomen and both hands	<u>7/</u>		10
6/12/64	Rocky Flats	One	Explosion in "drybox"	Pu lodged in finger and thumb, necessitating amputation at proximal joint	<u>1/</u>		1000
7/7/65	Livermore	One	Changed materials in X-ray unit unaware it was operating	2nd degree burns right hand	1000 rem		12
9/15/65	Richland	One	Wiped moisture from chamber of emission spectrometer	Amputation of distal phalanx of index finger	80000 rem		100

1/ Information Not Available.

2/ Exposure refers to whole body gamma radiation. Injury caused by beta ray dose, amount of which exposure not available.

3/ Amount of beta ray dose not available. Total gamma ray exposure during week in which accident occurred was 0.27 rem.

4/ Amount of beta ray dose not available. Total gamma ray exposure during week in which accident occurred was 1.8 rem

5/ Amount of beta ray dose not available. Total gamma ray exposure during week in which accident occurred was 2.0 rem

6/ Three employees not requiring prolonged hospital care exhibited mild changes in blood elements but showed no symptoms of injury. The five employees requiring longer hospitalization showed significant decreases in blood elements and other clinical and laboratory findings characteristic of more severe radiation damage such as mild nausea and vomiting, and indications of possible hemorrhagic complications, although no bleeding actually occurred.

7/ Employee was not wearing his film badge. However an indirect measurement was made by placing a film badge at the 33 cm distance and exposing it under simulated conditions. Calibration was interpreted as 760 rads incident dose to the face at 33 cm.

CHART IX

TIME LOST from RADIATION INJURIES 1943-67 AEC OPERATIONS

PART IV

AEC EXPERIENCE—PROPERTY DAMAGE

Section 1

GENERAL

During the 25-year history of the Atomic Energy Commission (AEC) and the Manhattan Engineer District (MED), its predecessor, property damage accidents caused about \$31.0 million loss, of which 42% was from fire, 26% from reactor-associated incidents, and the remaining 32% divided almost equally between acts of nature, explosions, and miscellaneous causes. During the same period, the average AEC annual "all cause" loss rate (roughly 1.77¢ per \$100 of AEC property) was well below the comparable average for private industry, whose average annual loss rate from fire causes alone approximates 2.8¢ per \$100 of insured property.

Few AEC accidents . . . typically three per year . . . result in loss of \$50,000 or more; however, these infrequent occurrences have cumulatively inflicted about 90% or more of the aggregate loss suffered to date. The six accidents described below individually caused \$1,000,000 or more damage and, collectively, account for over 42% of the total property damage suffered during the past 25 years.

Chart XIV provides a listing and brief description of each AEC accident causing \$50,000 or more loss. The incidents are listed in decreasing order of loss magnitude, e.g., incident #6 caused the sixth largest accidental loss in AEC's 25-year history. Incident numbers given in the listing correspond with those given on the charts covering AEC property damage.

1. SL-1 REACTOR EXCURSION

Idaho Falls, Idaho, Jan. 3, 1961   \$4,350,000
(See description on page 29.)

2. CHEMICAL EXPLOSION AND FIRE

Paducah, Ky., Dec. 13, 1962   \$2,900,000

An explosion, followed by an intense, violent, local, chemical reaction-type fire within a gaseous diffusion cell, caused heavy damage to adjacent physical facilities. Water from overhead sprinklers was rapidly converted into high-temperature steam which actuated most of the 2,341 sprinkler heads that operated during the fire. The automatic fire sprinkler systems were successful in confining fire damage within the \$162,000,000 building.

There were no injuries to personnel. (See USAEC SERIOUS ACCIDENTS Issues #194, 1-3-63; #203, 4-29-63; #215, 1-17-64).

3. ROOF DECK FIRE

Paducah, Ky., Nov. 11, 1956   \$2,100,000

Failure of a process gas compressor seal permitted some of the leaking gas to escape, to impinge on, and to ignite oil in an adjacent drip pan and on flexible tygon tubing carrying oil to the compressor load bearings. The resulting intense, localized fire caused rupture of the lube oil supply line, thereby allowing additional fuel to feed the fire. The fire spread throughout the tar-treated built-up composition roof of the 70,000 sq. ft., nonsprinklered, two-story building constructed of unprotected steel frame with sheet asbestos siding and a metal roof deck. The roofing material consisted of a layer of tar which served both as a vapor barrier and to bind fiberglass insulation to the

metal roof deck. The roofing was topped by a layer of tar binding the outer layer of gravel to the thermal insulation below.

One firefighter was seriously injured in a fall during efforts to escape from the intense heat. (See USAEC SERIOUS ACCIDENTS Issue # 115, 2-11-57.)

4. ACT OF NATURE

Amarillo, Tex., Sept. 3, 1967   \$1,872,000

Winds, up to 106 miles per hour, rain, and hail caused major widespread damage to roofs, glass, doors, and walls of numerous buildings, and general damage and destruction to various segments of the electrical power distribution system, the steam condensate return, and compressed air distribution systems. Extensive flooding and water damage were experienced inside the buildings partially or wholly demolished by the cyclonic winds. Of 120 vehicles, 92 sustained damage.

5. EXPLOSION AND FIRE

Cambridge, Mass., July 5, 1965   \$1,453,000

An explosion and fire occurred in the experimental hall of an accelerator complex following the sudden release of 500 liters of liquid hydrogen. The incident was caused by the sequential failure of the inner and outer beryl-

lium windows of a liquid hydrogen bubble chamber. During the next three hours, the initial blaze slowly spread to involve propane cylinders, the contents of which burned intensely in a secondary fire which, in turn, accentuated combustion in the explosion-fragmented roof. Eight persons were injured, one fatally. (See TID-5360, Suppl. 6, p. 42; TID-22594.)

6. REACTOR MELTDOWN

Idaho Falls, Idaho, Nov. 18, 1958   \$1,100,000

To permit initial very low-level power testing of an experimental nuclear reactor aircraft engine, it was found necessary to modify instrumentation power supplies so as to reduce interference from extraneous electrical "noise" effects. However, these changes had the subsequent net effect of causing erroneously low-level power indications as the actual reactor power levels were subsequently increased. The instrumentation error (due to saturation) gave false security as the actual reactor power level was slowly increased far beyond that which the reactor was capable of safely withstanding. In addition to severe reactor damage due to overheating, small amounts of radioactive fission product activity was released within the test facility. There were no injuries. (See 1959 NUCLEAR SAFETY, Vol. 1, #2, p. 57.)

Chart X affords a broad view of the 1943-1967 accident experience broken down into five categories, which include "reactors" and four types of "loss cause." If the causes of the accidental losses associated with the nuclear reactor incidents had been distributed between the four loss causes shown on Chart X (i.e., fire, explosion, act of nature, and

miscellaneous), the type and relative magnitude of AEC loss causes would be found to parallel closely those of private industry. Stated differently, fire, explosion, and acts of nature are the principal causes of property damage in both AEC and private industry.

CHART X

Chart XI shows a breakdown by years of the AEC 1947-1967 property damage experience and reflects an average annual loss rate of approximately 1.77¢/\$100 of AEC-owned property, com-

paring favorably with that of private industry. The wide deviations in the AEC annual loss experience shown on chart XI are the result of a few high-loss incidents.

CHART XI

AEC PROPERTY DAMAGE RATIOS* . . 1947-1967

LOSS FROM FIRE

As indicated on Chart X, fire has been the largest single cause of AEC property damage. The AEC 1947-1967 fire experience (see Chart XII) compares favorably with that of private industry, a

fact similarly true of the MED experience from 1943-1946.

Two of the largest AEC fire losses occurred at Paducah, Ky., and the third at Cambridge, Mass. (See descriptions numbered 2, 3, and 5 on pages 15 and 16.)

CHART XII

AEC FIRE LOSS RATIOS 1947 - 1967

LOSS FROM CONTAMINATION

Chart XIII presents a breakdown by years of AEC property damage from contamination. As noted in the chart, AEC experienced its largest loss due to contamination in 1967 when a process tube failed, releasing fission products into the reactor core. Personnel exposures were within normal administrative limits and no appreciable radioactivity was released to the environment. The cost of the incident was \$895,000, of which \$435,000 was based on the expense incurred for cleanup of

radioactive contamination of the reactor system and containment shell.

The chart also reflects that contamination spread by fire has been a major cause of contamination damage. As an example, on September 11, 1957, some metallic plutonium ignited spontaneously within a glovebox and the fire spread via ventilating ductwork to destroy the main filter bank. Fire-fighting was inhibited by potential criticality and contamination concerns. Most of the loss resulted from contamination spread by drafts accompanying the fire.

CHART XIII

CAUSES OF AEC PROPERTY DAMAGE BY CONTAMINATION 1955-1967

CHART XIV

AEC INCIDENTS CAUSING OVER \$50,000 PROPERTY DAMAGE OR LOSS 1943-1967

Incident No.	Date	Field Office 1—Contractor	Remarks	AEC Property Damage
1	1- 3-61	ID—Combustion Engineering-----	<i>Reactor</i> excursion. (See TID-5360, Suppl. 4, p. 8; 1962 NUCLEAR SAFETY, Vol. 3, #3, p. 64.)	\$4, 350, 000
2	12-13-62	OR—Union Carbide Corp-----	<i>Explosion and fire</i> in gaseous diffusion cell. (See USAEC SERIOUS ACCIDENTS Issues #194, 1-3-63; #203, 4-29-63; #215, 1-17-64.)	2, 900, 000
3	11-11-56	OR—Union Carbide Corp-----	Intense localized <i>fire</i> from lube oil-process gas reaction spread to metal deck roof where fire got out of control due to combustible vapor barrier in roof deck. Damage limited to upper story of building. (See USAEC SERIOUS ACCIDENTS Issue #115, 2-11-57.)	2, 100, 000
4	9- 3-67	AL—Mason & Hanger-Silas Mason Co.	<i>Wind and hailstorm</i> damage-----	1, 872, 000
5	7- 5-65	NY—Harvard University; Massachusetts Institute of Technology.	Fire and explosion damage in experimental area ensued following beryllium window failure on liquid hydrogen bubble chamber. Eight people were injured, one fatally. (See TID-5360, Suppl. 6, p. 42; TID-22594.)	1, 453, 000
6	11-18-58	LAR—General Electric Co-----	<i>Reactor</i> fuel element <i>meltdown</i> resulted from radiation monitoring power system deficiency. (See 1959 NUCLEAR SAFETY, Vol. 1, #2, p. 57.)	1, 100, 000
7	9-29-65	RL—Battelle Northwest-----	Test <i>reactor</i> zirconium tube failure permitted gross contamination of reactor core and interior of containment shell. (See TID-5360, Suppl. 6, p. 27; 1965 NUCLEAR SAFETY, Vol. 7, #2, p. 242.)	895, 000
8	9-11-57	AL—Dow Chemical Co-----	Spontaneous metallic <i>plutonium</i> fire in production drybox line spread to flammable plastic drybox window through ventilating system to main filter bank. Much of damage due to spread of plutonium <i>contamination</i> during the fire. (See TID-5360, Suppl. 2, p. 23; USAEC SERIOUS ACCIDENTS Issue #130, 11-27-57.)	818, 600
9	1- 5-55	RL—General Electric Co-----	Partial <i>meltdown</i> of <i>reactor</i> during startup. Principal loss resulted from need to remove and replace part of reactor core. (See 1962 NUCLEAR SAFETY, Vol. 4, #1, p. 104.)	480, 134
10	1-10-56	OR—Union Carbide Corp-----	Large process <i>pressure vessel rupture</i> from fatigue--	480, 134
11	9-13-61	AL—Bendix Corp-----	<i>Flood</i> damage, attributed to effects of hurricane Carla, which caused adjoining creek to rise to record high of 44.5 feet.	449, 200
12	10-61	SR—E. I. du Pont de Nemours & Co.	Dislocation and fracture of <i>sluiceways</i> in reactor effluent canals.	400, 000
13	11- 6-63	RL—General Electric Co-----	<i>Explosion and fire</i> in plutonium purification facility. (See TID-5360, Suppl. 5, p. 23; USAEC SERIOUS ACCIDENTS Issue #237, 12-4-64.)	397, 000
14	11-20-59	OR—Union Carbide Corp-----	Chemical <i>explosion</i> occurred in processing vessel during cleanout and decontamination procedure. (See TID-5360, Suppl. 3, p. 15; USAEC SERIOUS ACCIDENTS Issue #162, 3-30-60.)	350, 000
15	11- 3-64	RL—General Electric Co-----	Roof <i>fire</i> severely damaged aquatic laboratory building.	316, 900

See footnote at end of table.

Chart XIV—Continued

AEC INCIDENTS CAUSING OVER \$50,000 PROPERTY DAMAGE OR LOSS 1943-1967

Incident No.	Date	Field Office 1—Contractor	Remarks	AEC Property Damage
16	2-14-66	OR—National Lead Co.....	Inadvertent release of uranium hexafluoride. No significant radiation exposures. (See TID-5360, Suppl. 6, p. 32.)	294, 826
17	6-10-53	SR—E. I. du Pont de Nemours & Co.	Platform failed, damaging reactor actuator rods...	270, 000
18	1-28-52	RL—General Electric Co.....	Fire destroyed one-story 75' x 140' frame construction warehouse. No sprinklers. (See USAEC SERIOUS ACCIDENTS Issue #21, 3-7-52.)	269, 578
19	4-23-50	SAN—Lawrence Radiation Laboratory.	Multistory, unsprinklered frame research building destroyed by fire.	258, 712
20	4-17-60	RL—General Electric Co.....	Fire involving spent fuel elements within process dissolver led to damage of equipment and contamination spread. (See TID-5360, Suppl. 3, p. 20; 1961 NUCLEAR SAFETY, Vol. 2, #4, p. 52.)	250, 443
21	9-13-60	SR—E. I. du Pont de Nemours & Co.	Contaminated cooling water discharged from canyon onto floor. No overexposures. (See TID-5360, Suppl. 3, p. 22.)	250, 050
22	12-29-52	AL—Holmes and Narver.....	Typhoon damage.....	250, 000
23	12-13-63	OR—Goodyear Atomic Corp.....	Transformer in switchyard suffered internal failure.	244, 800
24	5- 4-57	SR—E. I. du Pont de Nemours & Co.	Leak in reactor heat exchanger resulted in loss of heavy water moderator.	202, 000
25	10-29-52	OR—Government.....	Fire following tractor-trailer accident spread to, and ultimately destroyed, cargo and tractor-trailer. Bulk of loss due to self-sustaining combustion of massive uranium. (See TID-5360, p. 45; AECU 3613, p. 9.)	200, 000
26	8-15-58	OR—Union Carbide Corp.....	Welding sparks ignited fiberboard and fire spread rapidly through wood frame building. (See USAEC SERIOUS ACCIDENTS Issue #139, 10-23-58.)	199, 923
27	6-21-67	RL—Douglas United Nuclear....	Oil fire in heat exchanger cell of reactor.....	185, 000
28	7- 2-50	OR—Union Carbide Corp.....	Transformer in main switchyard. Fire.....	171, 000
29	4-23-58	SAN—Lawrence Radiation Laboratory.	Rotor bolt sheared off and got between generator rotor and stator, tearing insulation and shorting wiring.	140, 000
30	1-20-65	SAN—Lawrence Radiation Laboratory.	Material release to atmosphere. (See TID-5360, Suppl. 6, p. 16.)	140, 000
31	3-18-60	SR—E. I. du Pont de Nemours & Co.	Fire followed a hydrogen-sulfide gas release from a tritium process equipment condenser.	135, 300
32	6-17-55	OR—Union Carbide Corp.....	Hydrogen explosion occurred in 125,000-gallon evaporator feed tank. (See USAEC SERIOUS ACCIDENTS Issue #86, 9-1-55.)	132, 275
33	10-26-61	AL—Sandia Corp. (Sub-Wurlitzer.)	Fire followed friction or static ignition of "heat pad paper" containing powdered zirconium. (See TID-5360, Suppl. 4, p. 30.)	131, 210
34	8-21-59	SR—E. I. du Pont de Nemours & Co.	Solution leaked from loosened flange during maintenance work on waste evaporator in hot canyon, vaporized and contaminated a crane. (See TID-5360, Suppl. 3, p. 13; USAEC SERIOUS ACCIDENTS Issue #157, 12-15-59.)	129, 423
35	5- 6-65	NY—Harvard University; Massachusetts Institute of Technology.	Fire in modulator electrical pulsing equipment for accelerator.	127, 000

See footnote at end of table.

Chart XIV—Continued

AEC INCIDENTS CAUSING OVER \$50,000 PROPERTY DAMAGE OR LOSS 1943-1967

Incident No.	Date	Field Office 1—Contractor	Remarks	AEC Property Damage
36	1-23-49	RL—General Electric Co.-----	Hexone-nitric acid chemical <i>explosion</i> followed by fire seriously damaged building. Spread of contamination was minor factor from loss viewpoint.	125, 217
37	1945	AL—Los Alamos Scientific Laboratory.	<i>Fire</i> initiating in oil quench tank ignited and spread through frame shop building.	125, 000
38	1946	OR—Mallinckrodt Chemical Works.	Uncontrolled ether-nitric acid <i>explosion</i> in uranium solution purification plant.	110, 000
39	7-23-57	LAR—General Electric Co.-----	Crane overturned while handling a reactor core. Bulk of loss due to damaged <i>reactor core</i> .	105, 225
40	11-10-60	SAN—Lawrence Radiation Laboratory.	<i>Fire</i> started in curium processing cave by apparent overheating of oil bath in glovebox. Loss confined to one room, but all contents complete loss. Minor release of radioactive materials to environment. Damage due largely to fire destroying equipment. (See USAEC SERIOUS ACCIDENTS Issues #169, 11-25-60; #175, 4-5-61.)	101, 000
41	10-30-59	SNR—General Electric Co.-----	Air-oil <i>explosion</i> occurred in air flask component of a 3,000-psi hydraulic oil system. (See USAEC SERIOUS ACCIDENTS Issue #155, 11-19-59.)	100, 000
42	11- 8-57	SR—E. I. du Pont de Nemours & Co.	Zirconium-clad fuel element failed under test. A series of complications followed, chief of which was <i>contaminated water leakage</i> from earth basin through abandoned construction pipelines. No personnel exposure or property damage.	99, 007
43	3-26-63	SAN—Lawrence Radiation Laboratory.	<i>Criticality</i> occurred during subcritical experiment involving fissionable materials and small <i>fire</i> developed within enclosed concrete vault. (See TID-5360, Suppl. 5, p. 17.)	94, 881
44	2-20-52	SAN—Lawrence Radiation Laboratory.	<i>Fire</i> initiating in hot plate in research laboratory broke out in attic and spread through two-story, frame, unsprinklered building.	92, 798
45	11-13-63	AL—Mason & Hanger-Silas Mason Co., Inc.	Chemical <i>explosion</i> in explosives storage igloo-----	92, 568
46	8- 5-58	RL—General Electric Co.-----	Disintegration of emergency <i>turbo-generator</i> from overspeed following dual failure of the governor and the overspeed trip devices. (See USAEC SERIOUS ACCIDENTS Issue #142, 1-21-59.)	90, 000
47	1-17-59	OR—Union Carbide Corp.-----	Multiple circuit breaker failure led to severe <i>electrical fire</i> . (See USAEC ACCIDENT AND FIRE PREVENTION INFORMATION Issue #92, 2-17-59.)	86, 020
48	12- 8-54	SR—E. I. du Pont de Nemours & Co.	<i>Weld failure</i> in large water pipe at river pump-house.	81, 800
49	11-11-56	SR—E. I. du Pont de Nemours & Co.	Heavy water moderator loss due to <i>leak</i> in reactor heat exchanger.	80, 000
50	8-23-65	RL—Battelle Northwest-----	Minor <i>fire</i> and <i>explosion</i> following acetone ignition in glovebox caused extensive contamination spread. (See TID-5360, Suppl. 6, p. 24; USAEC SERIOUS ACCIDENTS Issue #261, 2-15-56.)	76, 800
51	5-19-57	AL—Sandia Corp.-----	<i>Fire</i> destroyed 36' x 60' Butler building. Major damage to generator.	76, 120

See footnote at end of table.

Chart XIV—Continued

AEC INCIDENTS CAUSING OVER \$50,000 PROPERTY DAMAGE OR LOSS 1943-1967

Incident No.	Date	Field Office 1—Contractor	Remarks	AEC Property Damage
52	2-13-58	RL—General Electric Co.-----	Chemical <i>explosion</i> occurred in silver nitrate reaction vessel used to absorb iodine vapors from process offgases. Incident occurred following introduction of efforts to extend useful life of iodine 131 removal equipment. (See USAEC SERIOUS ACCIDENTS Issue #134, 7-28-58.)	75,700
53	5- 5-65	NV—Reynolds Electrical & Engineering Co.	Drill rig overturned-----	75,000
54	7-31-65	RL—General Electric Co.-----	<i>Explosion</i> during manual reignition of oil-fired boiler after flameout during test.	75,000
55	8-31-57	AL—Holmes and Narver-----	<i>Helicopter</i> seriously damaged when dropped while being unloaded by crane from boat.	75,000
56	2- 1-51	OR—Mallinckrodt Chemical Works.	Ether-nitric acid explosion during attempts to remove scale from process tank in uranium solution purification building. (See USAEC SERIOUS ACCIDENTS Issue #2, 2-15-51.)	75,000
57	9-19-64	NV—Reynolds Electrical & Engineering Co.	While electrical cables were being lowered into a test hole, <i>cable broke</i> and fell into hole below drill rig. (See TID-5360, Suppl. 5, p. 44.)	74,000
58	12- 2-45	OR—Union Carbide Corp-----	<i>Fire</i> in cork pipe covering in purge and product room.	73,000
59	3-29-57	PNR—Westinghouse Electric Corp.	<i>Explosion</i> (pressure rupture) of high pressure autoclave during normal operation due to fatigue resulting from cyclic thermal and mechanical stresses. (See USAEC SERIOUS ACCIDENTS Issue #133, 6-24-58.)	71,500
60	3- 3-67	SR—E. I. du Pont de Nemours & Co.	<i>Heavy water loss</i> when water flowed onto reactor top from hydraulic lifting of upper shield plug.	71,000
61	9-21-58	AL—Holmes and Narver-----	Severe <i>wave action</i> from storm resulted in damage to cargo pier, barge slip, and fuel barge.	70,844
62	12-55	AL—Holmes and Narver-----	Damage by <i>wave action</i> to man-made island-----	70,000
63	1-18-57	SR—E. I. du Pont de Nemours & Co.	<i>Heavy water loss</i> due to leak in heat exchanger for reactor.	70,000
64	8-14/17-61	RL—Government-----	<i>Range fire</i> . Over three-day period, 62 known grass and range fires occurred involving 30,480 acres.	69,866
65	5-47	OR—Union Carbide Corp-----	<i>Fire</i> destroyed two-story, frame, unsprinklered office building.	69,000
66	7-24-64	SR—E. I. du Pont de Nemours & Co.	<i>Radioactive gas release</i> accidentally from stack to atmosphere. No property damage or personnel exposures resulted. (See TID-5360, Suppl. 5, p. 35.)	68,300
67	1-22-64 & 3-2-64	RL—Peter Kiewit Sons' Co-----	<i>Tunnel collapsed</i> while backfilling over tunnel roof.	66,000
68	9- 9-57	OR—Goodyear Atomic Corp-----	<i>Transformer failure</i> . No fire. Principal cost for transformer repair.	65,000
69	3-12-67	NV—Reynolds Electrical & Engineering Co.	Trailer <i>fire</i> caused by overheating of heater unit---	65,000
70	5-16-54	RL—Blaw-Knox-----	<i>Fire</i> followed by spontaneous combustion in janitor's closet, destroying building. (See USAEC SERIOUS ACCIDENTS Issue #67, 7-27-54.)	62,355
71	10-16-59	ID—Phillips Petroleum Co-----	<i>Criticality</i> accident occurred in process equipment waste collection tank. (See TID-5360, Suppl. 3, p. 14; USAEC SERIOUS ACCIDENTS Issue #163, 4-18-60; 1960 NUCLEAR SAFETY, Vol. 1, #3, p. 75.)	61,800

See footnote at end of table.

Chart XIV—Continued

AEC INCIDENTS CAUSING OVER \$50,000 PROPERTY DAMAGE OR LOSS 1943-1967

Inci- dent No.	Date	Field Office ¹ —Contractor	Remarks	AEC Property Damage
72	2-25-64	AL—Mason & Hanger-Silas Mason Co., Inc.	<i>Detonation of high explosives</i> during normal process- ing operation.	60,400
73	12- 9-56	SR—E. I. du Pont de Nemours & Co.	<i>Heavy water moderator loss</i> due to leak in heat exchanger for <i>reactor</i> .	60,000
74	12- 4-63	AL—Sandia Corp. (Sub-Eagle- Picher).	Transporting heat-pad paper in fibre containers to vault; the paper flashed and <i>fire</i> spread from paper to other parts of the dryroom adjacent to vault.	58,507
75	10-29-61	AL—Government-----	<i>Aircraft</i> struck 500' radio tower. Tower collapsed and wing tank torn from plane.	57,000
76	6-12-64	AL—Dow Chemical Co-----	<i>Explosion</i> occurred within drybox when burning <i>plutonium</i> chips dropped into carbon tetrachlo- ride bath. (See TID-5360, Suppl. 5, p. 32; USAEC SERIOUS ACCIDENTS Issue #246, 3-12-65.)	56,400
77	1-29-66	SR—E. I. du Pont de Nemours & Co.	<i>Water supply lines</i> and fire sprinkler lines <i>froze</i> ----	56,000
78	5-17-52	AL—Mason & Hanger-Silas Mason Co., Inc.	<i>Water damage</i> due to ruptured 4" waterline-----	54,000
79	9- 7-55	AL—Reynolds Electrical & Engineering Co.	<i>Fire</i> in temporary construction warehouse de- stroyed frame building housing combustible construction materials. Adjoining acetylene cyl- inder storage building also destroyed. (See USAEC SERIOUS ACCIDENTS Issue #111, 11-9-56.)	53,608
80	8-25-65	AL—Mason & Hanger-Silas Mason Co.	<i>Hailstorm</i> damage-----	52,537
81	1-21-66	RL—Douglas United Nuclear----	Boiler at <i>reactor</i> suffered internal damage from <i>firebox explosion</i> .	52,499
82	12- 9-63	OR—Goodyear Atomic Corp-----	<i>Compressor</i> in cell <i>debladed</i> while onstream. De- blading took place while psi test being con- ducted, and was accompanied by small fire on exterior of compressor shell.	51,500
83	4-17-64	RL—General Electric Co-----	The erroneous placement of some enriched (0.947 %) fuel elements within reactor necessitated <i>reactor</i> reloading with attendant increased costs for fuel handling and processing. (See TID-5360, Suppl. 5, p. 28.)	51,000
84	6- 5-54	AL—Government-----	<i>Forest fire</i> on an AEC reservation-----	50,000
85	1-12-53	SR—E. I. du Pont de Nemours & Co.	<i>Explosive chemical reaction</i> in evaporator outside building. Minor building and contamination damage. (See TID-5360, p. 58; USAEC SERI- OUS ACCIDENTS Issue #41, 3-23-53.)	50,000
86	12- 4-51	RL—General Electric Co-----	<i>Fire</i> of spontaneous origin broke out in nitric acid- saturated combustible waste used for cleaning up <i>contamination</i> from prior criticality incident. Extent and magnitude of contamination spread by fire caused abandonment of building. (See TID-5360, p. 53.)	50,000
87	9-29-59	SR—E. I. du Pont de Nemours & Co.	<i>Hurricane</i> Gracie damaged storage pond dam wall--	50,000
88	6- 5-66	CH—Atomics International-----	<i>Sodium leak</i> occurred in gas-fired sodium heater---	50,000
89	6- 2-67	AL—Mason & Hanger-Silas Mason Co.	<i>High explosives detonated</i> , cause not determined----	50,000

¹See footnote 1, page 47.

Section 2

CRITICALITY ACCIDENTS

In the AEC's operational activities (not licensed) for the past 25 years there have been a total of 25 occasions (see Chart XV) when the power level of fissile systems became uncontrollable because of unplanned or unexpected changes in the system reactivity. On three occasions, the power excursions were planned; however, the fission energy released during the excursion was significantly larger than was expected. There have been a total of six deaths attributable to criticality accidents. The property damage resulting from these excursions has been approximately \$4,455,000; however, 98% of the property loss was due to the SL-1 reactor excursion.

Further study of this accident record reveals that nine of the unplanned excursions occurred

behind heavy shielding and three of them occurred in facilities remotely located with respect to personnel. Hence, the probability of injuries to people was reduced almost to the vanishing point. It is also noted that fourteen of the accidents occurred during experiments, five occurred in production or processing facilities, and five in reactor activities. In these laboratory, production, and reactor facilities there were, respectively, two, one, and three fatalities.

A review of these incidents has been made by W. R. Stratton, University of California, Los Alamos Scientific Laboratory, Los Alamos, N. Mex. All we have done below is to prepare a brief description of each incident.

CHART XV

CRITICALITY ACCIDENTS IN USAEC FACILITIES*

Date	Location	Active Material	Geometry	Total Fissions	Cause	Physical Damage	\$ Loss
METAL SYSTEMS IN AIR							
Aug. 21, 1945	Los Alamos, New Mexico	6.2 Kg δ -phase Pu	Spherical core tungsten-carbide reflected	$\sim 10^{16}$	Hand stacking reflector	None	-
May 21, 1946	Los Alamos, New Mexico	6.2 Kg δ -phase Pu	Spherical core Be reflected	$\sim 3 \times 10^{15}$	Hand stacking reflector	None	-
Apr. 18, 1952	The Los Alamos Scientific Lab., New Mexico	92.4 Kg uranium metal, 93% U-235	Cylinder unreflected	1.5×10^{16}	Computation error	None	-
Feb. 3, 1954	The Los Alamos Scientific Lab., New Mexico	53 Kg uranium metal, 93% U-235	Sphere unreflected	5.6×10^{16}	Incorrect operation	Slight warping of pieces	\$600
Feb. 12, 1957	The Los Alamos Scientific Lab., New Mexico (GODIVA)	54 Kg uranium metal, 93% U-235	Sphere unreflected except for experiment	1.2×10^{17}	Shift of experiment	Warping, oxidation near melting close to center	\$2,400
Nov. 10, 1961	The Oak Ridge National Lab., Tennessee	75 Kg uranium metal, 93% U-235		$\sim 10^{16}$	Too rapid assembly	None	-
Mar. 26, 1963	LRL Livermore Calif.	47 Kg 93% U-235	Cylinder reflected	5×10^{17}	Too rapid assembly	Assembly machine and fire effects	\$94,881
SOLUTION SYSTEMS							
Dec., 1949	The Los Alamos Scientific Lab., New Mexico	~ 1 Kg U-235 $\text{UO}_2(\text{NO}_3)_2$ in 13.6 liters water	Sphere graphite reflected	$3-4 \times 10^{16}$	Manual withdrawal of two poison control rods	None	-
Nov. 16, 1951	The Hanford Works, Richland, Washington	1.15 Kg Pu $\text{PuO}_2(\text{NO}_3)_2$ in 63.8 liters water	Sphere 93% full unreflected	8×10^{16}	Poison control rod run out too fast	None	**
May 26, 1954	The Oak Ridge National Lab., Tennessee	18.3 Kg U-235 UO_2F_2 in 55.4 liters water	Cylindrical annulus unreflected	1×10^{17}	Tilting of inner poison cylinder	None	-
Feb. 1, 1956	The Oak Ridge National Lab., Tennessee	27.7 Kg U-235 UO_2F_2 in 58.9 liters water	Cylinder unreflected	1.6×10^{17}	Falling scram set up waves creating a critical geometry	Warping of bottom of cylinder	-
June 16, 1958	Y-12 Processing Plant Oak Ridge, Tennessee	2.5 Kg U-235 $\text{UO}_2(\text{NO}_3)_2$ in 56 liters water	Cylinder concrete reflected below	1.3×10^{18}	Wash water added to $\text{UO}_2(\text{NO}_3)_2$ solution	None	\$1,000
Dec. 30, 1958	The Los Alamos Scientific Lab., New Mexico Pu Processing Plant	3.27 Kg Pu $\text{PuO}_2(\text{NO}_3)_2$ in ~ 166 liters water	Cylinder water reflected below	1.5×10^{17}	Agitator created a critical geometry	None	-
Oct. 16, 1959	Chemical Processing Plant, Idaho Reactor Testing Area	34.5 Kg U-235 ~ 300 liters $\text{UO}_2(\text{NO}_3)_2$ water	Cylinder concrete reflected below	$\sim 4 \times 10^{18}$	Solution surged from safe to unsafe geometry	None	\$61,800 (to recover contam. solution)
Jan. 25, 1961	Chemical Processing Plant, Idaho Reactor Testing Area	8 Kg U-235 $\text{UO}_2(\text{NO}_3)_2$ in 40 liters water	Cylinder	6×10^{17}	Solution pumped from safe to unsafe geometry	None	\$6,000
Apr. 7, 1962	Hanford Atomic Products	Pu Solution	Cylinder	8×10^{17}	Solution over flow down unsafe geometry transfer tank		\$1,000
INHOMOGENEOUS WATER MODERATED SYSTEMS							
June 4, 1945	Los Alamos, New Mexico	35.4 Kg uranium $\sim 93\%$ U-235 1/2-in. cubes	Pseudosphere water reflected	$\sim 3 \times 10^{16}$	Water seeping between blocks	None	-
Mar. 20, 1951	The Los Alamos Scientific Lab., New Mexico	2 cylinders uranium 24.4 and 38.5 Kg 93% U-235	2 cylinders water reflected	10^{17}	Scram increased reactivity	Slight oxidation	-
June 2, 1952	The Argonne National Lab.	6.8 Kg U-235 oxide particles in plastic	Inhomogeneous cylinder water reflected	1.22×10^{17}	Manual withdrawal of central safety rod	Plastic destroyed	-
July 22, 1954	The Reactor Testing Area, Idaho Falls, Idaho (BORAX)	U-Al plates clad with Al	Inhomogeneous cylinder water moderated	4.68×10^{18}	Estimate of expected excursion too low	Reactor destroyed intentionally by test	-
Jan. 3, 1961	Idaho Reactor Testing Area (SL-1)	U-Al plates clad with Al	Inhomogeneous cylinder water moderated	1.5×10^{18}	Under study	Extensive to reactor	\$4,350,000
MISCELLANEOUS SYSTEMS							
Feb. 11, 1945	Los Alamos, New Mexico	UH pressed in styrex	Cylinder	$\sim 6 \times 10^{15}$	Reflector added and/or source too large	UH ₃ -styrex cubes swollen and blistered	-
Nov. 29, 1955	Idaho Reactor Testing Area (EBR-1)	1/2-in. U-235 rods	Cylinder, rods cooled by NaK	4.7×10^{17}	Incorrect scram used	Core molten	Not reported
July 3, 1956	The Los Alamos Scientific Lab., New Mexico	58 Kg uranium 93% U-235, 2 and 5 mil foils	Cylinder	3.2×10^{16}	Too rapid assembly	None	-
May 18, 1967	Los Alamos, New Mexico	U-235 in graphite	Cylindrical	4×10^{16}	Improper Procedures	None	-

* For additional information on these accidents, see previous TID-5360 series and "A Review of Criticality Accidents" by W. R. Stratton, University of California (LASL)

ACCIDENTAL CRITICALITY EXCURSION

Los Alamos, N. Mex., May 18, 1967

A nuclear excursion of 4×10^{16} fissions took place in the critical mockup of a high power density reactor. There was neither damage to the equipment nor significant exposure of persons; nevertheless, the incident indicated poor practice and an undesirable interpretation of operating procedures which has been corrected. The reactor mockup is fueled with elements composed of fully enriched uranium in a graphite matrix, and a smaller number of graphite moderating elements. This permits a relatively small core volume (250 liters). The core, housed in a graphite cylinder, drops out of its Be reflector for loading. Control and safety drums are within the annular reflector.

Before the incident, fuel along the core axis was replaced by additional moderating elements to investigate flux-trap effects. Instead of the usual step-wise interchange of elements, the entire moderating island was installed. Then, instead of step-wise multiplication measurements while inserting the core into the reflector, which is proper for initial approaches to criticality, there were no measurements during interrupted insertion. It had been inferred from the behavior of different moderating elements in an earlier mockup that the overall reactivity change would be minor. This was a serious mistake, for the actual change proved to be about \$10. Before complete closure was achieved, a very short period and scram (dropping the core and actuating the safety drums) occurred.

NUCLEAR EXCURSION AND FIRE

Livermore, Calif., Mar. 26, 1963

A nuclear excursion and subsequent fire took place during a subcritical experiment in a shielded vault designed for critical assembly experiments. The excursion was estimated at 4×10^{17} fissions and was followed by oxidation of the enriched uranium metal in the assembly.

The cause of the excursion is believed to have been directly attributable to mechanical failure.

The total property loss was \$94,881.

NUCLEAR EXCURSION

Richland, Wash., Apr. 7, 1962

An unplanned nuclear excursion occurred in a plutonium processing facility because of the inadvertent accumulation of approximately 1500 grams of plutonium in 45-50 liters of dilute nitric

acid solution in a 69-liter glass transfer tank. The sequence of events which led to the accumulation of the plutonium in the tank cannot be stated positively. However, it is believed that, when a tank valve was opened, the solution from another process vessel overflowed to a sump and was drawn into the transfer tank through a temporary line between this tank and the sump.

When the excursion occurred, radiation and evacuation alarms sounded. All but three employees left the building immediately, according to well-prepared and -rehearsed evacuation plans. Fortunately, they were not in close proximity to the involved system nor in a high radiation field.

The course of the nuclear reaction involved initial criticality (10^{16} fissions); a subsidence; one or more later peaks; and after approximately one-half hour, a declining rate of fission, which terminated in a subcritical condition 37 hours later. The total number of fissions was approximately 8×10^{17} .

Of the 22 persons in the building at the time, only four employees, those who were in the room with the system, were hospitalized for observation. Three of them were the system operators, who were in close proximity to the excursion, and who received estimated radiation doses of 110, 43 and 19 rem. None of them showed symptoms definitely referable to their radiation exposures. The fourth was sent to the hospital only because he was in the room at the time of the incident.

Some fission product activity, airborne via the vent system and the exhaust stack, was detected in the atmosphere for a brief period after the accident. The physical damage amounted to less than \$1,000. (See TID-5360, Suppl. 4, page 17.)

NUCLEAR EXCURSION

Oak Ridge, Tenn., Nov. 10, 1961

A criticality excursion occurred as enriched uranium metal, neutron-reflected and -moderated by hydrogen, was being assembled. The excursion was caused by a too rapid approach of the two pieces of metal used in the experiment.

There was no personnel exposure or property damage. The energy release was estimated to be between 10^{15} and 10^{16} fissions. Fission product contamination, both airborne and contained in the metal, decayed sufficiently overnight to allow unhindered continuation of the experiment.

The incident occurred in a critical experiment laboratory specifically designed to accommodate

such occurrences, since events of this nature cannot be considered entirely unexpected in an experimental facility of this sort. (See TID-5360, Suppl. 4, p. 14.)

CRITICALITY ACCIDENT

Idaho Falls, Idaho, Jan. 25, 1961

A nuclear excursion of approximately 6×10^{17} fissions occurred in a first-cycle product evaporator at a chemical processing plant. The criticality accident resulted when a solution of enriched uranyl nitrate accidentally surged from a geometrically safe section of the evaporator into the upper critically unsafe, vapor disengagement section. The accident occurred behind thick concrete walls in a processing cell which is part of the first cycle for processing highly radioactive spent-fuel elements.

Personnel response to the radiation alarms and the evacuation signal was prompt and orderly.

Analyses of badges from 65 individuals indicated a maximum exposure of 55 millirem gamma and 0 beta. The maximum thermal neutron exposure detected in the badges analyzed was less than 10 millirem. Analyses of nuclear accident dosimeters indicated that there was negligible fast neutron flux associated with personnel exposures.

The radioactivity released to the atmosphere as a result of the accident was about twice normal background when it left the area. Loss of \$6,000 resulted from cleanup of the incident. (See TID-5360, Suppl. 4, p. 9; 1961 *Nuclear Safety*, Vol. 3, #2, p. 71.)

SL-1 EXCURSION

Idaho Falls, Idaho, Jan. 3, 1961

A nuclear excursion occurred within the reactor vessel, resulting in extensive damage of the reactor core and room, and in high radiation levels (approximately 500-1,000 rem/hr) within the reactor room.

At the time of the accident, a three-man crew was on the top of the reactor assembling the control rod drive mechanisms and housing. The nuclear excursion, which resulted in an explosion, was caused by manual withdrawal, by one or more of the maintenance crew, of the central control rod blade from the core considerably beyond the limit specified in the maintenance procedures.

Two members of the crew were killed instantly by the force of the explosion, and the third man died within two hours following the incident as a

result of an injury to the head. Of the several hundred people engaged in recovery operations, 22 persons received radiation exposures in the range of three to 27 rem gamma radiation total-body exposure. The maximum whole-body beta radiation was 120 rem.

Some gaseous fission products, including radioactive iodine, escaped to the atmosphere outside the building and were carried downwind in a narrow plume. Particulate fission material was largely confined to the reactor building, with slight radioactivity in the immediate vicinity of the building.

The total property loss was \$4,350,000. (See TID-5360, Suppl. 4, p. 8; 1962 *Nuclear Safety*, Vol. 3, #3, p. 64.)

CRITICALITY INCIDENT

Idaho Falls, Idaho, Oct. 16, 1959

A nuclear incident occurred in a process-equipment waste collection tank when an accidental transfer was made of about 200 liters of uranyl nitrate solution, containing about 34 kilograms of enriched uranium (91 percent U^{235}), from critically safe process storage tanks to a geometrically unsafe tank through a line formerly used for waste transfers.

Limited visual inspections and test indicated that no significant property damage or loss resulted beyond the approximately \$60,000 cost to recover contaminated uranium solution resulting from the incident.

Of the 21 personnel directly involved in this incident, seven received external exposures to radiation. The exposures were 8, 6, 3.95, 1.50, 1.38, 1.17, and 1.17 rem. Two individuals also received external exposures to the skin of 50 rem and 32 rem. No medical treatment was required for the 21 personnel involved. (See TID-5360, Suppl. 3, p. 14; *USAEC Serious Accidents* Issue #163, 4-18-60.)

FATAL INJURY ACCOMPANIES CRITICALITY ACCIDENT

Los Alamos, N. Mex., Dec. 30, 1958

The chemical operator introduced what was believed to be a dilute plutonium solution from one tank into another known to contain more plutonium in emulsion. Solids containing plutonium were probably washed from the bottom of the first tank with nitric acid and the resultant mixture of nitric acid and plutonium-bearing solids was added to the tank containing the emulsion. A criticality

excursion occurred immediately after starting the motor to a propeller type stirrer at the bottom of the second tank.

The operator fell from the low stepladder on which he was standing and stumbled out of the door into the snow. A second chemical operator in an adjoining room had seen a flash, which probably resulted from a short circuit when the motor to the stirrer started, and went to the man's assistance. The accident victim mumbled he felt as though he was burning up. Because of this, it was assumed that there had been a chemical accident with a probable acid or plutonium exposure. There was no realization that a criticality accident had occurred for a number of minutes. The quantity of plutonium which actually was present in the tank was about ten times more than was supposed to be there at any time during the procedure.

The employee died 35 hours later from the effects of a radiation exposure with the whole-body dose calculated to be 12,000 rem $\pm$.

Two other employees received radiation exposures of 134 and 53 rem, respectively. Property damage was negligible. (See TID-5360, Suppl 2, p. 30; *USAE C Serious Accidents* Issue #143, 1-22-59.)

NUCLEAR EXCURSION

Oak Ridge, Tenn., June 16, 1958

A nuclear accident occurred in a 55-gallon stainless steel drum in a processing area in which enriched uranium is recovered from various materials by chemical methods in a complex of equipment. This recovery process was being remodeled at the time of the accident.

The incident occurred while they were draining material thought to be water from safe 5-inch storage pipes into an unsafe drum.

Eight employees were in the vicinity of the drum carrying out routine plant operations and maintenance. A chemical operator was participating in the leak testing which inadvertently set off the reaction. He was within three to six feet of the drum, while the other seven employees were from 15 to 50 feet away.

Using special post hoc methods for determining the neutron and gamma exposures of the employees involved, it was estimated that the eight men received: 461 rem, 428 rem, 413 rem, 341 rem, 298 rem, 86 rem, 86 rem, and 29 rem.

Area contamination was slight, with decontamination costs amounting to less than \$1,000.

During this incident 1.3×10^{18} fissions occurred. (See TID-5360, Suppl. 2, p. 25; *USAE C Serious Accidents* Issue #136, 8-25-59; *USAE C Health and Safety Information* Issue # 82, 9-5-58; 1959 *Nuclear Safety*, Vol. 1, #2, p. 59.)

GODIVA EXCURSION

Los Alamos, N. Mex., Feb. 12, 1957

The "Godiva" assembly was to be used to irradiate uranium-loaded graphite samples. The samples were to be heated in a shielded furnace, exposed to a "prompt" burst of neutrons and then transferred to a counter for evaluation. The experiments are conducted at an isolated site in a building separated from the control room and all personnel by about a quarter of a mile.

On the occasion of the accident, preliminary bursts were being produced. In the process of lowering the top safety block, an unexpected burst occurred that was estimated to have produced 1.2×10^{17} fissions. The energy was great enough to tear the uranium parts from the assembly, knocking one to the floor, and to distort the steel rods in the frame. The uranium was deformed and there was much more surface oxidation than usual.

There were no personal injuries or overexposures. No gamma radiation above background was detected outside the reactor building. Radiation levels in the building were high initially . . . seven roentgens per hour gamma just inside the door (12' from Godiva) and 5,000 to 20,000 counts per minute (per 55 cm² probe) alpha on horizontal surfaces about the room; therefore cleanup procedures were delayed 2½ days until they could be completed without unnecessary exposure to cleanup personnel.

The total property loss was estimated at \$2,400. (See TID-5360, Suppl. 2, p. 18; *USAE C Health and Safety Information* Issue #75, 1-8-58.)

HONEYCOMB EXCURSION

Los Alamos, N. Mex., July 3, 1956

Too rapid assembly caused the system to become promptly critical. The burst yield was 3.2×10^{16} fissions.

There were no radiation exposures nor any property damage as a result of the incident.

EXPERIMENTAL REACTOR

Oak Ridge, Tenn., Feb. 1, 1956

A homogenous UO_2F_2 water-moderated critical assembly was made prompt critical by an overaddition of fuel to the assembly. Before reaching the critical point, the hand-operated valve was turned off. However, fuel continued to be added to the reactor because of air pressure in the line. Although the automatic safety system operated, assuring termination of the burst, considerable fuel was displaced from the reactor. The number of fissions in the burst was estimated to be about 1.6×10^{17} .

No serious exposures resulted, since all personnel were shielded by a minimum of five feet of concrete. There was no significant property damage and all uranium was recovered. (See TID-5360, Suppl. 1, p. 5.)

CORE MELTDOWN

Idaho Falls, Idaho, Nov. 29, 1955

The Experimental Breeder Reactor (EBR-I) was undergoing a series of experiments.

Without modification, certain safety instrumentation would not permit the conduct of the experiment; therefore, reliance was placed on manual control to shut down the reactor.

During an experiment, the scientist in charge told the operator to press the "emergency reactor off" button. This would have instantaneously removed sufficient reactivity. Owing to a misunderstanding, the operator began by withdrawing the control rods at normal speed. This allowed the reactor to reach a higher power than anticipated and resulted in consequent melting of the fuel elements.

Shortly after the accident, there was a rise in the radiation level in the building. The building was evacuated. There were no personnel injuries. There was minor contamination of the sodium potassium coolant. (See TID-5360, p. 30.)

BORAX I EXPLOSION

Idaho Falls, Idaho, July 22, 1954

Destruction of the Borax I Reactor released 135 MW-sec of fission energy.

More than 200 safety experiments were made on the Borax I Reactor simulating control rod accidents. For the last test, conditions were set up so that the reactor would be run to destruction.

The tests were carried out by withdrawing four of the five control rods far enough to make the

reactor critical at a very low power level. The fifth rod was then fired from the core by means of a spring. In this test, the rod was ejected in approximately 0.2 seconds. After the control rod was ejected, an explosion took place in the reactor which carried away the control mechanism and blew out the core. At half a mile, the radiation level rose to 25 mr/hr. Personnel were evacuated for about 30 minutes.

No one was injured and the destruction of the reactor was part of the cost of the experiment. (See TID-5360, p. 29.)

EXCURSION IN AN ENRICHED URANIUM WATER SOLUTION

Oak Ridge, Tenn., May 26, 1954

The experiment in progress at the time of the incident was one in a series designed to study criticality conditions of uranium-water solutions in annular cylindrical containers.

The cause of the accident was a displacement of the central tube, effectively a poison rod, to a region of less importance. This displacement resulted from a dislocation of the positioning spider by a pin, used to connect sections of the liquid level indicator rack, protruding beyond the side of the rack and engaging a leg of the spider as the indicator was raised. Removing the compressional force from the top of the central tube allowed it to fall against the inside of the 10-inch cylinder. Although the displacement was small, it was sufficient to cause a large increase in the effective neutron multiplication.

The safety system apparently operated normally and the reaction was stopped automatically. All personnel in the building during the incident were protected by a minimum of five feet of concrete shielding; therefore, no serious exposures were incurred. (See TID-5360, p. 18.)

SUPERCriticalITY EXPERIMENT

Los Alamos, N. Mex., Feb. 3, 1954

The incident occurred in the course of an extensive study of the properties of supercritical radiation bursts produced by an assembly of fissionable metal. This study was covered by a specific procedure. A reference check of critical conditions preceded each supercritical burst.

To attain rapidly sufficient power for a delayed critical check, it was customary to set control rods

at the position of minimum reactivity and insert a reactivity booster in the form of a fissionable metal slug. This time, when the booster was inserted, radiation indicators and the assembly temperature recorded went offscale (to return in a few minutes), and scrams were actuated. The resulting shock separated parts of the assembly and damaged steel supporting members.

There was no injury. The property loss was an expenditure of \$600 for repair of the assembly. (See TID-5360, p. 9.)

SUDDEN INCREASE IN REACTIVITY DURING CONTROL ROD TESTS

Lemont, Ill., June 2, 1952

Manual withdrawal of a control rod from a critical assembly caused an accidental super-criticality.

The operation being conducted was the comparison of a series of newly-manufactured control rods. The assembly had been operated with the standard control rod. It was then shut down by inserting all control rods and draining the water moderator, a standard safe method of shutting down the assembly when core changes are to be made. The standard rod was removed and the first of the series of control rods to be tested was inserted.

The assembly was filled with water with the test control rod fully in and the standard type control rods fully inserted. Withdrawal of one of the standard control rods 32 centimeters caused the assembly to become critical and the power was leveled off while the desired measurements were made. The control rod was then reinserted into the original "in" position.

With the water still in the assembly, the four members of the crew then went into the assembly room for the purpose of replacing the control rod which they had just tested. The group leader went up on the platform, reached out with his right hand and started to pull out the tested rod. As soon as he had withdrawn it about one foot, the center of the assembly emitted a bluish glow and a large bubble formed. Simultaneously, there was a muffled explosive noise. The group leader let go of the control rod which he was removing and it fell back into position. The crew left the assembly room immediately and went to the control room.

Four employees received radiation exposures ranging from 12 to 190 rem. (See TID-5360, p. 23.)

CRITICALITY RESULTS FROM ERROR IN CALCULATIONS

Los Alamos, N. Mex., Apr. 18, 1952

Two stacks of fissionable disks were being built up stepwise to give a slightly subcritical assembly with the two stacks brought together by remote control. The individual stacks were built up by hand in fixed assemblies and the two stacks brought together only by remote mechanisms.

After two members of the operating crew calculated erroneously from previous steps that one more disk could be added safely, the disk was added and, with attempted caution, the system was assembled remotely. Radiation indicators went offscale, actuating scrams, neutron counters jammed, and a puff of smoke was observed on the television viewer. Within three to five minutes indicators and counters returned to operating ranges.

There was no injury, no loss of material, no damage to facilities, and negligible loss of operating time. (See TID-5360, p. 7.)

EXCURSION IN A PLUTONIUM NITRATE SOLUTION

Richland, Wash., Nov. 16, 1951

Upon completion of volume measurements, it was thought that some additional information as to the required dilution could be determined by finding where criticality might occur on the rods. The control rod was pulled first with very minor reactivity effect. Following this, the safety rod was withdrawn intermittently at high speed (2.3"/sec). A waiting period for the delayed neutron effect of about 15 seconds was made just prior to the incident. This was too short a time to determine whether or not the assembly was critical. The operators next heard the safety controls actuate, instrument indicators moved offscale, scalers jammed, and the most startling manifestation was that of the breakdown of "counters" playing back through the public address system. The portable "Juno" in the control room was offscale. Presumably, a further rod withdrawal had been made.

There were no injuries. The building was successfully decontaminated, except for the test room and assembly. Before decontamination of this area was completed, a fire occurred and, subsequently, the building was abandoned because of the respread of contamination. (See TID-5360, p. 14.)

SCRAM MECHANISM CAUSES CRITICALITY

s Alamos, N. Mex., Mar. 20, 1951

Interactions between two masses of fissionable material in water were measured at progressively decreasing horizontal separations. Remotely controlled operations established the desired horizontal separation of the two components and flooded the system.

After the final measurement, the system was "scrammed" (a rapid disassembly mechanism was actuated). Safety monitor indicators went off-scale, neutron counters jammed, and the television viewer indicated steaming. Within a few minutes, indicators and counters returned to operating ranges and indicated a rapid decay of radiation.

There was no injury, no loss of material, and no damage to facilities. (See TID-5360, p. 13.)

CRITICALITY DURING CONTROL ROD TESTS

Los Alamos, N. Mex., December 1949

The reactor was being remodeled for higher power operation. As part of the required alterations, two new control rods had been placed in the system in addition to the three existing control rods.

The employee who had built the rod control mechanism wanted to test the comparative fall times of these new rods. He opened the enclosure on top of the reactor and manually lifted the rods, neglecting the possibility that this would affect the reactivity of the reactor because of its higher power arrangement. Heretofore, the three existing rods were sufficient for safety.

Normally, rods are raised remotely from the control room when the control panel is activated by a key switch. Since the rods were pulled out manually with the panel being off, no equipment was turned on except a direct reading temperature meter. Therefore, there were no neutron sensitive devices to record or warn of a rise in the neutron level. It was not observed until after the incident that the reactor temperature had risen about 25° centigrade.

The removal of the two rods probably gave a ΔK of about 0.86 percent, producing an initial period of about 0.16 second. Since the measured temperature coefficient is approximately -0.034 percent k/C° , the observed temperature rise indicates the rods were out sufficiently long so that the reactor was stopped by the negative temperature coefficient.

There were no injuries. The employee doing the work received 2.5 rem of gamma radiation according to his film badge. There was no damage done to the reactor and no loss of active material. (See TID-5360, p. 21.)

INADVERTENT SUPERCRITICALITY RESULTS IN DEATH

Los Alamos, N. Mex., May 21, 1946

A senior scientist was demonstrating the technique of critical assembly and associated studies and measurements to another scientist. The particular technique employed in the demonstration was to bring a hollow hemisphere of beryllium around a mass of fissionable material which was resting in a similar lower hollow hemisphere.

The system was checked with two one-inch spacers between the upper hemisphere and the lower shell which contained the fissionable material; the system was subcritical at this time.

Then the spacers were removed so that one edge of the upper hemisphere rested on the lower shell while the other edge of the upper hemisphere was supported by a screwdriver. This latter edge was permitted to approach the lower shell slowly. While one hand held the screwdriver, the other hand was holding the upper shell with the thumb placed in an opening at the polar point.

At that time, the screwdriver apparently slipped and the upper shell fell into position around the fissionable material. Of the eight people in the room, two were directly engaged in the work leading to this incident.

The "blue glow" was observed, a heat wave felt, and immediately the top shell was slipped off and everyone left the room. The scientist who was demonstrating the experiment received sufficient dosage to result in injuries from which he died nine days later. The scientist assisting received sufficient radiation dosage to cause serious injuries and some permanent partial disability.

The other six employees in the room suffered no permanent injury. (See TID-5360, p. 4.)

FATALITY FROM CRITICAL MASS EXPERIMENTS

Los Alamos, N. Mex., Aug. 8, 1945

During the process of making critical mass studies and measurements, an employee working in the laboratory at night alone (except for a guard seated 12 feet away) was stacking blocks of tamper material around a mass of fissionable material.

As the assembly neared a critical configuration, the employee was lifting one last piece of tamper material which was quite heavy. As this piece neared the setup, the instrument indicated that fission multiplication would be produced, and as the employee moved his hand to set the block at a distance from the pile, he dropped the block, which landed directly on top of the setup.

A "blue glow" was observed and the employee proceeded to disassemble the critical material and its tamper. In doing so, he added heavily to the radiation dosage to his hands and arms.

The employee received sufficient radiation dosage to result in injuries from which he died 28 days later.

The guard suffered no permanent injury. (*See* TID-5360, p. 2.)

UNANTICIPATED CRITICALITY IN WATER-SHIELDED ASSEMBLY

Los Alamos, N. Mex., June 4, 1945

An experiment was designed to measure the critical mass of enriched uranium when surrounded by hydrogenous material. The enriched uranium was in the form of cast blocks of the metal, $\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{1}{2}''$ and $\frac{1}{2}'' \times \frac{1}{2}'' \times 1''$. The blocks were stacked in a pseudospherical arrangement in 12 courses in a $6'' \times 6'' \times 6''$ polyethylene box. The voids in the courses were filled with polyethylene blocks of appropriate dimensions. The polyethylene box was supported by a 2-foot-high stool within a 3-foot cubical steel tank. The tank had a 2-inch opening in the bottom through which it could be filled and drained by means of supply and drain hoses attached to a $\frac{3}{4}$ -inch tee. The opening in the tank was fitted with a shutoff valve, as was the drain hose. A polonium-beryllium source of about 200 mc strength was placed on top of the assembly. A fission chamber and a boron proportional counter were used to follow the experiment.

The immediate supervisor was absent from the scene when the experiment was begun. Accord-

ing to one of the operators, the water level was raised above the polonium-beryllium source with the supply valve almost fully open. At this point, a slight increase in counting rate was observed, which corresponded with what had been observed previously when the source alone was immersed in water. A few seconds later, the counting rate began to increase at an alarming rate.

At this point, the supervisor returned, walked to within three feet of the tank and noted a blue glow surrounding the box. Simultaneously, the two operators were hastily closing the supply valve and opening the drain valve. The building was evacuated.

The three individuals involved received excessive radiation exposures, estimated in two cases as about 66.5 rem, and in the third as 7.4 rem. The doses delivered to the head and neck of these individuals may have been considerably greater. They were hospitalized for observation, but no untoward symptoms appeared. No significant changes in blood counts were observed, and sperm counts on one occasion, sometime after the incident, were normal. It is not believed that the individuals concerned received any significant radiation damage. There was no damage to equipment, no loss of active material, and no local contamination problem. (*See* TID-5360, p. 10.)

DRAGON REACTOR EXCURSION

Los Alamos, N. Mex., Feb. 11, 1945

This was the first reactor designed to generate prompt power excursions. Prompt critical was obtained by dropping a slug of UH_3 in styrex through a vertical hole in a small assembly of the same material, which was diluted with polyethylene and reflected by graphite and polyethylene. Near the end of the planned sequence of burst of increasing power, a 6×10^{15} fission burst blistered and swelled the small cubes comprising the assembly matrix. No material was lost, there was no contamination, and there were no exposures.

PART V

BEST NO-INJURY RECORDS KNOWN IN AEC ACTIVITIES

The following list, broken down into the six principal categories of work involved in the AEC's activities, shows the names of the top three contractors and field offices completing the largest number of continuous man-hours in their category without a disabling injury.

Contractor or Field Office and Location	Man-Hours	Dates
Production:		
The Dow Chemical Co., Rocky Flats Division, Golden, Colo.....	24, 295, 542	9-17-57 to 7-10-63
The Dow Chemical Co., Rocky Flats Division, Golden, Colo.....	11, 802, 581	2-20-65 to 12-30-66
General Electric Co., Hanford Atomic Power Operation, Richland, Wash.....	11, 270, 000	1-12-60 to 10- 3-60
Research:		
Westinghouse Electric Corp., Bettis Atomic Power Laboratory, West Mifflin, Pa..	19, 194, 917	10-27-62 to 11-22-65
Sandia Corp., Albuquerque, N. Mex.....	14, 936, 169	7-16-59 to 9- 6-60
Phillips Petroleum Co., Idaho Falls, Idaho.....	12, 921, 162	12- 5-62 to 1-13-66
Services:		
Lucius Pitkin, Inc., Grand Junction, Colo.....	1, 572, 944	12-12-60 to 12-31-67
The Zia Co., Los Alamos, N. Mex.....	1, 480, 774	11-23-54 to 7- 5-55
Management Services, Inc., Oak Ridge, Tenn.....	1, 462, 753	10-10-54 to 8- 7-55
Construction:		
E. I. du Pont de Nemours & Co., Inc., Augusta, Ga.....	4, 251, 396	2-26-57 to 12-30-57
E. I. du Pont de Nemours & Co., Inc., Augusta, Ga.....	3, 730, 361	2-22-54 to 4- 7-54
Peter Kiewit Sons' Co., Portsmouth, Ohio.....	3, 225, 186	3-31-55 to 5-25-55
Architect-Engineering:		
Hanford Engineering Services, Richland, Wash.....	1, 142, 862	5-15-63 to 3-31-67
Holmes & Narver, Inc., Las Vegas, Nev.....	942, 430	9-15-58 to 10-31-62
Giffels & Vallet, Inc., Oak Ridge, Tenn.....	475, 058	1- 1-53 to 12-31-54
Government:		
Richland Operations Office.....	4, 844, 125	3-28-51 to 3-10-58
Idaho Operations Office.....	4, 301, 828	1-22-62 to 5- 1-66
Chicago Operations Office.....	3, 721, 434	11-28-57 to 12- 3-64

APPENDIX A

FATALITIES

**Manhattan Engineer District—Atomic Energy Commission
1943–1967**

BRIEF DESCRIPTIONS OF FATALITIES

MED-AEC 1943-1967

No	Date	Field Office ¹ & Facility ²	Remarks
1	4-15-43	ALA-C	A plumber drowned when the driver of a pickup truck, in which ten men were riding, lost control of the truck and it overturned, landing in a water filled drainage ditch
2	5- 3 -43	CL-C	A laborer was crushed to death when he walked in front of a moving Caterpillar tractor
3	5- 5-43	CL C	While working under a railway cement car, a laborer was crushed to death when a mechanical failure caused the brakes to release the car and it ran over him
4	5-29-43	HA-C	While a truckdriver was servicing a dump truck with the bed in the raised position, the bed dropped, crushing his chest
5	7-26-43	HA-C	While a tractor was being operated, it dropped into an unbarricaded gravel pit, crushing the driver, a mechanic
6	7-26-43	CL-C	While working on a scaffold, a bricklayer suffered a broken neck when he was thrown 10' to the ground after the staging collapsed
7	7-28-43	HA-C	A heavy equipment operator was crushed by a Caterpillar when it dropped off the edge of the working area, throwing him onto the Caterpillar track which carried him over the front of the track and ran over him
8	7 28-43	CL-C	A lineman was electrocuted while working on a transformer platform when he placed his hand, protected by a canvas glove only, on a primary bushing which connected directly to an insulated neutral bus
9	8-16-43	CL-C	A laborer was decapitated by a Caterpillar drawn scraperpan which ran over him after he had slipped in soft dirt and fallen in the track of the machine
10	8-17-43	WR-C	A painter died of multiple internal injuries from a 25' fall to the ground when stepping through a door into a room where the temporary flooring had been removed, preparatory to the installation of the permanent flooring
11	8-19-43	CL-C	An oiler was crushed to death under the wheels of a railway freight engine where he was thrown from a truck The driver of the truck had started across the tracks at a railway crossing after the engine had passed, when the engine suddenly backed up and struck the truck
12	9- 9-43	CL-C	A brakeman was crushed to death under the wheels of a railway freight engine where he had fallen when he slipped while crossing in front of the drawbar
13	10- 3-43	HA C	The driver of a water tank truck stopped by the roadside to offer assistance to another trucker The driver of a third truck, attempting to avoid a head on collision, veered, striking both of the standing drivers, resulting in the death of the water tank driver from multiple internal and skeletal injuries The other driver fractured both legs
14	10 16-43	HA C	A lineman, in changing his position on a pole, erroneously thought his safety belt had "clicked" shut, and fell 26' He died from a fractured skull and brain injury
15	11- 2-43	CL-C	While standing on wet ground, a crane oiler was electrocuted when the crane boom contacted overhead wires
16	17- 9-43	HA-C	A truckdriver was riding in a tractor with an inexperienced driver The tractor skidded, causing the trailer to push the truckdriver into a windshield frame He died four days later as a result of a crushed chest and a collapsed lung caused by the accident
17	11-17-43	CL-C	A laborer was burned to death when his oil splashed clothing ignited after he had thrown fuel oil on an open fire He increased the intensity of the flames by running through an open field for help
18	11-20-43	HA-C	During the unloading of heavy structural steel from a freight car, a 24' steel column fell on a rigger, crushing his chest cage
19	11-29-43	CL-C	A laborer's chest was crushed when a wall section of an unshored 8 foot trench in which he was working caved in and covered him with dirt
20	1- 4-44	CL-C	The skull of a laborer was fractured when he was thrown from the bed of a convoy truck, with no tailgate, after the driver hit a small depression in a dirt road, causing the truck to lunge to one side
21	1-13-44	HA-C	The collision of two onsite railroad trains, operating in a fog, resulted in the deaths of two engineers, a conductor and a fireman from multiple internal and skeletal injuries
22			
23			
24			
25	2-11-44	CL C	Fatal injuries were suffered by a welder when the chain hoist broke and the suspended station wagon, under which he was working, fell across his back
26	2 14-44	CL C	The skull of a carpenter was fractured as the result of a 10' fall from a ladder after the ground, which had been frozen when the ladder was put in place, thawed sufficiently to allow one of the footings to settle and the ladder to slip
27	2 29-44	IO-O	A chemist was working on an experiment when a chemical explosion took place He died of multiple internal injuries
28	3 31-44	CL C	A carpenter received a fractured skull and brain injury when he fell 3', striking his head against a 12'x12' piece of lumber
29	3-24-44	CL-C	While standing near a crane, a carpenter was electrocuted when the crane boom contacted high voltage wires

See footnote at end of table

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943-1967

No	Date	Field Office ¹ & Facility ²	Remarks
30	5- 2-44	CL-C	During a welding operation in an elevator shaft, an ironworker was fatally burned in an explosion caused by a spark from his welding torch igniting oxygen remaining after the air had been purged
31	5- 4-44	CL-C	When a truckdriver lost control of the truck he was driving, it overturned and he was crushed under it
32	5 9-44	CL C	A truckdriver was crushed between the seat and the steering wheel of the Dumpster he was operating when a dump truck backed into him
33	5-27-44	CL-C	While standing on the unplaced end of a 24' steel I beam, an ironworker received fatal head and neck injuries when the beam end sheared off when he struck it with his sledge hammer to force it into place, causing him to fall into the angle formed by the beam and the upright column
34	6-12-44	DE-C	An electrician was fatally injured by receiving an electric shock caused by a short in a rectifier
35	6-14-44	HA C	Five welder chippers were crushed to death when a 49-ton steel tank fell upon them when its shoring failed
36			
37			
38			
39			
40	6-22-44	HA-C	While standing on a 4' pipe, a carpenter foreman fell 23' He died the following day of a fractured skull and brain injury received from the fall
41	7-11-44	CL-C	When a sheet metal worker crawled through an opening in the roof to pry open a hatch cover, he fell 35' through transite flooring to the cell floor He died from a fractured skull and brain injury
42	7-15-44	CL-C	An electrician was electrocuted while standing adjacent to exposed leads operating an electrical testing machine, when he threw the switch on the tester, energizing the cables, and his leg came into contact with the leads
43	7-17-44	HA-C	A machine operator was crushed between two 9400 lb concrete pipes, while engaged in storing the pipe
44	7-22-44	HA-O	While driving a pickup truck at a high rate of speed, the driver, an instrument engineer, was thrown from the truck and killed when it turned over twice He died of multiple internal and skeletal injuries
45	8-12-44	CL-C	Three crew members disappeared (presumed dead) when an airplane was lost Numerous searching missions failed to yield any evidence of plane or crew
46			
47			
48	8-17-44	CL-O	An electrician was electrocuted when he climbed upon the top of the cab in the course of repairing a crane and fell into a 440-volt bus
49	10-14-44	CL-C	A cement finisher received a fractured skull and brain injury from a 28½' fall through the transite cover over a floor opening
50	10-19-44	CL-C	A boilermaker received a fractured skull and brain injury in a 35' fall to a concrete floor when he lost his balance
51	10-25-44	CL-O	After testing motor field coils for faulty insulation, an electrician failed to open the switch to disconnect the current and was electrocuted when he removed the electrodes simultaneously with both hands
52	11 6-44	CL O	A low-voltage panel cover had been removed and the leads within the cubicle extended outside A serviceman, holding the leads in his hand, was startled when they contacted, creating an arc, causing him to strike his knee against the energized cubicle, resulting in his electrocution
53	11-11-44	CL C	When an ironworker lost his hold while descending between two joists from a scaffold, he fell 11' to a concrete floor, fracturing his skull
54	1 15-45	CL C	An ironworker and an inspector were crushed to death when a boom collapsed and the load and boom fell on them
55			
56	1-18-45	CL C	When a carpenter placed his hands, bearing the weight of his body, on the unsupported end of a scaffold, it tilted, throwing him 18' to the floor below He died from a fractured skull and brain injury
57	1-22-45	CL O	A millwright was burned to death when he drew gasoline from a welding generator into a metal pail, which contacted the energized terminal on the starter motor, causing a spark to ignite the gasoline
58	2- 6-45	CL-O	A millwright died as the result of the inhalation of chemical fumes while replacing a plug cock in a distillation line
59	4- 5-45	CL-C	An electrician was electrocuted when his arm contacted exposed terminals as he was drilling a hole in a panel box
60	5- 8-45	CL-O	A process operator was electrocuted when his arm made contact with a metal part of a circuit while he was cleaning glass in a tank

See footnotes at end of table

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943-1967

No	Date	Field Office ¹ & Facility ²	Remarks
61	6- 4-45	CL-C	An ironworker rigger was electrocuted when the rigging swung into a 13,800 volt powerline as he was steadying the load by holding to the choker line
62	6-11-45	CL-O	A carpenter was electrocuted while repairing a door hinge on an inoperative unit when he removed the insulated barrier from the adjacent operating unit and reached through the opening to tighten the nut holding the hinge assembly, and his hand contacted the current-carrying part
63	7- 2-45	CL-C	The chest cage of a rigger was crushed when a crane boom fell on him
64	7-23-45	CL-O	A painter was electrocuted when he lost his balance, and grasped a 460-volt trolley line and an I-beam and fell 9' to the floor
65	8- 4-45	CL-O	An electrician was electrocuted while repairing a light fixture when he contacted the circuit through the pliers in his right hand and the conduit in his left hand
66	8- 7-45	SF-G	A carpenter was crushed to death when a bulldozer, being used to push dirt onto the roof of a leanto shelter, was run onto the top of the shelter, collapsing the roof and burying him in the dirt that caved in
67	8- 8-45	SF-O	A physicist, working alone at night, caused an inadvertent criticality, which resulted in his receiving radiation from which he died 28 days later (See TID-5360, p 2)
68	9-12-45	HA-C	While riding in the back of a pickup truck, a laborer received fatal internal injuries when he was thrown out of the truck when it was hit by another truck
69	9-21-45	CL-C	A steamfitter was about to ascend a stairway when a piece of angle iron fell 35' from the floor above, fracturing his skull.
70	10- 9-45	CL-C	An electrician was electrocuted while conducting a dummy load test at a tank that had not been de energized. He neglected to use ground hooks before entering the unit, and his hand contacted the current when he attempted to attach the dummy load cable
71	11-14-45	CL-O	While working in a dimly lighted area, an inspector stepped into a duct to inspect a fan, unaware that the grating had not been installed, and fell 15' through the opening to the floor
72	11-19-45	CL-O	A baker was electrocuted while working in his bare feet washing the floor and hosing down the walls of a bakeshop when he contacted current from a defective ungrounded pedestal electric fan
73	2- 5-46	SF-G	A blacksmith was struck by a truck
74	3-19-46	SL-C	While installing a light fixture, an electrician fell approximately 7½' from a scaffold. He died from a fractured skull and brain injury
75	4- 4-46	CL-G	A guard drowned when he lost control of the jeep he was driving and ran off a bridge into a creek
76	5-21-46	SF-O	While demonstrating the technique of critical assembly, an inadvertent criticality occurred, resulting in the death nine days later of the demonstrator, a senior scientist (See TID-5360, p 4)
77	7- 1-46	SF-O	A truckdriver was killed when his truck turned over
78	8- 2-46	SF-O	An engineer was killed as the result of a chemical explosion
79	8- 7-46	SF-O	A tractor driver died from multiple internal injuries when he lost control of the tractor he was driving
80	8-10-46	HA-G	A pilot was killed in an airplane crash
81	10- 7-47	OR-O	An electrician was electrocuted when he contacted a 460-volt line which he assumed to be de energized
82	11-18-47	SF-O	An ironworker was electrocuted when a crane beam came into contact with a high tension line while he was attempting to block up the outriggers of the crane
83	11-28-47	OR-C	An oiler received fatal second and third degree burns when the hose from a gasoline tank truck sprayed gasoline on him, as well as on the surrounding area, after which fire from a nearby salamander ignited the gasoline
84	1943-46	SF-O	A junior scientist received chronic beryllium poisoning as a contractor employee between 1943 and 1946. He died in December 1947
85	3-18-48	SF-O	Speeding while driving resulted in an automobile accident which pinned the driver under the automobile. He died of a skull fracture and brain injury
86	3-29-48	HA-C	A truckdriver was pinned between the body and the frame of a concrete dump truck when the elevated body fell. He died of multiple internal and skeletal injuries
87	4- 9-48	OR-C	A runaway gondola car containing sand pinned a bin operator, working on a nearby cement car, under its wheels, crushing his chest
88	6-26-48	SF-O	A lineman was electrocuted while climbing a pole

See footnotes at end of table.

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943-1967

No	Date	Field Office ¹ & Facility ²	Remarks
89	7 31-48	HA-O	The driver of a weapons carrier was pinned between the ground and the rim of the steering wheel when the carrier went out of control and landed in a ditch. He died from a skull fracture and a crushed chest.
90	9-25-48	SF-C	An ironworker was electrocuted during the installation of electrical cables.
91	11-22-48	HA-G	A motor vehicle collision resulted in internal injuries to a records analyst. He died from pneumonia complications of his injuries five days later.
92	11-25-48	OR-O	During horseplay, a guard accidentally shot another guard in the abdomen, thinking the gun was unloaded.
93	12-13-48	OR-C	An air tool operator and a pipelayer died of suffocation as the result of the cave in of a newly dug trench.
94			
95	6-20-49	SF-C	A truckdriver was killed when the truck he was driving hit debris in the roadway and went out of control. The driver jumped from the truck and the truck passed over his body, crushing him.
96	6-29-49	CH-O	While working in a pit of a power plant steamline, a steam valve broke, enveloping a maintenance man in steam, resulting in fatal second and third degree burns.
97	8 26-49	SF-C	When a scaffold rope broke, a painter fell 26' to the bottom of a steel tank, striking his head, causing a basal skull fracture.
98	11-14-49	OR-O	A laborer died of multiple internal injuries received when he got caught between a truck and a loading platform.
99	11 23-49	HA-C	A piledriver operator fell 4' into a river and drowned.
100	12-1-49	SF-C	During the construction of a building wall, one section fell, killing an ironworker and injuring six others.
101	2 11-50	SF-G	Two security guards were killed in an airplane crash.
102			
103	4- 6-50	SF-C	A deckhand received foot injuries when his foot was caught between the deck of a boat and the guardrail of a tug. Complications of the injuries caused his death.
104	6-23-50	OR C	A laborer, cleaning cement residue from supporting beams while standing on a ladder, fell 18', striking his head on the concrete floor, causing a basal skull fracture.
105	8- 2-50	OR-C	An ironworker foreman was electrocuted when a crane boom contacted overhead energized wires as he was making a hitch.
106	8-31-50	SF-G	A warehouseman was riding on the running board of a pickup truck. When it became evident that the truck was going to collide head on with a bus, the warehouseman either jumped or fell from the truck into the path of the bus. He died of the internal injuries received.
107	9-21-50	OR-O	A tractor, being driven by a farm laborer, got out of control, turned over and crushed him to death.
108	11 29-50	SF-C	While working in a pipe trench, an air tool operator was crushed by a 16" pipe falling on him.
109	1- 2-51	SF C	A painter fell 45' from a scaffold fracturing his skull. (See USAEC SERIOUS ACCIDENTS Issue #1, 1-24-51.)
110	1-23-51	SF-C	A carpenter fell 23' from a fire tower striking the base of his skull on a concrete pad. (See USAEC SERIOUS ACCIDENTS Issue #2, 2-15-51.)
111	2 9-51	OR-O	A rigger died as a result of injuries received when his head was caught between two switchgear cabinets being loaded on a railroad car. (See USAEC SERIOUS ACCIDENTS Issue #2, 2-15-51.)
112	3- 8 51	OR C	While lowering a transformer section, a lineman's hands slipped off the hoist handle, which swung upward and struck him under the right eye. He died as a result of head and neck injuries. (See USAEC SERIOUS ACCIDENTS Issue #3, 3-16-51.)
113	3-18 51	SNR O	A laboratory employee was asphyxiated by the accidental presence of nitrogen in a process air line to which his respirator was attached. (See TID-5360, p. 9, USAEC SERIOUS ACCIDENTS Issue #4, 4-10-51.)
114	3-20-51	OR C	A truck driver was electrocuted when a crane boom came into contact with an energized electric powerline while he was helping adjust the cables of the crane.
115	3-20-51	ID C	While working on a water tower, a welder fell 15' when a truck was driven over a cable supporting the platform upon which he was standing, breaking the cable. He died of a fractured skull and brain injury. (See USAEC SERIOUS ACCIDENTS Issue #5, 4-12-51.)
116	4-11-51	SF-O	A painter died after using carbon tetrachloride in cleaning procedures prior to spraying with paint. (See USAEC SERIOUS ACCIDENTS Issue #8, 6-20-51.)
117	6-25-51	OR-C	During the cleaning procedures of a condenser being installed, the use of carbon tetrachloride resulted in the death of a millwright.
118	7 23-51	SR-C	A steamfitter suffered a heatstroke while helping to hook up a river suction pump.

See footnotes at end of table.

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943-1967

No.	Date	Field Office ¹ & Facility ²	Remarks
119 120	7-27 51	SF C	The head on collision of two 5,000 gal water tank trucks crushed the bodies of both drivers (See USAEC SERIOUS ACCIDENTS Issue #10, 8 24-51)
121	8-13 51	OR C	During the unloading of crane sections from a boxcar with a winch truck, one load fell on an ironworker foreman, resulting in his death from a skull fracture and brain injury (See USAEC SERIOUS ACCIDENTS Issue #12, 10-4 51)
122	8-13-51	SF-C	A mechanical engineer's chest was crushed when a dump truck he was directing backed over him
123	8 24-51	OR O	A lineman fell 15' while checking the output current of a lighting transformer. He died from a fractured skull and brain injury.
124	10-13 51	OR-C	While working 22½' aboveground, a carpenter stepped on a faulty board and fell, dying two days later as a result of head and brain injuries received in the fall
125	10-20-51	OR-C	When a sheetmetal worker stepped on an unsupported piece of metal roofing, he fell 41', resulting in his death from multiple internal and skeletal injuries
126	10-29-51	ID-C	The wall of a warehouse under construction was blown over by high winds, pinning a carpenter underneath it. He died as the result of a broken neck (See USAEC SERIOUS ACCIDENTS Issue #14, 1-3 52)
127	11-14 51	SR C	A traffic clerk was killed when the car he was driving got out of control and dropped into a 6' ditch. He died from a crushing injury to his chest with total transection of the aorta
128	11-14-51	SF C	A laborer was suffocated when he was buried alive under loose earth which was pushed down upon him by a bulldozer
129	11 21-51	CH O	A machinist was electrocuted when the boom of a crane came into contact with a live powerline as he lifted a floodlight from a truck, the current traveling through the boom and truck (See USAEC SERIOUS ACCIDENTS Issue #16, 1-11-52)
130	11-29 51	SR-C	An ironworker fell 70' when the unfastened board he was standing on was pushed off its bearing by the reactionary force of the impact wrench he was using. He died from a comminuted basal skull fracture (See USAEC SERIOUS ACCIDENTS Issue #17, 1-14-52)
131	12- 7 51	OR-C	An ironworker died from a skull fracture and brain injury in a 22' fall onto a concrete floor (See USAEC SERIOUS ACCIDENTS Issue #17, 1-14-52)
132	12-14 51	SR C	A carpenter died from a broken neck in a 28' fall when he removed a piece of plywood covering from a floor opening, and fell through the hole to the concrete floor below (See USAEC SERIOUS ACCIDENTS Issue #17, 1-14-52).
133	1-30-52	OR-C	A pipefitter's head was crushed when a dumptruck backed over him
134	3-13-52	SF-O	A truckdriver died of a compound fractured skull when a large magnet fell on him
135	3 21-52	OR-C	An ironworker was electrocuted when a crane hit live electric wires while he was guiding the crane with his hand on the load
136	3 27-52	SF-C	A heavy equipment foreman died of multiple internal and skeletal injuries when the track of a heavy crane passed over him (See USAEC SERIOUS ACCIDENTS Issue #25, 6 23-52)
137	5 26-52	SF C	An ironworker was crushed between the counterweight of a crane and the angle iron at the equipment box on the truck chassis of the crane (See USAEC SERIOUS ACCIDENTS Issue #25, 6-23-52)
138	7- 3 52	SF-C	An ironworker was electrocuted when the boom of a crane came into contact with a temporary distribution line while he was handling a steel column suspended from the crane
139	8 11 52	SF-C	While repairing a boat, a mechanic was electrocuted while handling an electric pump
140	9 4 52	OR-C	A painter was killed, during the moving of a scaffold, when he fell 45' to the concrete floor, fracturing his skull (See USAEC SERIOUS ACCIDENTS Issue #35, 1-7-53)
141	9-18-52	GJ O	An equipment operator apparently fell asleep while driving a jeep and was killed when the jeep struck a bridge abutment. He died of a skull fracture and brain injury (See USAEC SERIOUS ACCIDENTS Issue #31, 10 15-52)
142	9-29 52	OR-C	A laborer hauling concrete fell 29' when a concrete hauling cart started moving backward, causing him to be pushed off the platform on which he was standing. He died of a skull fracture and brain injury
143	11- 8 52	OR C	A crane flagman was struck by a dirt loading truck when he stepped in its path after signaling its driver to proceed. He died of multiple internal injuries
144	1-14 53	OR-C	While repairing a road scraper, which was blocked up, a welder was pinned under the machine when the blocking gave way. He died two days later from multiple internal injuries
145 146	3 6 53	SR-C	While spray painting a pump intake basin, two employees received fatal second and third degree burns during a flash fire, probably caused by the ignition of the flammable solvent in the paint by an open light bulb (See USAEC SERIOUS ACCIDENTS Issue #42, 3-24 53)

See footnotes at end of table.

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943-1967

No.	Date	Field Office ¹ & Facility ²	Remarks
147	3-17-53	OR C	The right wheels of a dump truck ran over an operating engineer when he stepped into its path as it was backing up. He died of multiple internal injuries.
148	4-27-53	HA-C	An equipment operator was crushed against a concrete basin wall by the counterweight of a crane. (See USAEC SERIOUS ACCIDENTS Issue #49, 6-30-53)
149	6-16-53	HA-C	A rigger died as the result of multiple internal injuries received in a fall from a flatbed truck.
150	6-20-53	OR C	A truckdriver was standing beside a truck crane when the crane swung around, struck him in the head, and threw him between the counterweight and the truck cab, crushing his head (compound fracture of the skull). (See USAEC SERIOUS ACCIDENTS Issue #49, 6-30-53)
151	9-15-53	OR-C	A pipefitter was crushed between the counterweight and frame of a crane truck. (See USAEC SERIOUS ACCIDENTS Issue #56, 12-15-53)
152	9-19-53	HA-C	While working on steel girders at the 90' level and attempting to move a scaffold plank, it swung upward, striking a steel construction foreman in the face, throwing him off balance and he fell. He died of multiple internal and skeletal injuries.
153	10-15-53	SR-C	An ironworker fell 50' while engaged in removing an air duct. He died as a result of a fractured skull and brain injury.
154	10-30-53	HA-C	An operator received a compound skull fracture when the bulldozer he was driving overturned, pinning him underneath. (See USAEC SERIOUS ACCIDENTS Issue #54, 12-2-53)
155	1-14-54	OR-C	An ironworker fell 21' from a steel girder while engaged in bolting procedures. He died of a fracture at the base of his skull.
156	1-29-54	HA-C	An electrician fell 9' from a scaffold. He died as a result of a fractured skull and brain injury. (See USAEC SERIOUS ACCIDENTS Issue #62, 3-23-54)
157	2-18-54	SF-C	An electronics technician was electrocuted while disconnecting an energized 110 volt power lead when his body came into contact with grounded equipment. (See USAEC SERIOUS ACCIDENTS Issue #66, 7-7-54)
158 159	3-15-54	NY-O	Two pilot plant operators died as a result of second and third degree burns received in a chemical explosion. (See USAEC SERIOUS ACCIDENTS Issue #63, 6-9-54)
160	3-17-54	NY-C	A crane backed over an oiler, crushing his entire body.
161	5-5-54	OR-C	A laborer's chest and trunk were completely crushed between a dump truck tailgate and a Gradall while giving a truck driver signals.
162	5-19-54	OR-C	A welder fell from the roof, through a ventilator shaft, 82' to the ground, receiving multiple internal and skeletal injuries from which he died two days later.
163	5-24-54	HA-C	A cement finisher fractured his skull in a 25' fall through an access hole to a concrete floor.
164	6-5-54	GJ C	A laborer's chest and trunk were completely crushed between the boom of a crane and the forms into which he was helping to pour concrete.
165	7-30-54	OR-O	A lineman was electrocuted while working on a street lighting circuit from the platform of a ladder truck.
166	8-9-54	OR-O	A plumber received fatal injuries (crushed chest and lacerations of left lung) when he fell 38' from a 24" pipe.
167	8-11-54	SF-O	A supervisory employee broke his neck in a 25' fall from a built-in iron ladder to the concrete floor in a power generating plant.
168	8-18-54	OR-O	An electrician was electrocuted while handling a 115-volt extension cord.
169 170	9-7-54	SR-O	Two maintenance mechanics, removing a blank flange from a rundown tank, released toxic gas and scalding liquid, resulting in extensive second and third degree burns of their entire bodies, causing their deaths. (See USAEC SERIOUS ACCIDENTS Issue #72, 10-19-54)
171	10-12-54	OR-O	A chemical operator fell 20' to a concrete floor. He died as a result of a fractured skull and brain injury. (See USAEC SERIOUS ACCIDENTS Issue #79, 3-21-55)
172	11-16-54	OR C	While climbing a ladder, a pipefitter fell 17' to the concrete floor below, fracturing his skull and causing brain injury.
173	4-2-55	SF-C	An asbestos worker received a fractured skull when he was struck on the head by a piece of 4" iron pipe thrown from the top of a water tower 30' above ground.
174	5-2-55	OR-C	An ironworker received a compound fractured skull and brain injury when he slipped from a ladder, falling 50' to the concrete floor.
175	6-6-55	SF-G	An equipment operator was crushed to death when a pickup truck he was driving turned over, pinning him in the truck.
176	7-29-55	SF-O	A hot mix plant operator was electrocuted when he touched the load and the load line cable of the crane contacted an overhead powerline.

Footnotes at end of table.

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943-1967

No.	Date	Field Office ¹ & Facility ²	Remarks
177	8-30-55	HA-O	An explosion occurred in an electric furnace, causing hot dry salt to be blown into the face of the operator, who died as a result of second and third degree burns. (See USAEC SERIOUS ACCIDENTS Issue #88, 10-14-55.)
178	9- 9-55	GJ-O	A utility man suffocated in a fine ore bin while trying to determine why the ore was not feeding into the conveyor belt when an undermined area gave way, killing him by suffocation. (See USAEC SERIOUS ACCIDENTS Issue #98, 3-22-56).
179 180	10-16-55	OR-O	Two chemical operators suffocated in a tank during degreasing operations involving the use of Freon-113. (See USAEC SERIOUS ACCIDENTS Issue #91, 11-30-55).
181	11-22-55	NY-O	A cyclotron operator was electrocuted while investigating the cause of the trouble in a modulator circuit. (See USAEC SERIOUS ACCIDENTS Issue #96, 3-19-56).
182	11-25-55	HA-O	A coal handler suffocated when the coal slid, covering him, as he prodded it with a bar. (See USAEC SERIOUS ACCIDENTS Issue #98, 3-22-56).
183	4-11-56	OR-C	During the installation of girders, an ironworker was thrown off balance as a crane load dropped suddenly, causing him to fall 17' to the ground. He died as a result of a broken neck.
184 185	5-14-56	OR-O	Zirconium drums exploded, followed by fire, resulting in second and third degree burns to two salvage handlers, both of whom died as a result of their burns. (See USAEC ACCIDENT AND FIRE PREVENTION INFORMATION Issue #44, 6-20-56).
186	6-26-56	AL-O	The accidental detonation of an experimental explosive caused fatal multiple blast injuries to a technician.
187	7- 2-56	NY-O	A chemical engineer died as a result of extensive second and third degree burns received in a fire following a thorium explosion. (See TID-5360, Suppl. 1, p. 16; USAEC SERIOUS ACCIDENTS Issue #107, 8-20-56).
188	7-24-56	AL-C	A labor relations director was killed when the car he was driving overturned on a curve. He died from a crushed chest and internal injuries.
189	8-26-56	CH-O	An ironworker was electrocuted when a truck crane struck and broke an overhead high-voltage line. (See USAEC SERIOUS ACCIDENTS Issue #112, 11-16-56).
190	9-19-56	AL-O	A pipefitter received internal crushing injuries when a truck backed over him while he was working on a hydrant. (See USAEC SERIOUS ACCIDENTS Issue #113, 12-7-56).
191	1-29-57	OR-C	A millwright was electrocuted while helping to move a cover plate assembly fixture into position when it came into contact with two power cables. (See TID-5360, Suppl. 2, p. 7; USAEC SERIOUS ACCIDENTS Issue #120, 5-17-57).
192	3-11-57	OR-C	A rigger was electrocuted when a boom on a crane contacted a 13,800-volt feeder line while he had hold of a pipe being lifted by the crane. (See TID-5360, Suppl. 2, p. 8).
193	6-22-57	AL-O	A surveyor was killed when his body was thrown 40' from a car which overturned several times after he lost control of it. He died from multiple skull and internal injuries. (See TID-5360, Suppl. 2, p. 8).
194	8- 1-57	GJ-G	A geologist died of multiple skull and internal injuries received in an airplane crash. (See TID-5360, Suppl. 2, p. 9).
195	12- 4-57	SR-O	An area engineer was thrown out of the car he was driving when it collided with a train, which he apparently did not see until it was too late. He died of multiple skull and internal injuries. (See TID-5360, Suppl. 2, p. 9).
196	1-13-58	WASH-G	A project officer was killed in a motor vehicle accident.
197	4- 7-58	SAN-O	A nuclear physicist was drowned when a helicopter crashed in the ocean. (See TID-5360, Suppl. 2, p. 10).
198	6-17-58	AL-C	A laborer died from a fractured skull and brain injury when two tons of rock fell on him. (See TID-5360, Suppl. 2, p. 10).
199	8-25-58	AL-C	A lineman was electrocuted while chipping rust on a switch. (See TID-5360, Suppl. 2, p. 11).
200	12-18-58	OR-C	A laborer was asphyxiated when trapped under 192 cubic feet of earth when a trench wall toppled. (See TID-5360, Suppl. 2, p. 11).
201	12-30-58	AL-O	A chemical operator died as the result of radiation received during a criticality accident. His whole-body exposure was 12,000 rem $\pm$ 50%. (See TID-5360, Suppl. 2, p. 30; USAEC SERIOUS ACCIDENTS Issue #143, 1-22-59).
202 203	2-24-59	AL-O	A machine operator and a toolmaker were blown to fragments when the explosives they were machining detonated. (See TID-5360, Suppl. 3, p. 26).
204	4-10-59	HA-C	While attempting to move himself along a 4" pipe which he was straddling, a boilermaker rigger lost his balance and fell 50'. He died from a skull fracture and brain injury. (See TID-5360, Suppl. 3, p. 27; USAEC SERIOUS ACCIDENTS Issue #146, 7-15-59).
205	5-13-59	ID-C	When the overhead tielines of the scaffold upon which a sheetmetal man was working were removed, the scaffold crashed to the concrete floor, causing him to fall 60'. He died from multiple internal and skeletal injuries. (See TID-5360, Suppl. 3, p. 27; USAEC SERIOUS ACCIDENTS Issue #146, 7-15-59).

See footnotes at end of table.

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943-1967

No	Date	Field Office ¹ & Facility ²	Remarks
206	8 7-59	OR-C	An electrician was electrocuted while attempting to start an arc welder at a time when the ground was wet and charged with electricity (See TID-5360, Suppl 3, p 28, USAEC SERIOUS ACCIDENTS Issue #149, 10-9-59)
207	10-14-59	AL-O	Four laborers were killed while unloading explosives scraps at a burning ground when the explosives inadvertently exploded. They died from multiple blast injuries (See TID-5360, Suppl 3, p 29)
208			
209			
210			
211	12- 2-59	AL-O	A medical administrator was killed in an automobile collision when an oncoming car tried to pass another vehicle and hit his car head on. He died from multiple internal injuries (See TID 5360, Suppl 3, p 29)
212	12-18 59	CH-O	A reactor assembly inspector was asphyxiated while taking measurements, without proper respiratory equipment, on the bottom of an argon filled pit (See TID-5360, Suppl 3, p 30, USAEC SERIOUS ACCIDENTS Issue #159, 1 13 60)
213	12 23 59	AL C	A broken pendant line on a crane caused a one-cubic-yard bucket of concrete to fall on a laborer, crushing him (See TID-5360, Suppl 3, p 31)
214	1 29-60	AL-O	A skindriver, engaged in placing dynamite charges under water, drowned (See TID-5360, Suppl 3, p 31)
215	3 18-60	AL-C	A kitchen helper slipped while carrying a 20 gal container of hot soup, and died of uremia, a direct complication of the burns he received (See TID-5360, Suppl 3, p 32)
216	4 13-60	NY-C	A carpenter, while standing on a 36" wall, lost his balance and fell 20' to a concrete floor. The cause of death was a fractured cervical vertebrae and a crushed chest (See TID-5360, Suppl 3, p 32)
217	8-31 60	ID C	A painter, engaged in painting railings, ladders and cages on a silo, fell 70' to the ground. He died from a skull fracture (See TID 5360, Suppl 3, p 33)
218	1- 3 61	ID-O	All three members (military) of an operating crew were killed when a reactor excursion occurred. The three men died of multiple blast skeletal and internal injuries (See TID-5360, Suppl 4, p 8, 1962 NUCLEAR SAFETY, Vol 3, #3, p 64)
219			
220			
221	1-24-61	AL-O	While working atop a bunker, a physics laboratory technician lost his balance and fell backward over the edge of the bunker 10' to a concrete pad. He died of severe brain damage and brain hemorrhage resulting from the fall (See TID-5360, Suppl 4, p 27, USAEC SERIOUS ACCIDENTS Issue #173, 2 24-61)
222	2- 2-61	AL-O	A technician died of multiple internal injuries received in a head-on collision when the car he was driving veered (cause unknown) to the wrong side of the road (See TID-5360, Suppl 4, p 28)
223	2-14-61	AL-O	A fabrication technician was asphyxiated by solvent vapors (methyl chloroform) while working alone inside of a vacuum annealing furnace shell (See TID-5360, Suppl 4, p 28, USAEC SERIOUS ACCIDENTS Issue #174, 2 28-61)
224	3-10-61	OR-C	While two tower erectors were helping to erect the top beam section of an instrument tower, the top 70' of the tower broke off, catapulting both employees 145' to the ground. One employee died from a broken neck the day of the accident, the other employee died almost a year later from complications of internal injuries received from the fall (See TID-5360, Suppl 4, p 29)
225			
226	3-16-61	PNR-C	While engaged in painting a ceiling, the scaffold, upon which a painter was standing, collapsed, and he fell 15' to the floor below, fracturing his skull and causing brain hemorrhage (See TID-5360, Suppl 4, p 29)
227	8-14-61	HA-O	A heavy equipment operator was killed when a tractor, out of control, rolled backwards over him, crushing his body (See TID-5360, Suppl 4, p 29)
228	9- 7-61	AL-O	A group leader was thrown out of a car he was driving when it overturned. He died of a fractured skull and brain injury (See TID-5360, Suppl 4, p 30)
229	1-22-62	SR-C	A carpenter, atop a 2600-lb concrete form, was crushed to death between the form and the steel mat when the form fell away from its reinforcing steel, carrying him with it (See TID-5360, Suppl 4, p 31, USAEC SERIOUS ACCIDENTS Issue #182, 5-24-62)
230	3-18-62	OR-O	An explosion in a metal reduction furnace sprayed hot liquid on two operators, one of whom died 12 days later of extensive second and third degree burns on 70% of his body. The other operator, although severely burned, survived (See TID-5360, Suppl 4, p 31)
231	3-23-62	OR-C	A pipeman's chest cage was crushed when a large, solid section of a trench caved in upon him (See TID-5360, Suppl 4, p 32, USAEC SERIOUS ACCIDENTS Issue #183, 6-1-62)
232	3-29-62	CH-C	A pipefitter fractured his skull in a 21' fall while walking on an 18" pipe (See TID-5360, Suppl 4, p 32)
233	6-20-62	OR-O	While two coal handlers were using rods to break a bridge formation in a coal pile, the pile suddenly gave way, The men were covered with coal, one escaped, the other died of suffocation (See TID-5360, Suppl 4, p 32)

See footnote at end of table.

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943—1967

No	Date	Field Office ¹ & Facility ²	Remarks
234	8-15-62	OR-O	An electrical maintenance supervisor died nine days after receiving second degree burns when an explosion occurred during routine maintenance of a circuit breaker tank (See TID 5360, Suppl 4, p 33, USAEC SERIOUS ACCIDENTS Issue #189, 11-19 62)
235	10- 7-62	NV-O	A fireman was thrown out of a power wagon when it overturned He died of a fractured skull and a brain injury (See TID-5360, Suppl 4, p 33)
236	1- 5-63	CH-O	A shift supervisor died of internal injuries and a basal skull fracture resulting from a 54-foot fall when he stepped backward into an open shield plug hole while giving signals to a crane operator (See TID-5360, Suppl 5, p 39, USAEC SERIOUS ACCIDENTS Issue #204, 5 13-63)
237	2-16-63	NV-C	During excavation work, a construction worker was crushed by a Caterpillar when the entire length of the Caterpillar tread ran over his body, causing multiple internal injuries (See TID 5360, Suppl 5, p 40)
238	4-30-63	OR-O	While testing an ion source on a developmental power supply, a physicist was electrocuted (See TID-5360, Suppl 5, p 40)
239	6-25-63	SNR-C	A carpenter fell 65' from a cooling tower The cause of death was a compound fractured skull, broken neck and multiple internal injuries with massive hemorrhage (See TID-5360, Suppl 5, p 40)
240	6-25-63	NY-O	While an operator's helper was kneeling on the top of a box, being moved by a forklift truck, to counterbalance the over hanging weight, the box tipped forward and he fell to the ground He was reported to have died of a pulmonary embolism 17 days after the accident (See TID 5360, Suppl 5, p 41, USAEC SERIOUS ACCIDENTS Issue #213, 11 8 63)
241	7-23-63	OR-C	An apprentice pipefitter was asphyxiated while checking for an inert gas leak in a valve pit (See TID-5360, Suppl 5 p 42, USAEC SERIOUS ACCIDENTS Issue #223, 4-3-64)
242	8- 1-63	OR-C	While an ironworker was climbing down a rolling-type scaffold, the scaffold began to swing and fold, finally toppling to the floor He held on until the scaffold was about halfway down, then fell the remaining distance to the concrete floor, dying five days later as a result of multiple skull fractures (See TID-5360, Suppl 5, p 42, USAEC SERIOUS ACCIDENTS Issue #218, 2 14-64)
243	7-10-63	NV-C	A custodial employee suffered a fatal pulmonary embolism as the result of injuries (femoral vein thrombosis) received in an automobile accident three months earlier (See TID-5360, Suppl 5, p 41)
244	9-26-63	AL-O	When a truck backed over a can of paint thinner, the can ruptured, spraying the contents on a laborer's clothing Flames from a dump fire ignited his coveralls, and he died about six weeks later as a result of the chemical burns received (See TID-5360, Suppl 5, p 42)
245	3-11-64	SAN-O	An electronics coordinator died as the result of a skull fracture received when the car in which he was driving overturned when he failed to manipulate a curve (See TID-5360, Suppl 5, p 43, USAEC SERIOUS ACCIDENTS Issue #234, 10-23-64)
246	4-21-64	NV-C	A teamster was crushed to death beneath an 8,000-gallon water tanker which he was driving when it got out of control (See TID-5360, Suppl 5, p 44)
247	7- 1-64	AL-C	A roofer died three days after a fall 22' from a flat roof from injuries sustained in the fall (See TID-5360, Suppl 5, p 44)
248	9-19-64	NV-C	Electrical cables were being lowered into an underground complex when a drill rig cable broke causing the cable spools to be jerked from their racks Four men were hit by the spools, one receiving extensive head and chest injuries from which he died The other three received multiple contusions and abrasions (See TID-5360, Suppl 5, p 44)
249	9-23-64	SAN-C	A drill rig crew member was electrocuted when a rig boom contacted overhead electric powerlines (See TID-5360, Suppl 5, p 45, USAEC SERIOUS ACCIDENTS Issue #238, 12-15-64)
250	12-15-64	NV-C	When a drill rig assembly failed, allowing the swivel assembly pipe to fall, the rig operator was killed instantly from a crushing blow on the head (See TID-5360, Suppl 5, p 46)
251	12- 8-64	RL-O	A track maintenance man died two weeks after an accident in which the maintenance car in which he was riding had a head-on collision with a locomotive He died from a fractured skull and brain injury (See TID-5360, Suppl 5, p 45)
252	1-28-65	NV-C	A rotary drill helper was killed instantly when a "finger" (a 4' length of 4" pipe weighing 87 lbs) fell 85' from the finger-board of the mast of a drill rig, striking him on the head, neck, and shoulders The cause of death was depressed occipital skull fracture with a 4" laceration of the scalp (See TID-5360, Suppl 6, p 49)
253	2-23-65	NV-C	A wireman foreman was electrocuted while working in a switchgear cabinet (See TID-5360, Suppl 6, p 41)
254	6-14-65	OR-O	A lineman was fatally injured when he fell 18' from an electric pole to the sidewalk Investigation revealed that his body belt was unbuckled The cause of death was a fractured skull (See TID-5360, Suppl 6, p 41, USAEC SERIOUS ACCIDENTS Issue #252, 8-27 65)
255	6-21-65	NV-C	An employee suffered fatal injuries when he fell 24' from a derrick platform to a concrete pad The cause of death was severe depressed skull fracture, frontal region, multiple fractures both arms, possible internal injuries (See TID-5360, Suppl 6, p 41)

See footnote at end of table

BRIEF DESCRIPTIONS OF FATALITIES—Continued

MED-AEC 1943-1967

No	Date	Field Office ¹ & Facility ²	Remarks
256	7- 5-65	NY-O	An explosion and fire occurred in the experimental hall of an accelerator complex. Eight persons were injured, one of whom died fifteen days later as the result of third-degree burns over 60% of the body and of a ruptured liver. (See TID 5360, Suppl. 6, p. 42, TID-22594)
257	12-23-65	SAN-C	A six ton concrete plank fell, seriously injuring one employee and crushing another to death. (See TID-5360, Suppl. 6, p. 43)
258	1-11-66	NV-C	A miner died thirteen days after being struck on the top of the head by a falling rock. His death was caused by respiratory failure due to transverse myelitis of the cervical cord caused by the injury. (See TID 5360, Suppl. 6, p. 44)
259	1-12-66	SNPO-N-C	An employee died of third degree burns over 100% of the body surface as the result of inadvertent ignition of gasoline and acetate recording tapes in preparation for disposal in a burn pit. (See TID-5360, Suppl. 6, p. 44, USAEC SERIOUS ACCIDENTS Issue #263, 5-27-66)
260	5- 1-66	AL-O	An employee died from crushing injuries to chest and head in a head on motor vehicle collision while driving a Government owned car. (See TID 5360, Suppl. 6, p. 45)
261	5-26-66	AL-C	While painters were engaged in spray painting the outside and top surfaces of a water storage tank, one painter stepped backward into an opening on the tank top, and fell 35' to the bottom of the tank. The cause of death was a fractured skull. (See TID-5360, Suppl. 6, p. 45)
262	6-10-66	NV-C	An employee died on July 16 of a pulmonary embolism suffered as a complication of injuries (compound fracture of the right ankle, fracture of the right shoulder, scalp lacerations) received on June 10, when a bucket fell on him during the filling of sand bags. (See TID-5360, Suppl. 6, p. 46)
263	6-17-66	NY-G	Two employees were involved in a single-car accident, one died eight days later as the result of brain and chest injuries, the other received only minor injuries. (See TID-5360, Suppl. 6, p. 47)
264	6-24-66	SAN-C	An employee was killed when the dirt loader he was operating overturned and crushed him. (See TID-5360, Suppl. 6, p. 47)
265	9-22-66	AL-C	A crane moving a steel stanchion contacted an 11,000-volt powerline. The employee guiding the stanchion into place died a few hours later as the result of the electric shock he received. (See TID-5360, Suppl. 6, p. 48)
266	10-12-66	AL-C	An electrician was electrocuted while working alone on a transformer. (See TID-5360, Suppl. 6, p. 49)
267	3-11-67	SR-O	During normal railroad car switching movements, an employee fell under a moving train and was decapitated. Since there were no witnesses, the cause was not determined.
268	4- 5-67	AL-O	When his foot slipped while servicing a tractor, an employee fell 7' to the ground. Surgery was performed the following day to pin the fracture of neck of left femur that resulted from the fall. He appeared to be recovering satisfactorily when he died unexpectedly five days after the accident of a pulmonary embolism secondary to the injury sustained.
269	4-10-67	AL-O	A painter fell 14' from a roof to the ground when, apparently, he slipped on a freshly painted area. He died six days later of a fat embolism secondary to fractures of the pelvis and arm.
270	4-14-67	RL-C	A clamshell bucket assembly toppled over, striking an employee on the neck and shoulder and driving him to the ground, the arm of the assembly coming to rest on his chest. He died immediately. Post mortem examination revealed the cause of death as ruptured aorta at aortic arch. (See USAEC SERIOUS ACCIDENTS Issue #282, 7-28-67)
271	5-25-67	SNPO-C-O	A laboratory technician was found dead inside a core leaching furnace. Evidence indicates the employee climbed down into the furnace to retrieve a brush. Death was due to resultant asphyxiation from fumes.
272	6- 9-67	SAN-O	A fireman was helping to unload a firefighting vehicle from a trailer. It is not known what happened, however, evidence indicated that he jumped from the trailer truck, crashing into the windshield of a passing police car. The fatal injuries were a fracture of the base of the skull and a broken neck.
273	6-30-67	NV-C	Two miners were working at the bottom of a 3,200-foot hole when, without warning, a strong surge of muck and water flowed into their working area. One miner drowned immediately, the other was found alive, buried up to his neck in the muck and water, but drowned before he could be extricated.
274			
275	7- 8-67	NV-C	An employee was steadying a row of 21 stored doors while another employee removed two of them. The doors suddenly shifted and fell over on the first man, crushing his head against shelving behind him. He was pronounced dead at the scene. The cause of death was multiple skull fractures with severe intracerebral hemorrhages causing central respiratory paralysis.
276	7-17-67	ID-C	A carpenter fell more than 13' when he attempted to climb down on the forms inside a containment vessel under construction. He was found conscious, although paralyzed completely from the neck down. He suffered severe neck, back, and leg injuries, in addition to shock, and he died the next day.

¹ Field Offices

ALA—Alabama Ordnance Works
AL—Albuquerque Operations Office
BH—Brookhaven Office
CH—Chicago Operations Office
CL—Clinton Engineer Works
DE—Decatur Area
GJ—Grand Junction Office
HA—Hanford Operations Office
ID—Idaho Operations Office

IO—Iowa Area
NV—Nevada Operations Office
NY—New York Operations Office
OR—Oak Ridge Operations Office
PNR—Pittsburgh Naval Reactors Office
RL—Richland Operations Office (Formerly HA)
SAN—San Francisco Operations Office
SF—Santa Fe Operations Office
SNPO—C—Space Nuclear Propulsion Office—

Cleveland
SNPO—N—Space Nuclear Propulsion Office—
Nevada
SNR—Schenectady Naval Reactors Office
SR—Savannah River Operations Office
WASH—Washington Headquarters
WR—Wabash River Ordnance Works

² Facilities C—Construction G—Government O—Operation

APPENDIX B

RADIATION EXPOSURES OVER 15 REM
(Whole-Body)

Atomic Energy Commission 1947–1967

FATAL RADIATION EXPOSURE ACCOMPANIES CRITICALITY ACCIDENT

**Los Alamos, N. Mex., Dec. 30, 1958—12,000
($\pm 50\%$), 134, and 53 rem**

After placing emulsion in a tank, the operator was believed to have added a dilute plutonium solution from a second tank. Solids containing plutonium were probably washed from the bottom of the second tank with nitric acid and the resultant mixture of nitric acid and plutonium-bearing solids added to the tank containing the emulsion. Shortly after starting the stirrer motor to initiate an expected mild nonnuclear reaction between the emulsion and the acid, the operator observed a "blue flash", also observed by an employee in an adjoining room.

The employee died 35 hours later from the effects of a radiation exposure tentatively estimated at 12,000 rem ($\pm 50\%$).

Two other employees received radiation exposures of 134 rem and 53 rem, respectively. Property damage was reported as negligible. (See TID-5360, Suppl. 2, p. 30; *USAE C Serious Accidents Issue* #143, 1-22-59.)

RADIATION EXPOSURES ACCOMPANY CRITICALITY ACCIDENT

**Oak Ridge, Tenn., June 16, 1958—461, 428, 413,
341, 298, 86, 86, and 29 rem**

A nuclear accident occurred in a 55-gallon stainless steel drum in a processing area in which enriched uranium is recovered from various materials by chemical methods in a complex of equipment. This recovery process was being remodeled at the time of the accident.

The incident occurred while they were draining material thought to be water from safe 5-inch storage pipes into an unsafe drum.

Eight employees were in the vicinity of the drum carrying out routine plant operations and maintenance. A chemical operator was participating in the leak testing which inadvertently set off the reaction. He was within three to six feet of the drum, while the other seven employees were from 15 to 50 feet away.

Using special post hoc methods for determining the neutron and gamma exposures of the employees involved, it was estimated that the eight men received: 461 rem, 428 rem, 413 rem, 341 rem, 298 rem, 86 rem, 86 rem, and 29 rem.

Area contamination was slight, with decontamination costs amounting to less than \$1,000.

During this incident 1.3×10^{18} fissions occurred. (See TID-5360, Suppl. 2, p. 25; *USAE C Serious Accidents Issue* #136, 8-25-59; *USAE C Health and Safety Information Issue* #82, 9-5-58: 1959 *Nuclear Safety*, Vol. 1, #2, p. 59.)

SUDDEN INCREASE IN REACTIVITY DURING CONTROL ROD TESTS

Lemont, Ill., June 2, 1952—190, 160, and 70 rem

Manual withdrawal of a control rod from a critical assembly caused an accidental supercriticality.

The operation being conducted was the comparison of a series of newly-manufactured control rods. The assembly had been operated with the standard control rod. It was then shut down by inserting all control rods and draining the water moderator, a standard safe method of shutting down the assembly when core changes are to be made. The standard rod was removed and the first of a series of control rods to be tested was inserted.

The reactor was filled with water with the test control rod fully in and the standard type control rods fully inserted. Withdrawal of one of the standard control rods 32 centimeters caused the assembly to become critical and the power was leveled off while the desired measurements were made. The control rod was then reinserted into the original "in" position.

With the water still in the assembly, the four members of the crew then went into the assembly room for the purpose of replacing the control rod which they had just tested. The group leader went up on the platform, reached out with his right hand and started to pull out the tested rod. As soon as he had withdrawn it about one foot, the center of the assembly emitted a bluish glow and a large bubble formed. Simultaneously, there was a muffled explosive noise. The group leader let go of the control rod which he was removing and it fell back into position. The crew left the assembly room immediately and went to the control room.

Four employees received radiation exposures ranging from 12 to 190 rem. (See TID-5360, p. 23.)

SUSPECT RADIATION EXPOSURE

Stanford, Calif., May-June 1966—150 rem

An employee's badge indicated a radiation exposure had occurred over a period of several weeks

while he was engaged in his routine duties at a linear accelerator.

Investigation indicated that the film badge did receive an estimated radiation exposure of 150 rem; however, there was no evidence that the employee had actually received the exposure.

RADIATION EXPOSURES ACCOMPANY NUCLEAR EXCURSION

**Richland, Wash., Apr. 7, 1962—110, 43 and
19 rem**

An unplanned nuclear excursion occurred in a plutonium processing facility due to the inadvertent accumulation of approximately 1500 grams of plutonium in 45–50 liters of dilute nitric acid solution in a 69-liter glass transfer tank. The sequence of events which led to the accumulation of the plutonium in the tank cannot be stated positively. However, it is believed that, when a tank valve was opened, the solution from another vessel overflowed to a sump and was drawn into the transfer tank through a temporary line between this tank and the sump.

When the excursion occurred, radiation and evacuation alarms sounded. All but three employees left the building immediately, according to well-prepared and -rehearsed evacuation plans. Fortunately, they were not in close proximity to the involved system nor in a high radiation field.

Of the 22 persons in the building at the time, only four employees, those who were in the room with the system, were hospitalized for observation. Three of them were the system operators, who were in close proximity to the excursion, and who received estimated radiation doses of 110, 43 and 19 rem. None of them showed symptoms definitely referable to their radiation exposures. The fourth was sent to the hospital only because he was in the room at the time of the incident.

Some fission product activity, airborne via the vent system and the exhaust stack, was detected in the atmosphere for a brief period after the accident.

The physical damage amounted to less than \$1,000. (See TID-5360, Suppl. 4, p. 17.)

IRRADIATED FUEL INCIDENT

**Puerto Rico, July 24, 1962—100, 58, 24, 18 and
18 rem**

Seven employees were accidentally exposed to radiation from irradiated fuel elements when a

crane operator mistakenly thought he had been given the all-clear signal to move a rack of hot fuel elements into a position against the aluminum window which separates the exposure room from the reactor pool. The room was to be vacated and the shield door closed before positioning the fuel elements against the window. The gamma room door could not be seen from the crane operator's position.

When the crane operator began moving the fuel elements into the window position, the 10-millirem monitor near the gamma room door tripped an alarm. The reactor supervisor immediately ordered the fuel elements moved away from the window, terminating the incident.

The estimated exposure time of the individuals was $11\frac{1}{4}$ seconds. The seven employees' exposures were 100 rem, 58 rem, 24 rem, 18 rem, 18 rem, 8 rem, and 4 rem. There were no radiation injuries as a result of the accident. (See TID-5360, Suppl. 4, p. 21.)

ACCIDENTAL EXPOSURE

Oak Ridge, Tenn., Oct. 4, 1957—63 rem

An employee received an exposure to radiation for less than one minute when he mistakenly entered a room containing tanks of radioactive residues used in processing irradiated fuel elements.

The exposure was first discovered when a pocket dosimeter was examined at the end of the day's shift and was confirmed when the employee's film badge was processed. He apparently suffered no ill effects and continued working; however, he was transferred to other duties. (See TID-5360, Suppl. 2, p. 23.)

SUSPECT RADIATION EXPOSURE

Minneapolis, Minn., June 6–19, 1966—50 rem

An employee's film badge indicated a radiation exposure had occurred over a period of approximately 14 days while he was engaged in his routine duties at a linear accelerator.

Although neither proved nor disproved, since the employee's film badge showed an estimated external whole-body cumulative radiation exposure of 50 rem, it was charged to his record.

ELECTRON ACCELERATOR EXPOSURE

Livermore, Calif., Jan. 6, 1959—41 rem

A physicist was exposed while a series of adjustments were being made on beam-defining plates in a new electron linear accelerator. Radiation surveys were made with negative results when personnel entered the cell after the first three adjustment runs. No survey was made after the fourth and fifth runs. A survey made after the sixth run showed a 1,000 rem/hr level.

During all entries to the cell, the key which was designed to lock all controls in the "OFF" position was removed from the control panel. It was determined that the film badges had been exposed to about 200 Kev energy gamma radiation. An exposure dose of 41 rem was assigned to physicist "A". This dose was received in a period of about one minute, which was the established time he worked alone on plates 3 and 4 and entered the cell to measure very high radiation levels. The next highest reading of 400 millirem was received by physicist "B". All others received less than 50 millirem. (See TID-5360, Suppl. 3, p. 8.)

INADVERTENT EXPOSURE

Mercury, Nev., Mar. 1, 1955—39 rem

A security guard was to accompany the radiation safety monitors into the exclusion area after a weapons test and establish surveillance of equipment. The guard had his own vehicle.

When he arrived at the place where he was to meet the monitors, the guard found that they had already left and started out after them. Somehow, he lost his way and drove beyond the established safety point. When it became apparent that he could not find the radiation safety monitors, he contacted his headquarters by radio and notified them of his position. He was immediately ordered out of the area.

The guard's film badge indicated he had received a dose of 39 rem. (See TID-5360, p. 72.)

RADIATION EXPOSURE

Las Vegas, Nev., Jan. 18, 1956—28 and 19 rem

When the prescribed time after a shot had elapsed, four employees, dressed in the proper protective clothing, were recovering samples from a nuclear test area.

It had been prearranged to have a monitor enter the area in advance of the men; however, they

entered the area to redeem the samples without the monitor.

The four men received external radiation exposures of 28, 19, 14 and 4 rem, respectively. Upon medical examination, the men showed no signs of ill effects. (See TID-5360, Suppl. 1, p. 4.)

CONTAMINATED EQUIPMENT CAUSES EXPOSURE

Mercury, Nev., 1954—27.8 rem

An employee unknowingly worked and slept in close proximity to highly contaminated equipment while it was in transport between testing sites. He received a 24 rem whole-body exposure in 24 hours; his total yearly exposure was 27.8 rem.

SL-I EXCURSION

Idaho Falls, Idaho, Jan. 3, 1961—27, 27, 25, 23, 21, 18, 16 and 15 rem

A nuclear excursion occurred within the reactor vessel, resulting in extensive damage of the reactor core and room, and in high radiation levels (approximately 500-1000 rem/hr) within the reactor room.

At the time of the accident, a three-man crew was on the top of the reactor assembling the control rod drive mechanisms and housing. The nuclear excursion, which resulted in an explosion, was caused by manual withdrawal, by one or more of the maintenance crew, of the central control rod blade from the core considerably beyond the limit specified in the maintenance procedure.

Two members of the crew were killed instantly by the force of the explosion and the third man died within two hours following the incident as a result of an injury to the head. Of the several hundred people engaged in recovery operations, 22 persons received radiation exposures in the range of three to 27 rem gamma radiation total-body exposure. The maximum whole-body beta radiation was 120 rem.

Some gaseous fission products, including radioactive iodine, escaped to the atmosphere outside the building and were carried downwind in a narrow plume. Particulate fission material was largely confined to the reactor building, with slight radioactivity in the immediate vicinity of the building.

The total property loss was \$4,350,000. (See TID-5360, Suppl. 4, p. 8; 1962 *Nuclear Safety*, Vol. 3, #3, p. 64.)

COBALT 60 EXPOSURE

Mercury, Nev., Oct. 4, 1960—18 rem

Two employees were following through the routine involved in the calibration of photocell detectors. The detectors were placed in the radiation beam area, 30'' in front of the 340-curie cobalt 60 source unit. Currents were being recorded for each detector with the source exposed. Three detectors had previously been calibrated; the fourth was placed in position; both employees returned to the console; the source was exposed and the current output of the detector was recorded. After recording the current value, employee "A" noted that the warning lights were out and assumed that the source was no longer exposed. He approached the detector located in front of the source, without making a precautionary radiation survey, and started making mechanical adjustments on the photodiode. Employee "B" followed "A" and aided him in the adjustments.

"A" received a total-body dose of 18 rem as determined by film badge reading. "B" received a total whole-body dose of 5 rem. (*See* TID-5360, Suppl. 3, p. 23.)

EXPOSURE DURING REACTOR SHUTDOWN

Idaho Falls, Idaho, July 23, 1956—21.5 rem

During a shutdown operation for scheduled refueling, six employees were working on the reactor top adjacent to the reactor tank opening, while two men were present as observers and advisors. All were exposed to radiation when a highly radioactive reactor component was placed in a position where it was not adequately shielded because of lowered water level in the reactor tank. The moving of the component and the coincident lowering of the water level were done to facilitate insertion and removal of experiments in the reactor.

The eight employees received radiation exposures ranging from 2.5 rem to 21.5 rem. (*See* TID-5360, Suppl. 1, p. 18.)

EXPOSURES RESULT FROM HANDLING FISSION SAMPLES

Eniwetok, May 14, 1948—17 rem

Four employees, who were handling fission samples improperly, received whole-body exposures ranging from 1.7 rem to 17 rem.

GAMMA EXPOSURE

Mercury, Nev., 1954—15.1 rem

While handling 55-gallon drums, whose greasy surfaces had trapped considerable amounts of radioactive fallout, an employee received 13 rem whole-body exposure during one working day. His total yearly exposure was 15.14 rem.

RADIOGRAPHY INCIDENT

Richland, Wash., May 16, 1963—15.2 rem

Construction employees, who wore no dosimeters, were inadvertently exposed to a lost 27-curie iridium 192 radiography source during the construction of a new production reactor. Exposures were estimated based upon radiation surveys and interviews with the personnel involved. The exposures ranged from 3.9 rem to 15.2 rem.

X-RAY TECHNICIAN EXPOSURE

**Middletown, Conn., October 1958—15 rem
($\pm 40\%$)**

An employee was in a shielded X-ray room using a portable X-ray unit. The circumstances indicated that the employee was not exposed to the radiation shown by his film badge. However, investigation could not prove this; therefore, it was assumed that the employee was exposed.