UNCLASSIFIED

TID-5360

Subject Category: HEALTH AND BIOLOGY

UNITED STATES ATOMIC ENERGY COMMISSION

A SUMMARY OF ACCIDENTS AND INCIDENTS INVOLVING RADIATION IN ATOMIC ENERGY ACTIVITIES, JUNE 1945 THROUGH DECEMBER 1955

By
Daniel F. Hayes

August 1956

Safety and Fire Protection Branch
Division of Organization and Personnel
Washington, D. C.

Technical Information Service Extension, Oak Ridge, Tenn.

UNCLASSIFIED

Printed in USA, Price $2.25. Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

USAEC Office of Technical Information Extension
Oak Ridge, Tennessee

A SUMMARY OF ACCIDENTS AND INCIDENTS INVOLVING RADIATION IN ATOMIC ENERGY ACTIVITIES

June 1945

thru

December 1955

D. F. Hayes
Safety and Fire Protection Branch
Division of Organization and Personnel
U. S. Atomic Energy Commission
Washington, D. C.

August 1956

PREFACE

The motto on the Archives Building in Washington - "Study the Past - What is Past is Prologue" - should be equally applicable to the accidents which have occurred in the atomic energy program. This paper is written to set down the past so that full benefit may be obtained from the experience gained as a result of accidents which have occurred.

There are three broad classifications of accidents in the atomic energy program. In the first group, and by far the most numerous, are those in no way related to atomic energy. Falls, electrocutions, motor vehicle accidents, and construction equipment accidents comprise the majority of accidents in this classification.

The second classification includes those accidents which are somewhat peculiar to the atomic energy industry in that the materials or the processes are closely related to the program and possibly not in widespread use outside the industry.1/

The third classification includes those accidents in which radiation is the prime or at least a major factor. This report will deal with this classification.

Before reading the text and drawing any conclusions, the reader must thoroughly understand the basic difference between the radiation safety program which started with the Manhattan Engineer District, and which has been carried forward by the Atomic Energy Commission, and all other safety programs as we know them.

In industry generally, safety regulations have grown out of a number of serious accidents related to a particular cause. Finally, public opinion has reacted and a safety program has been designed to reduce the number of accidents from this specific cause.

Prior to the commencement of work on the atomic bomb, radiation accidents and injuries in industry were relatively few. These cases were sufficiently serious, however, to point out the necessity for a stringent radiation safety program right from the start. Human nature being what it is, many people consider a period of trial and error to be a necessary evil in the control of traumatic injury. Because of the long-range possibilities of radiation injury, however, the trial-and-error method was not at all acceptable. From the beginning, the policy was "to maintain strict control over the manner and methods of work . . . which should result in the prevention of all the conditions associated with delayed injurious effects."

1/ In the section "Fires " there are a number of instances which fall partially in the second and third categories. No attempt has been made, therefore, to record every fire here, but a representative sampling has been included.

2/ INDUSTRIAL MEDICINE ON THE PLUTONIUM PROJECT, page 20.

For this reason, the report cannot be considered in the same light as would be a report, for instance, of all of the explosions which took place as steam boilers were developed to their present level. Consideration must be given to the hundreds of hazard evaluation studies which were made in one form or another and which provided vicariously the knowledge which, in earlier times, was gained at the cost of human suffering and property damage.

It must be realized, therefore, that the comparatively few incidents here cited form the total of the unfavorable incidents[3] over a period of 11 years in this field, in which upwards of 300,000 people were engaged at the peak.

The principal lesson to be drawn is that, if the record of safe operation is to be maintained, we cannot slip back into old-fashioned methods of hazard evaluation by bitter experience only.

The effect of hazard evaluation on the over-all safety program is evidenced by the fatality record which is a good single index of safety performance on a project of this size. During the years 1943-1955, the atomic energy program suffered 184 fatalities. This is exactly half the number of fatalities that would have occurred had the atomic energy program incurred fatal accidents at the rate reported by the National Safety Council industrial members (who generally have records superior to those of industry as a whole). Of the 184 fatalities, only 2 were attributable to radiation; the balance to typical industrial accident causes: falls (43), electrocutions (31), mobile equipment, e.g. cranes and bulldozers (25), motor vehicle (20), miscellaneous (63).

It is therefore apparent that hazard evaluation and preplanning will provide safe working conditions not only in the field of nuclear energy but in all industry. Experience has taught us that it is not necessary to have accidents to learn how to prevent accidents.

* * *

The recommendations for corrective action in the reports, which were written shortly after the incident occurred, are not necessarily to be construed as general in application since they are often only appropriate locally or at the time.

D. F. Hayes

[3] A few incidents which occurred outside AEC sponsored activities are included because of their happening in the field of Nuclear Research. The pertinent Canadian NRX reactor failure is not included. A report on this incident was published in MECHANICAL ENGINEERING, February 1955, page 124.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

CRITICALITY INCIDENTS

FATALITY FROM CRITICAL MASS EXPERIMENT
(1945)

Nature of Incident

Inadvertent super-critical assembly of fissionable material.

Description of Operation

In the process of making critical mass studies and measurements, an employee was stacking blocks of tamper material around a mass of fissionable material.

Details of Incident

Employee was working in the laboratory at night alone except for a guard seated 12 feet away.

As the assembly neared a critical configuration, employee was lifting one last piece of tamper material which was quite heavy. As this piece neared the set-up, 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 set-up.

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.

Nature of Injuries or Loss

Employee who performed the experiment received radiation dosage sufficient to result in injuries from which he died 24 days later.

The guard was exposed beyond the established daily limit, but suffered no observable permanent injury.*

Remarks

As a result of this incident, a special committee was set up to review the work carried on whenever fissionable material was being assembled under conditions where the assembly might conceivably become critical, and to make appropriate safety recommendations. The regulations given below

---

*The Annals of Internal Medicine, Volume 36, Part I, February 1952, published by the American College of Physicians, describes the medical aspects of this incident (Cases 1 and 2).

resulted from the work of this committee and these aimed not only at reducing the possibility of a similar incident but also at moderating the severity should an untoward incident occur:

1. Two special lists were prepared naming the persons who were the only ones permitted to do this work; one list carried the names of persons who would head up such work.

2. A minimum of two persons was required to be present in addition to guard personnel. The maximum number of people permitted was also controlled.

3. Before starting, the experiment must be planned including mode of operation and behavior in all contingencies.

4. At least two monitoring instruments must be operating, each giving a clearly audible indication of the neutron intensity at all times during the experiment.

5. Any changes in an assembly involving fissionable material must be made by one person at a time, slowly and readily reversible.

6. There shall never be two assemblies, which might become critical, in the same building at the same time.

7. All operators associated with the experiment must be in agreement about the safety of procedures all through the operation. If any disagreement arises, operations must be stopped until agreement has been reached.

Substantial consideration was given to the development of mechanical remote control devices as a long-range program, although there was not universal agreement whether or not this should be done. In the ensuing months some design and fabrication work was carried on. After 1946, all similar work was carried out with remote control systems without exposure to personnel.

Los Alamos, New Mexico
Aug. 8, 1945

FATALITY FROM CRITICAL MASS EXPERIMENT
(1946)

Nature of Incident

Inadvertent super-critical assembly of fissionable material.

Description of Operation

A senior scientist was demonstrating 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.

Details of Incident

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 sub-critical 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 screw driver. This latter edge was slowly permitted to approach the lower shell. While one hand held the screw driver, the other hand was holding the upper shell with the thumb placed in an opening at the polar point.

At this time, the screw driver apparently slipped and the upper shell fell into position around the fissionable material.

There were eight people present in the room where this demonstration was being carried out. Of these, 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.

Nature of Injuries or Loss

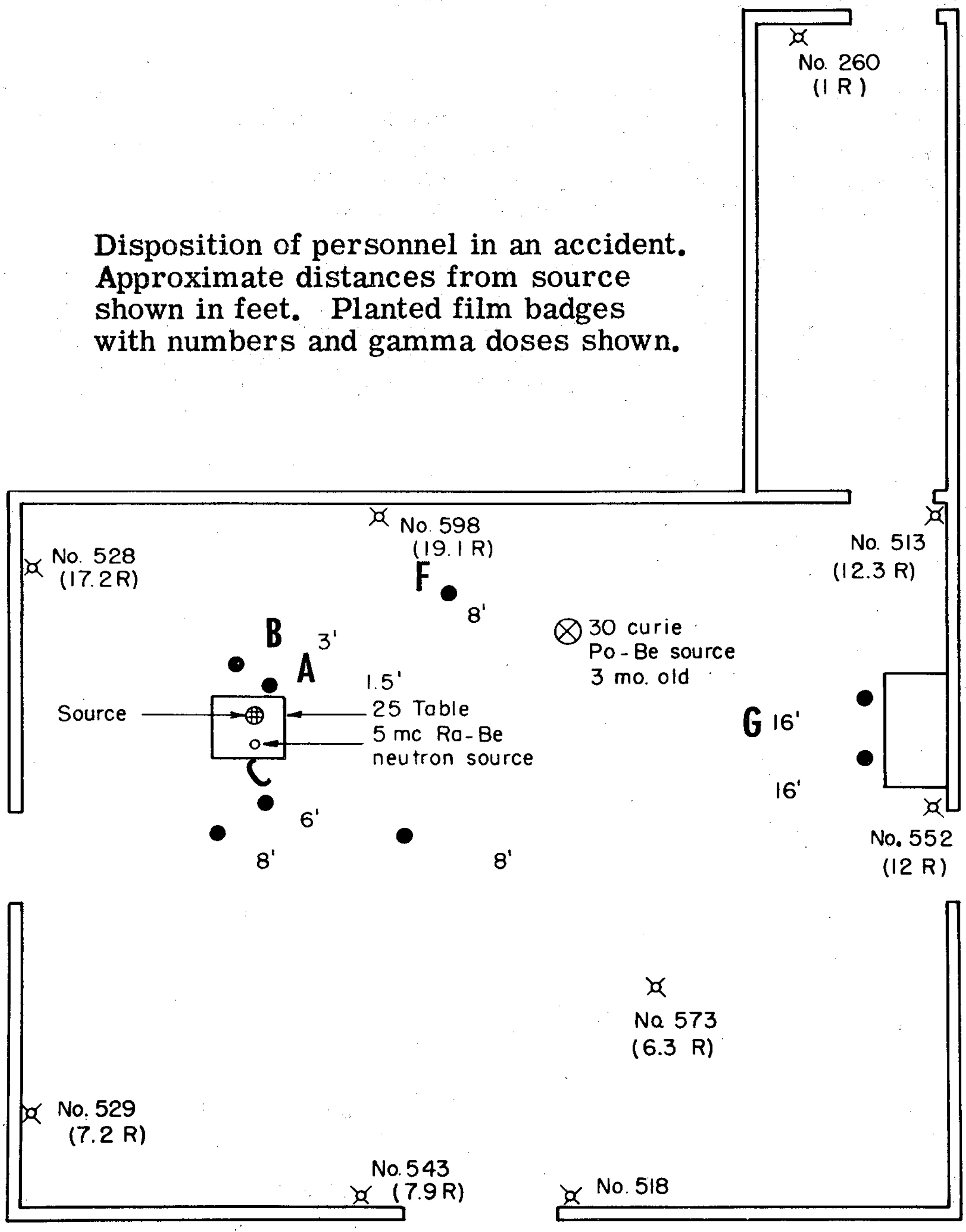
Scientist (A) who was demonstrating the experiment received radiation dosage sufficient to result in injuries from which he died 9 days later. The scientist (B) working with the deceased received radiation dosage sufficient to cause serious injuries and some permanent partial disability.

The other six employees in the room (C, D, E, F, G, H) were exposed beyond the established daily limit, but suffered no observable permanent injury.*

---

*The Annals of Internal Medicine, Vol. 36, Part I, February 1952, published by the American College of Physicians, describes the medical aspects of this incident (Cases 3 through 10).

Disposition of personnel in an accident. Approximate distances from source shown in feet. Planted film badges with numbers and gamma doses shown.



Remarks

While some work had been done in fabricating mechanical remote controls previous to this incident, as a result of an earlier similar critical assembly accident, such devices had not been fully developed to the point where they were considered sufficiently reliable to perform the task of critical assembly studies.

The regulations developed as a result of this earlier accident were considered adequate but, as was demonstrated, depended on the fallibility of individuals observing them. Immediately following this incident, all such work was stopped until mechanical remote control devices could be designed and fabricated to carry out critical assemblies.

Since the introduction of these remote assembly devices, there have been no incidents which resulted in excessive exposure to personnel. It should further be pointed out that the development of reliable remote control devices permitted critical studies, knowingly marginal, that would not have been attempted manually and thus permitted extended scientific research in such matters.

Los Alamos, New Mexico
May 21, 1946

CRITICALITY RESULTS FROM ERROR IN CALCULATIONS

Nature of Incident

A fissionable material assembly, remote from personnel, inadvertently was made supercritical.

Description of Operation

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.

Details of Incident

After two members of the operating crew calculated from previous steps that one more disk could be added safely (they thought), the disk was added and, with attempted caution, the system was assembled remotely. Radiation indicators went off scale, 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.

Nature of Injuries or Loss

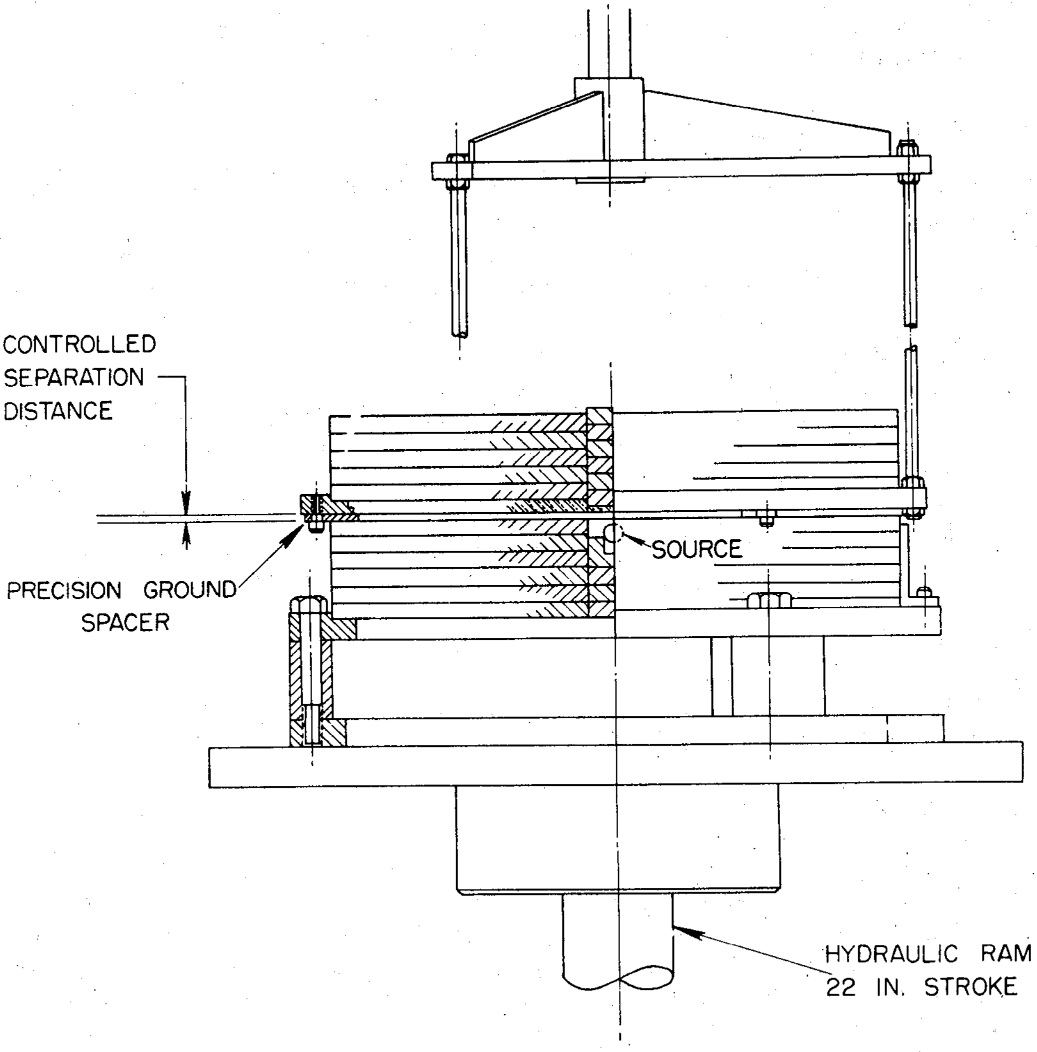
There was no injury, no loss of material, no damage to facilities, and negligible loss of operating time.

Remarks

The crew members who checked safety of the final addition of fissionable material made the same algebraic error. The error would have been detected if data had been plotted as required by operating rules. Also, it was determined subsequently that the assembly rate of the system exceeded the maximum established by regulation. It is believed that there was just one radiation burst, terminated by thermal expansion, with a yield of $1 - 2 \times 10^{16}$ fissions.

Existing operating regulations were re-emphasized.

Los Alamos, New Mexico
April 18, 1952



A criticality test assembly.

SUPERCRITICALITY EXPERIMENT

Nature of Incident

A fissionable material assembly, remote from personnel, inadvertently was made excessively supercritical.

Description of Operation

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 involved operations of a type that the normal regulations are designed to prevent, so was covered by a specific procedure. A reference check of critical conditions preceded each supercritical burst.*

Details of Incident

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 recorder went off scale (to return in a few minutes), and scrams were actuated. The resulting shock separated parts of the assembly and damaged steel supporting members.

Nature of Injuries or Loss

There was no injury. The property loss was an expenditure of $600 for repair of the assembly.

Remarks

Apparently, the control rods had been run to their wrong extreme, i.e., to the position of maximum reactivity, before the booster was inserted. An interlock to prevent this had been omitted in the course of remodeling the assembly and, contrary to regulation, only one crew member was in the control room during the operation that led to the incident. There was a single burst, terminated by thermal expansion. The yield was 6×10^{16} fissions, about three times that of the largest planned burst.

The operating procedure was revised so that maximum available reactivity is limited to a tolerable value.

*See NUCLEONICS, October 1955, Page 48, for a description of this experiment known as "Godiva."

Los Alamos, New Mexico
Feb. 3, 1954

UNANTICIPATED CRITICALITY IN WATER SHIELDED ASSEMBLY (1945)

Nature of Incident

Exposure of three individuals to external radiation resulting from a supercritical assembly of fissionable material.

Description of Operation

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, ½" x ½" x ½" and ½" x ½" x 1". The blocks were stacked in a pseudospherical arrangement in 12 courses in a 6" x 6" x 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 3/4-inch tee. The opening in the tank was fitted with a shut-off 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.

Details of Incident

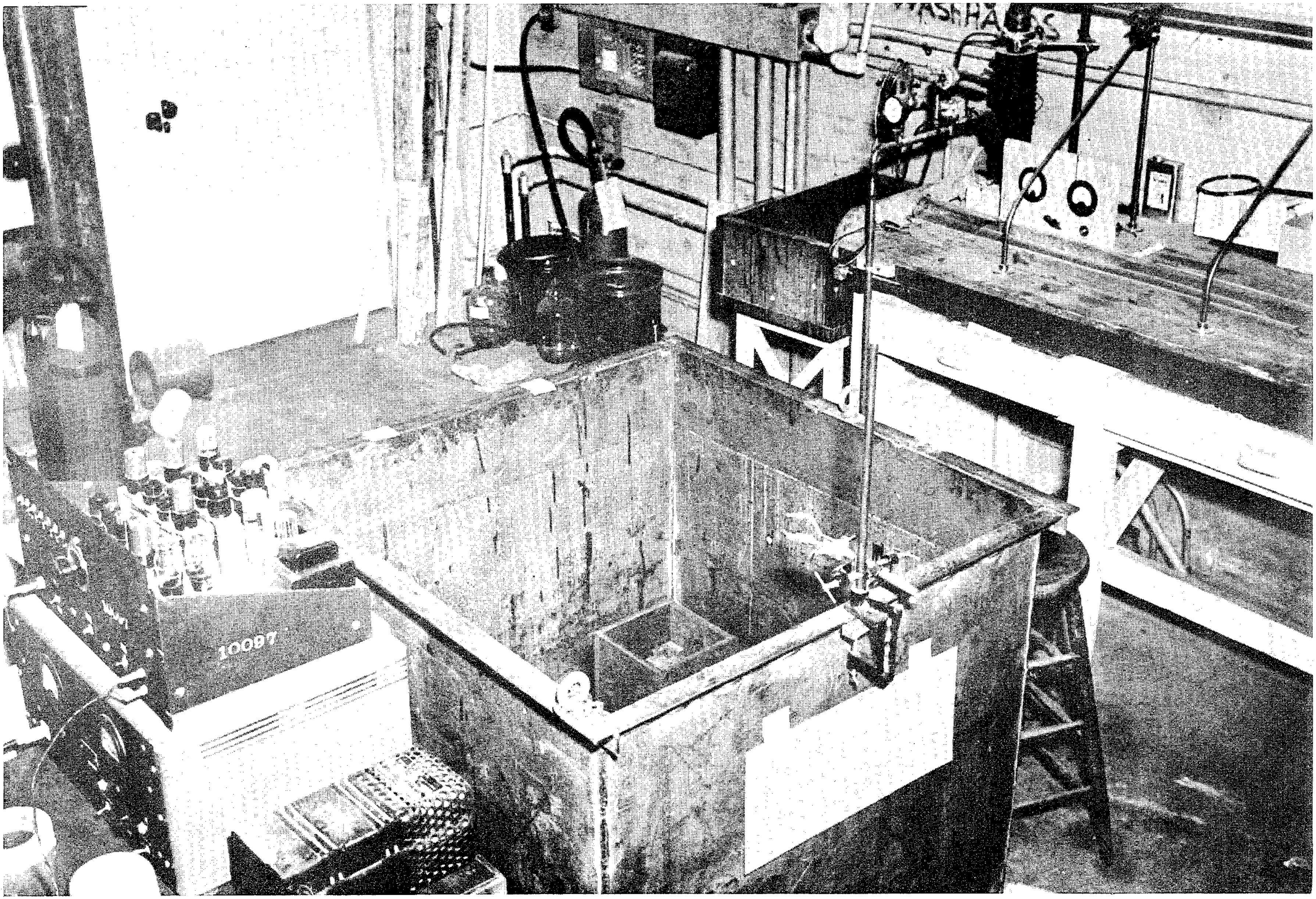
The immediate supervisor was absent from the scene when the experiment was begun. According to one of the operators, the water level was raised above the polonium-beryllium source with the supply valve nearly full open. At this point, a slight increase in counting rate was observed, which corresponded 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 and walked to within 3 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 then evacuated.

Nature of Injuries or Loss

The three individuals involved received excessive radiation exposures, estimated in the case of two as about 66.5 rep, and in the third as 7.4 rep. The doses delivered to the head and neck of these individuals may have been considerably greater. The involved individuals were hospitalized for observation, but no untoward symptoms appeared. No significant changes in blood counts were observed, and sperm counts on one occasion some time 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.

Remarks

It seems most probable that the unanticipated increase in reactivity



Test equipment for water shielded assembly.

occurred because of water seeping between the blocks of active material and increasing the internal moderation of the assembly. Sufficient heating occurred to melt and deform the plastic bottom of the assembly container, and the water between the blocks must have vaporized, thus stopping the reaction. More water would then seep in and the cycle would repeat. It was estimated that three such cycles occurred before the water level in the tank fell sufficiently low to prevent further reaction.

The experiment was of poor design in that the rate of addition of moderating material was not restricted in any way beyond the inherent limitation of the supply valve, and the changes in water level were not readily reversible since in the first place the supply and drain valves were at least fifteen feet apart, and in the second place there was a considerable lag between the water level in the tank and that within the assembly. There was no provision made for rapidly dumping the moderator or poisoning the assembly if a predetermined upper safe limit of reactivity were reached. It is not apparent that any nuclear safety considerations whatever entered into the planning. It was the opinion of the experimenters that criticality would not be reached during this run.

While no further experiments of this specific type were performed, similar experiments after 1946 were carried out with remote control systems without exposure to personnel.

Los Alamos, New Mexico
June 4, 1945

SCRAM MECHANISM CAUSES CRITICALITY

Nature of Incident

A fissionable material assembly, remote from personnel, inadvertently was made super-critical.

Description of Operation

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.

Details of Incident

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.

Nature of Injuries or Loss

There was no injury, no loss of material, and no damage to facilities.

Remarks

Unlike normal slow disassembly, the scram rapidly raised one component vertically instead of horizontally separating the two masses. Subsequent tests showed that the center of reactivity of the movable component was below that of the stationary unit thus shortening the distance between them as the movable unit rose to the level of the stationary unit. Furthermore, the movable unit when rapidly raised through the water swung towards the stationary unit (Bernoulli effect).

There probably were several radiation bursts, each stopped by bubble formation in the water. The total yield was about 10^{17} fissions.

"Tangential scrams" were outlawed for future designs. All assembly machine design must be reviewed by several persons rather than be the work of an individual.

Los Alamos, New Mexico
March 20, 1951

RADIATION EXCURSION IN A PLUTONIUM NITRATE SOLUTION CRITICAL ASSEMBLY

Nature of Incident

An inadvertent super criticality of a spherical plutonium nitrate reactor when a safety rod was withdrawn too rapidly during a test.

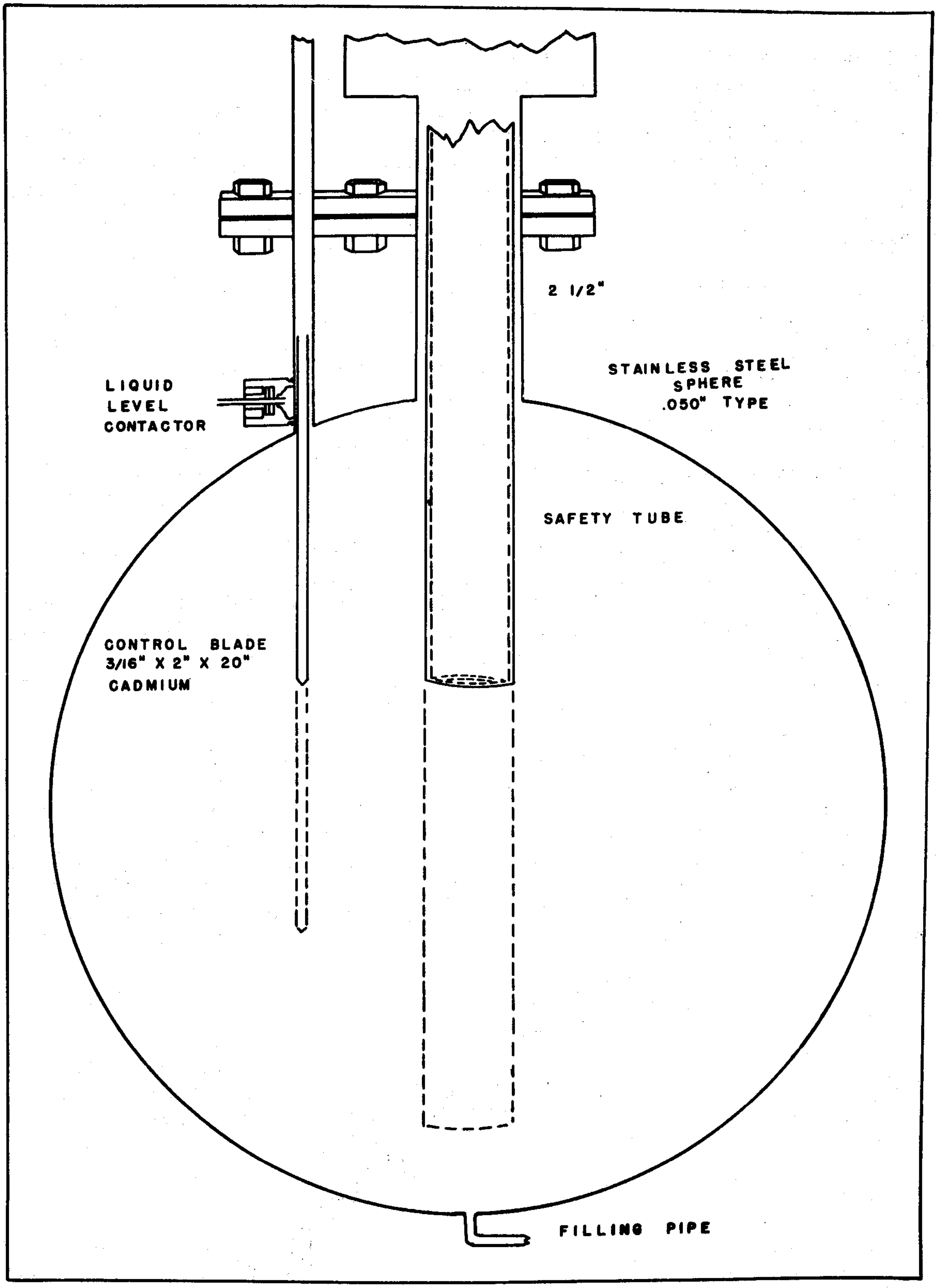
Description of Operation

A critical mass program was under way. A prime consideration of this program was the review of chemical separation plant operations from the standpoint of nuclear safety. An attempt was made to determine the maximum safe mass of plutonium for each part of the processing equipment. To this end criticality experiments were performed for several container geometries and process reagent concentrations. The fuel consisted of solutions of plutonium nitrate and the container geometries studied were tamped cylinders and tamped and bare spheres of different sizes.

In the course of the criticality program it became apparent that it would be desirable to determine experimentally the critical mass of a hemispherical shape.

Details of Incident

As the program had called for a series of experiments in bare spherical reactors, it was decided to make this measurement by half-filling an available sphere and adjusting the concentration to obtain criticality. This was obtained in a spherical segment slightly larger than a hemisphere in a nominal 20-inch diameter sphere. Three additional critical points were found as the fuel was diluted and greater fractions of the sphere volume filled. The last critical point reached was in a volume 88 percent of the full sphere. As the critical concentration of the sphere was predictable, it was decided to make the final dilution for the full sphere as closely as possible. This required that the total fluid volume be known quite accurately. The method of making this measurement was to add the remaining fuel to the reactor and to determine the total volume by means of the reactor sight glass which gave an accurate measure of the fluid volume. The control and safety rods were inserted and were known to be sufficiently strong to easily override the reactivity of the excess fuel addition. The volume measurement was done carefully and without incident or significant increase in neutron level. Then, instead of draining the reactor for concentration change, an attempt was made to determine where criticality might occur on the rods. As the total strength of the safety rod was known, it was thought that some additional information as to the required dilution could be determined by this measurement. The control rod was pulled first with very minor reactivity effect. Following this, the safety rod was withdrawn intermittently at high speed



A SCHEMATIC DIAGRAM OF THE REACTOR ASSEMBLY.

(2.3 inches/second). 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 off scale, 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 off scale. Presumably, a further rod withdrawal had been made.

An important effect to be considered is the production of gases in the reactor fuel. These gases are formed by the disassociation of the fuel caused by the ionization resulting from stopping the charged particles in the fuel. Most of the ionization results from the fission fragments, of course. The gas production is important in two respects. First, the energy absorbed in the gas formation is not measured in the temperature rise of the fuel; secondly, the formation of gases in the fuel may cause an expansion of the fuel. This expansion would result in density and volume changes in the fuel which could be very important.

That gas was formed during the incident is evident from the resulting contamination of the reactor room and known loss of fuel. The temperature of the fuel was well below boiling, yet a small amount of fuel was sprayed through the gaskets of the reactor assembly. These gaskets sealed a volume of air of about 18 liters above the fuel level prior to the incident. Pressures considerably in excess of atmospheric must then have existed in the assembly during the incident.

In order to estimate the manner in which the incident took place, the probable actions of the personnel and apparatus machinery involved must be analyzed. The first item to be noted is that the operator had been removing the safety rod from the reactor at high speed prior to the incident. At least partly because of the insensitive scales on which the instruments were set at the time the operator was watching, the operator was not cognizant of the impending runaway. Therefore, it seems likely that the safety rod was given another pull at high speed of a duration similar to the preceding pulls.

Nature of Injuries or Loss

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 (see page 51).

Remarks

Emphasis must be placed on the fact that the incident was the direct result of the rapid withdrawal of a strong poison from the reactor. Increasing the reactivity at this rate allowed the system to become prompt critical before the power level had increased sufficiently to actuate the scram device. Short periods were then obtained in a time interval which was short compared to that necessary for the mechanical safeties to stop the reaction. Safe reactor design requires that no mechanism be employed which will allow the rapid withdrawal of a strong poison from the system, to eliminate possible errors in judgment on the part of the operators.

An interesting result of the analysis is the extremely unfavorable change in geometry resulting from fuel expansion in the partially filled sphere. Had the sphere been full in this incident so that the fuel expansion immediately expelled fuel from the sphere, no incident of this magnitude could have occurred. Extreme caution is indicated in experiments involving such partially filled geometries.

THE ABOVE EVENT WAS ACCURATELY ANTICIPATED IN THE HAZARDS STUDY PREPARED TWO YEARS PREVIOUSLY AS FOLLOWS:

> "In the design of the apparatus to be used in plutonium critical mass experiments considerable attention was given to safety features. This report examines the hazard which would result in the extremely unlikely event that all of the safety devices failed to operate either by accident or sabotage. The reactor is a cylindrical can filled with a water solution of plutonium tetranitrate and immersed in a tank of water. If it is made super-critical, energy is produced in the solution at a rate proportional to the degree of super-criticality. If the rate is low, the solution will heat to boiling and water will be boiled off until the remaining solution becomes sub-critical. In such a case the steam will be blown out through an opening and no explosion will occur. The surrounding area will be subjected to a dose of gamma rays proportional to the amount of energy evolved. Some plutonium may be blown out with the steam. If the rate is high, the pressure of steam would eventually rupture the can and the reaction would then cease on account of dilution by the surrounding water. The time behavior, critical mass, etc., of the reactor are calculated and used to estimate the hazards. The conclusion is that, in such a weakly confined system, explosions are impossible and further, at distances of about 175 feet, the danger from gamma and neutron radiation is negligible. The most serious hazard is the contamination of the reactor room with plutonium."

Hanford
Nov. 16, 1951

RADIATION EXCURSION IN AN EXPERIMENTAL ENRICHED URANIUM WATER SOLUTION CRITICAL ASSEMBLY

Nature of Incident

Inadvertent excess reactivity due to mechanical failure in the assembly.

Description of Operation

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 outer container of the annulus is a 10" inside diameter by 6' high 2S aluminum cylinder, having a 1/16" thick wall. The bottom of the container is 1/4" thick aluminum, with an off center 2" inside diameter aluminum tube for fuel solution flow. The 10" cylinder sits on a 23 cm high Plexiglas table and is secured to it by three bolts through angle lugs welded to the outside of the cylinder. The inner container of the annulus, which is a 2" outside diameter by 6' long aluminum tube also having a 1/16" thick wall, is lined on the inside by a 1/8" thick cadmium cylindrical shell and is filled with water. The inner container, or tube, is positioned at the lower end by a pin which fits into a recess in the bottom of the 10" cylinder. The upper end is held by downward pressure from a 120° spider, the legs of which are bolted to a flange on the top of the 10" cylinder. The legs of the spider are 1" aluminum angle welded about the center. The assembly is contained in a 9' x 9' cylindrical tank which can be filled with water to provide a neutron reflector, if desired.

Details of Incident

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" cylinder. Although the displacement was small, it was sufficient to cause a large increase in the effective neutron multiplication.

Nature of Injuries or Loss

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, so no serious exposures were incurred.

Remarks

While the total number of fissions during the transient has been estimated to be 10^{17}, there was no evidence of violent boiling in the system or of mechanical breakdown due to energy release.

Oak Ridge National Laboratory
May 26, 1954

REACTOR INCIDENTS

CRITICALITY DURING CONTROL ROD TESTS

Nature of Incident

Inadvertent super-criticality of reactor occurred when employee manually tested mechanism for two new control rods.

Description of Operation

The reactor was being remodeled for higher power operation. As part of 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 existing other three rods were sufficient for safety.

Details of Incident

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 seconds. 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.

Nature of Injuries or Loss

There were no injuries. The employee doing the work received 2.5r of gamma radiation according to his film badge. There was no damage done to the reactor and no loss of active material.

Remarks

To avoid any similar incident in the future, the use of the key to the locked enclosure, above the reactor, containing the rod mechanism was restricted to two senior individuals in the group.

In addition to this administrative arrangement, a special device was added to the rod control mechanism. This device was used whenever the enclosure had to be left open for any period of time. The special device built was a pivoted plate provided with a slide which would permit only one control rod to be moved at a time after the plate was locked into position on the top of the control rods.

Los Alamos, New Mexico
Dec. 1949

SUDDEN INCREASE IN REACTIVITY DURING CONTROL ROD TESTS

Nature of Incident

Manual withdrawal of a control rod from a reactor caused an accidental super-criticality. Four persons were over-exposed but apparently were not injured.

Description of Operation

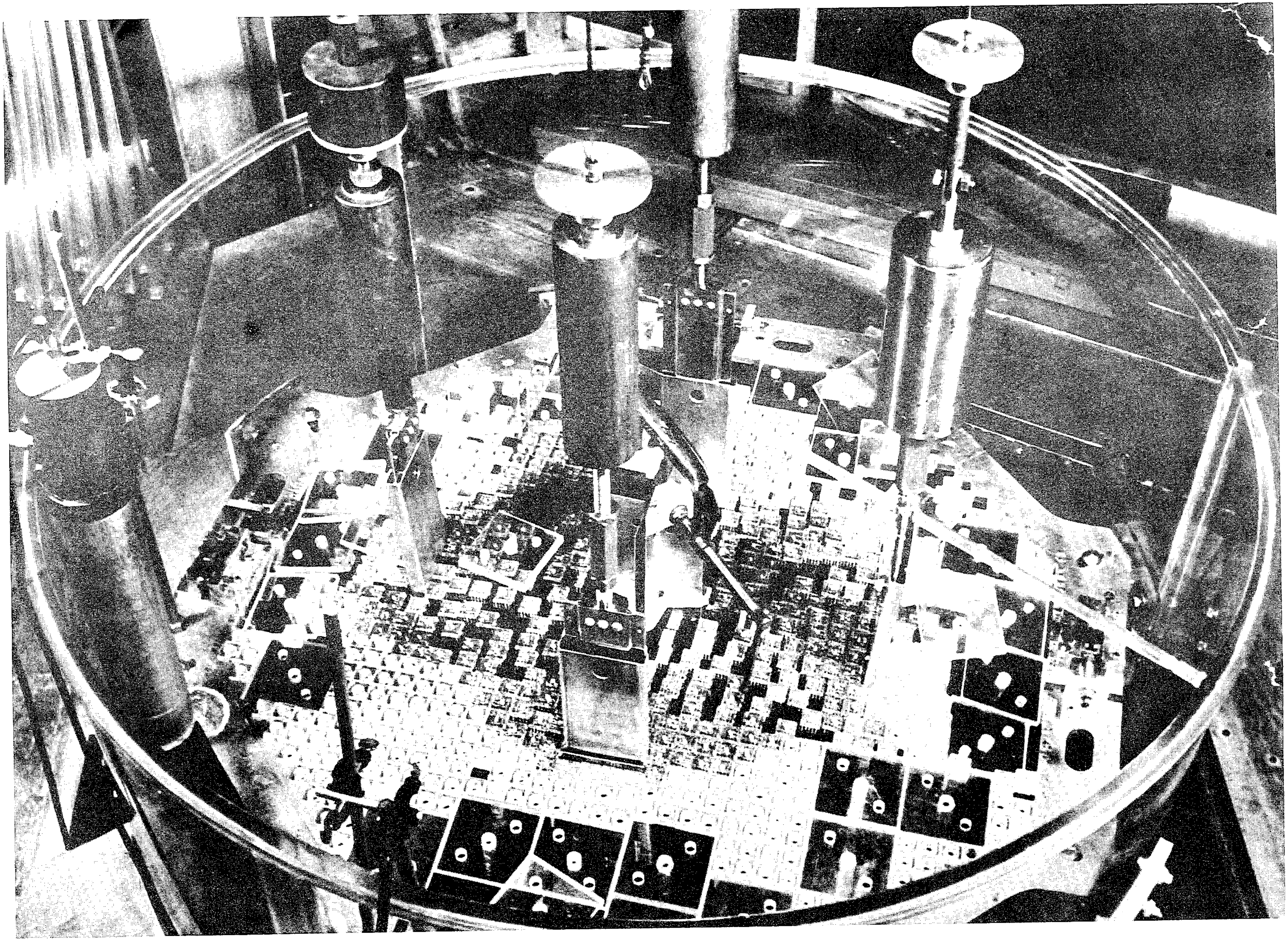
The operation being conducted was the comparison of a series of newly-manufactured control rods. The reactor had been operated with the standard control rod. It was then shut down by inserting all control rods and draining the water moderator, a standard safe method of shutting down the reactor when 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 reactor was filled with water with the test control rod fully in and the standard type control rods fully inserted. Withdrawing of one of the standard control rods, 32 cm, caused the reactor to become critical and the power was leveled off while the desired measurements were made. The control rod was then re-inserted into the original "in" position.

Details of Incident

With the water still in the reactor, 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 reactor 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.

The reactor became super-critical because the test rod being removed by the leader was highly effective in suppressing the chain reaction when fully inserted. But, as it was being removed, a point was reached when the reactor was critical even with the standard type rods fully inserted. In removing this rod, the reactor passed through the critical into the prompt critical stage. This would not have occurred if water had not been in the reactor assembly, since this thermal reactor was dependent upon water to moderate the neutrons from the fast energy level to the thermal energy level and the fission process can only be supported by thermal energy neutrons.



Top view of test reactor.

After this super-criticality was reached, several reactions took place, any one of which could have contributed to immediately shutting the reactor down:

1. Part of the uranium polystyrene fuel mixture expanded, displacing the water.

2. A bubble formed causing a change in density in the reactor, reducing the effectiveness of the moderator.

3. The group leader immediately dropped the rod back into place.

4. The instrument circuits detected a level of neutron intensity and opened the water dump valve.

Nature of Injuries or Loss

Damage caused by this incident appears comparatively slight and falls into three areas:

1. The radiological effect upon the victims is discussed in separate reports.*

2. The fuel assemblies were damaged to the extent that the uranium polystyrene mixture on the zirconium strips was no longer in usable condition and had to be reclaimed immediately rather than after the experiments planned for the reactor. Seventy-five percent of the fuel on hand was not involved in the incident. The reactor tank and fixtures were undamaged.

3. The program was delayed due to the loss of personnel available for this operation as a result of the incident, and by the time required to revise operating procedures to insure complete safety in the future.

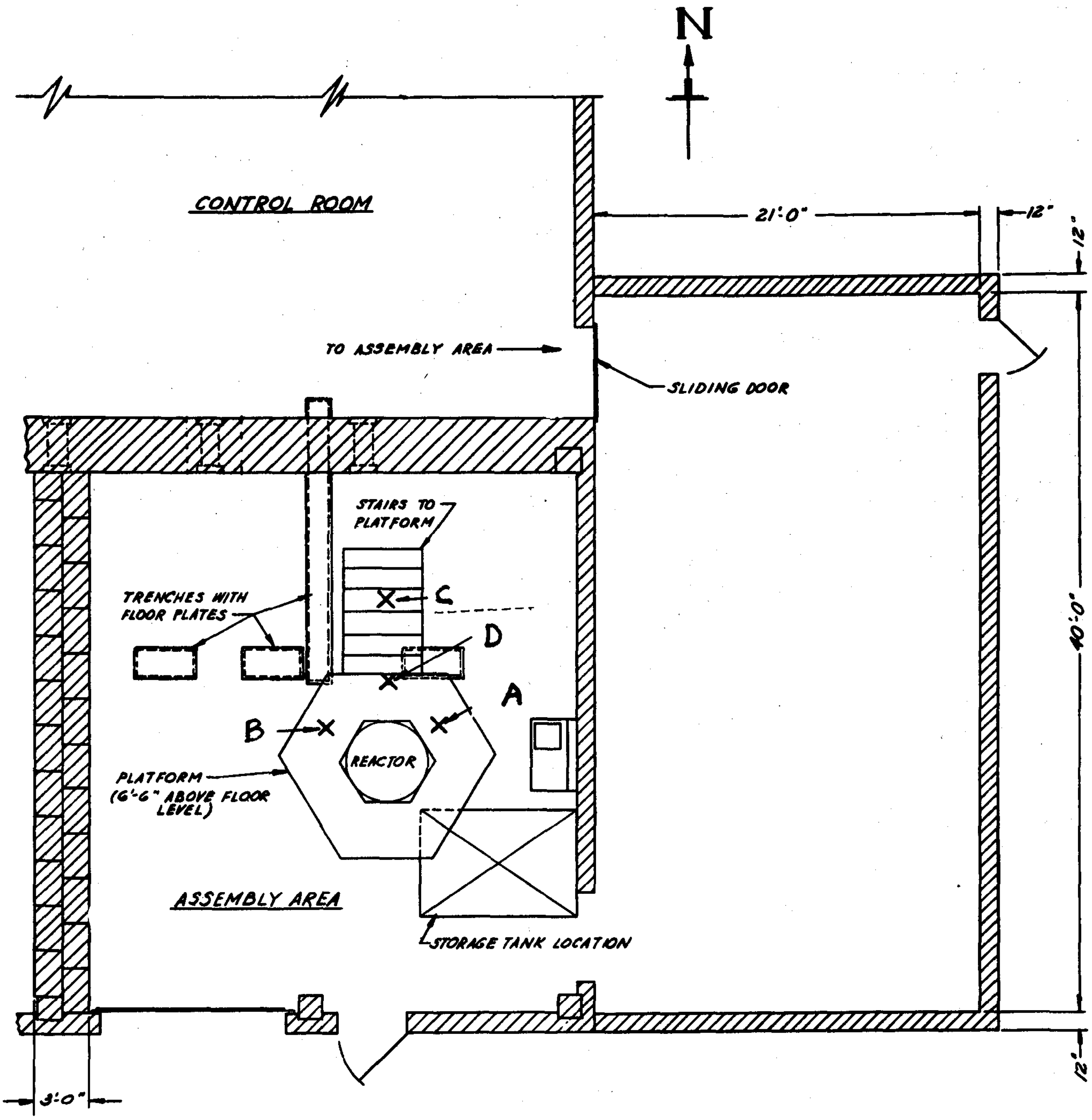
Remarks

The direct cause of the nuclear reaction comprising the incident was the rapid withdrawal by hand of the control rod being tested from the water-filled assembly. This effected a large increase in reactivity and the reactor achieved super-criticality in a very short time. The following recommendations were made and have been carried out to prevent occurrence of a similar incident:

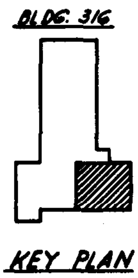
1. Absolutely prevent access to assembly room when there is water in the reactor.

2. Prepare and keep up to date an operating manual which would include not only standard operating procedures but operating restrictions imposed by nuclear safety considerations.

*See ANL 4971 and "Physical Dosimetry and Clinical Observations on Four Human Beings Involved in an Accidental Critical Assembly Excursion," by R. J. Hasterlik and L. D. Marinelli, p. 25, Vol. 11 - Proceedings of the International Conference on the Peaceful Uses of Atomic Energy (Held in Geneva, August 8-20, 1955).



Layout of reactor showing position of crew at time of the accident.



3. General safety measures.

4. Emergency procedures.

5. Control diagrams and wiring identification.

6. Written procedures to be prepared for each experiment to be performed.

7. Restrict the number of people in the assembly room to those actually required.

8. Require at least two qualified staff personnel on critical experiments.

Argonne National Laboratory, Lemont, Ill.
June 2, 1952

REACTOR FUEL LEAK*

Nature of Incident

The stainless steel core of a water boiler type reactor developed a leak allowing fuel solution to leak into the surrounding chamber and the cooling water.

Nature of Operations

This incident occurred in a university reactor being operated for research and training purposes.

Details of Incident

The first indication of trouble was the rise in pressure of the core. Further investigation revealed the presence of fission products in the surrounding chamber and the cooling water. The gases were carefully bled off the chamber and core and out the stack, the cooling water was drained, and the fuel solution was transferred to storage containers.

Remarks

Two possible causes of the leaks are:

1. Faulty welds.
2. Corrosion at points of local surface imperfections.

North Carolina State College
May 1955

*This incident occurred at a non-AEC location but is included as an example of a type of reactor failure. No one was injured or exposed to radiation.

BORAX I EXPLOSION

Nature of Incident

Deliberate destruction of the Borax I Reactor as part of reactor safety tests.

Description of Operation

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.

Details of Incident

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.

Nature of Injuries or Loss

No one was injured and the destruction of the reactor was part of the cost of the experiment.

Remarks

Although it was greater than anticipated, the explosion was comparable to that which could be produced by only a few pounds of TNT. It is believed that a cause of the explosion was the chemical reaction of aluminum and water.

National Reactor Testing Station, Idaho Falls, Idaho
July 22, 1954

EBR INCIDENT

Nature of Incident

Overheating of reactor core which may have resulted in partial melting of fuel elements.

Description of Operation

The experimental breeder reactor was undergoing a series of experiments. This particular experiment consisted of permitting the power to increase, from a very low initial level, in accordance with past observed behavior. It was well known that under conditions of low coolant flow and at low power, the power increased spontaneously, i.e., not due to any changes being made to the reactor controls. Without modification, the automatic controls would not permit the conduct of the experiment. They were therefore disconnected. Reliance was placed on manual control to shut down the reactor at the appropriate moment.

Details of Incident

At the appropriate moment, the scientist in charge told the operator to press the "reactor off" button. This would have removed sufficient reactivity. Due to a misunderstanding, the operator began instead to withdraw the rods at normal speed. This removed reactivity at an insufficient rate to prevent overheating and may have resulted in consequent melting of the fuel elements.

Nature of Injuries or Loss

Shortly after the accident, there was a rise in the radiation level in the building. The building was evacuated. There were no personal injuries. There was no appreciable contamination of the NaK coolant.

Remarks

Due to distortion, it was possible to remove only a few fuel rods in the normal manner. It has been necessary to construct a temporary hot cave on top of the reactor. This cave is equipped with viewing windows and remote control devices. As of this writing, the core has been raised into the cave preparatory to disassembling it.

It is important to note that even under ordinary circumstances, any handling, disassembly, etc., of the enriched fuel elements must be done in special hot caves with remote control equipment. The problem here arises from the fact that the fuel elements adhered to the bottom plate, thus making it necessary to raise the whole core structure as a unit. The system was designed to handle one fuel rod at a time and is not capable of lifting the entire core and transferring it to the regular remote handling facility. Thus, it was necessary to rig a remote handling facility on top of the reactor so the regular overhead crane could be used to raise the core.

Idaho Falls, Idaho
Nov. 29, 1955.

CONTAMINATION INCIDENTS

RADIUM CONTAMINATION INCIDENT

Nature of Incident

A radium sulphate capsule broke and contamination was tracked around laboratory.

Description of Operation

A 50-mg. radium sulphate source was used to calibrate pocket meters in a laboratory.

Details of Incident

During the course of the work, the capsule broke in some unexplained manner and approximately 10 milligrams of radium sulphate were released.

The material was spread through three wings of the building and was further spread by being tracked around on the shoes of personnel who were in the building and persons who entered the building (without instructions) to assist. The importance of the incident is due instead to its effect upon the instrumentation in the building, which depends on low background for satisfactory work.

The front end of the building remained usable; the first floor was not seriously affected, but two wings and the shop required decontamination. The ventilation in the building remained shut off although the south windows of the building were opened up.

Nature of Injuries or Loss

There were no injuries. There were no hazardous concentrations at any location.

Remarks

The shops had been engaged in fabricating an improved device for calibrating pocket meters which were scheduled for delivery in about two weeks. The new standard source will use canned cobalt rather than radium. Had the new device been in use, such an incident could not have occurred.

Argonne National Laboratory, Lemont, Ill.
June 13, 1952

NEUTRON SOURCE FAILURES (TWO)

Nature of Incident

There have been two serious and other minor cases of neutron sources leaking, causing contamination to laboratory buildings.

Description of Operations

Sealed metal capsules, containing a neutron source (such as polonium-beryllium), are used in laboratories for neutron experiments and for instrument calibration.

Details of Incident

Cases have occurred where the capsule failed permitting the release of polonium. In two of these the contamination spread through the entire building.

Nature of Injuries or Loss

Several people received over-exposure but none serious enough to be hospitalized.

The loss due to decontamination, and loss of the use of the building for that time, amounted to over $30,000 in each of the two serious cases.

Remarks

Laboratories using radioactive material should consider the possibility of a release and plan for this in the design of the building, Compartmentalization and use of materials that can easily be decontaminated or discarded will greatly reduce the costs of an accident.

SEWER CONTAMINATION INCIDENT

Nature of Incident

Discharge into sewer of waste containing greater quantities of radioactivity than anticipated.

Description of Operation

Metallic thorium was being produced from thorium nitrate tetrahydrate. During an early stage of the processing, a filtrate containing traces of thorium in the form of the nitrate and oxalate was released to the sewer which connected to the city sewerage system. This operation had been carried out for over a year.

Details of Incident

At the time disposal to the sewer was decided upon, it was believed that this waste had a very low level of radioactivity. A chemical method of reducing this still further and ensuring that no release would be made to the sewer had been developed and was being engineered to the necessary scale for this operation when it was discovered that, due to a change in feed material supplied to the laboratory, considerable quantities of mesothorium were being discharged in the filtrate. Mesothorium is one of the daughter products of thorium decay.

While mesothorium gives off hard gamma and beta radiation, its principal hazard as a waste product is due to alpha activity of its decay products.

All the sewage was processed in a "complete treatment" sewage plant. Such a plant discharges a waste liquid effluent and produces dry sludge which is used for fertilizer. The treatment process was found to remove mesothorium very effectively so that the effluent water from the sludge disposal plant had negligible quantities of mesothorium in it. The dry sludge produced during this period had been spread on the city airport, municipal parkway, and the cemetery.

A thorough study of this incident disclosed that there was no hazard to the public or to the employees of the sewer plant even though the radiation levels of the sewer discharges were higher than had been anticipated.

Nature of Injuries or Loss

None.

Remarks

This incident illustrates the necessity of extreme care in the identification and control of radioactive wastes discharged into public sewer and drainage systems.

Ames, Iowa
July 1951 to Aug. 1952

EXCESSIVE INTERNAL DOSE OF PLUTONIUM

Nature of Incident

An employee received one and one-half times the maximum permissible limit of plutonium in the body.

Description of Operation

Employee was doing semi-routine maintenance work on plutonium contaminated equipment.

Details of the Incident

At the time of the operation, the employee was wearing protective clothing and an assault mask. No definite cause can be assigned for the inhalation of the radioactive material. The mask was tested and found to be in proper operating condition. The possibility of improper adjustment of the mask, allowing in-leakage around the face-piece, is considered the most likely cause. Radiological monitoring disclosed that the employee's clothing and some skin surface were contaminated. Routine biological tests disclosed a deposition of plutonium about one and one-half times the recommended permissible limit.

Nature of Injuries or Loss

The employee has not missed any work and has suffered no detectable ill effects to date. It is not expected that any adverse effects will develop in the future because there is believed to be a margin of safety beyond the official permissible limit sufficient to make his exposure harmless. The employee is now assigned to work which does not involve radioactive material.

Remarks

This was the first case in the 12-year history of this facility in which an employee has received an internal dose of plutonium greater than the recommended limit.

Hanford
Feb. 16, 1955

FUME INCIDENT

Nature of Incident

A pressure surge in a system in which a highly radioactive material is dissolved in a solvent.

Description of Operation

Operation involves the use of acids and organics for the separation of metals from a highly radioactive solution.

Details of Incident

A pressure surge was apparently caused by the contacting of solvent with concentrated nitric acid. Brown fumes (nitrogen oxide) were observed coming from the cell at the same time that instruments indicated operating difficulties. A quick radiation check indicated a high level of activity. The entire exclusion area was evacuated.

Nature of Injuries or Loss

There was no injury or unusual exposure to radiation hazard by personnel during the incident. Decontamination required work in high-level fields and resulted in some exposures to personnel. Investigation indicated no over-exposure.

Remarks

Detailed engineering and process changes were carried out to prevent a repetition of this incident.

Hanford
Feb. 5, 1953

CONTAMINATION OF AIR IN A CHEMICAL PLANT

Nature of Incident

Air contamination of a chemical plant building due to an operational incident.

Description of Operation

Some highly radioactive liquid had overflowed into a sump which had been provided for this type of situation. An operator began to transfer the material back to the system by means of a steam jet.

Details of Incident

Radiation contamination was spread through several parts of the plant as the result of continued jetting of the sump after all the liquid had been transferred from it. Jetting was continued because the sump indicator light erroneously showed that liquid still remained in the sump and the operator did not recognize the change in the sound of the jet as it started to suck air. The jet steam escaped from the tank through drain lines into several rooms where the contamination was indicated by constant air monitors. The health physics group ordered evacuation of the rooms and initiated investigation as to the cause.

The trouble was quickly discovered and eliminated. Another room experienced air contamination about 30 minutes later which may or may not have been from the same cause. Air activity dropped to safe level within less than one hour and work was resumed.

Nature of Injuries or Loss

After the incident, most of the men involved were immediately given nose checks and those with significant readings had urine samples taken. Several days later, all people in the building at the time of the incident were sampled. The results showed that no one had received serious exposure.

Remarks

Two important lessons can be learned from this incident:

1. The most routine type of operation can lead to a serious incident when dealing with highly radioactive material. Therefore, all possible eventualities should be considered and definite plans formulated to cope with them.

2. It is difficult for operators to understand all the complexities and hazards of modern plants. Compounding this problem is the operator's dependence on instruments which sometimes fail. The closest possible supervision must be employed.

Chemical Processing Plant, Idaho Falls
Jan. 10, 1955

UNH SOLUTION SPILL

Nature of Incident

Over 1,500 gallons of uranyl nitrate hexahydrate solution spilled when a tank trailer overturned.

Description of Operation

An intra-plant transfer of UNH was being made in a tank trailer. Before starting out, the driver routinely tested the air brakes and found that those on the trailer were not working. In spite of this, he decided to go ahead with the trip.

Details of Incident

En route, he applied the tractor brakes to maintain control of the unit on a downhill grade. The trailer swerved left and right until it overturned.

Immediately after the spill, the road was blocked off. The fire department washed all the material from the road into a drainage ditch. This ground was dug up and removed for reworking. Not only was a large percentage of the uranium recovered, but the radiation level was reduced to a point where no controls were necessary on the road. Within four hours after the accident the road was reopened.

Nature of Injury or Loss

Damage to the equipment, salvage, recovery, and loss of material cost approximately $59,000. No one was injured.

Remarks

The following factors seem pertinent:

1. Design of the tank trailer incorporated a high center of gravity and difficult front suspension with susceptibility to overturning, which had been overlooked when design was approved by AEC and contractor's safety departments.

2. Although the driver is a qualified heavy duty truck and trailer operator, this was his first trip with this trailer.

3. He was aware of the standard practice which prohibited use of defective equipment.

4. He also knew that delivery of the load was desired promptly.

5. He elected to go without trailer brakes, believing he could make the trip safely.

Action taken:

1. The operator has been disciplined for violation of an established safe operating practice.

2. The tank has been mounted on a 25-ton lowboy for increased equipment stability in over-the-road operation. Practical type and design of equipment for this work is being studied.

3. A relative material value will be declared on future movements.

Hanford
Dec. 30, 1954

FIRES

URANIUM SCRAP FIRE

Nature of Incident

Fire involving pressed normal uranium turnings in drums.*

Description of Operation

Uranium turnings received as scrap from machining operations were pressed into briquettes and stored awaiting a casting operation which recovered about one-third the uranium in elemental form.

There were 51 drums stored outdoors and away from any building because of the pyrophoric characteristics of the turnings. Each drum contained about 500 pounds of normal uranium in the form of 3-pound discs, each 3-1/2 inches in diameter and 1-1/2 inches thick.

Details of Incident

The fire was discovered and reported by inspectors who noticed a small amount of smoke, and one barrel was found to be on fire with a canvas tarpaulin covering the cans burning slowly. The fire department responded and the fire was attacked with a fine water spray. Thirty-one drums were removed from danger area before the intensity of the fire made it impracticable to move the others.

After the removal of the drums had been carried out, each of the remaining ones were attacked individually with solid streams of water. With the use of pike poles and wrecking bars, the burning mass in each barrel was agitated, while the water was played on it. The extinguishment was finally accomplished after about 20 minutes' work on each of nine barrels.

Nature of Injuries or Loss

There were no injuries.

The dollar loss, though difficult to evaluate accurately, was modest and probably amounted to several hundred dollars.

Remarks

The remaining drums were filled with water and covered with ventilated tops. The current practice is to store the turnings in smaller drums (about 100 pounds) under oil or water and ship by truck to the recovery plant.

---

*This fire is typical of a number which have occurred.

It was recognized that the hazard of fire presented a storage problem with respect to briquettes and accordingly the drums were stored out of doors and away from any building. Each drum was capped with a loose fitting lid to allow the escape of hydrogen gas generated by the reaction of any moisture present with the uranium metal. Submergence of the turnings under water or oil would reduce the fire risk, although such procedures must depend on the recovery requirements.

In fighting the fire, the firemen wore mechanical filter respirators in addition to their regular firefighting clothing; in accordance with standard procedure they worked from upwind. At the conclusion of the incident, careful monitoring found contamination only on the pike poles and wrecking bars; these were readily decontaminated and returned to service.

Los Alamos, New Mexico
June 27, 1949

URANIUM CASTING FIRE

Nature of Incident

Fire involving the casting of normal uranium.

Description of Operation

A unique casting of more than 3,000 pounds of uranium metal was being carried out in a graphite mold placed in a micarta induction furnace. The charge metal in the form of large discs was pre-melted in the same furnace in a graphite crucible located above the mold.

Details of Incident

This was the first such run and the first time a casting of this size had been attempted. The mold failed and the molten metal flowed to the bottom of the furnace where it flowed into the vacuum line. When the metal reached the vacuum line trap, it burned through and spilled onto the floor behind the furnace. However, not all of the metal flowed into this area; if it had done so, the uranium could have been covered with powdered graphite, thus excluding the air and extinguishing or reducing the rapid oxidation of the metal.

When the vacuum line trap was ruptured, this permitted a natural draft through the furnace. This draft, coupled with the reaction of the molten metal with the water from the sprinkler system and from the cooling coils of the furnace, produced hot flames above the furnace.

The fire was difficult to fight and while it was under control to the extent that the building and the general environment were never in jeopardy, the attention of stand-by firemen was required for several hours.

When the dismantling of the furnace was commenced 18 hours later, some glowing embers of uranium in the uranium oxide were still in evidence.

Nature of Loss or Injury

There were no injuries and the loss was limited to the furnace equipment, estimated at $1200.00 to $1500.00. All the uranium was recovered as oxide or metal. As a matter of interest, a duplicate furnace, located two feet from the furnace involved, showed no sign of damage.

Remarks

Considerable thought and planning took place before the run was started, since this was the first such operation and the graphite available for the mold was not of a size and quality that would have been preferred for this work.

The entire operation was planned so that the minimum number of personnel would be at the scene during the melting and casting operation. At the time the metal was poured, only one man was close to the operation and he had a clear exit which he immediately used.

Subsequent to this incident, many similar runs were made without difficulty.

A new and larger furnace was constructed which permitted the use of larger diameter molds. The mold that failed had been made to fit the old furnace and the mold wall thickness was limited by the furnace diameter. The larger new furnace permitted a thicker mold wall.

Subsequently, the availability of larger-sized graphite stock of a better quality permitted improved mold construction.

The sprinkler heads located directly over the large induction furnaces were removed as a consequence of this incident.

At the time of the incident, personnel were evacuated from the building to prevent their interference with fire control measures. General area monitoring showed no significant contamination other than the immediate vicinity of the spilled material.

Los Alamos, New Mexico
Dec. 9, 1952

FIRE IN A TRUCK LOAD OF URANIUM METAL

Nature of Incident

A truck load of solid pieces of uranium metal was involved in fire.

Description of Operation

Solid pieces of uranium metal were being transported by truck between plants.

Details of Incident

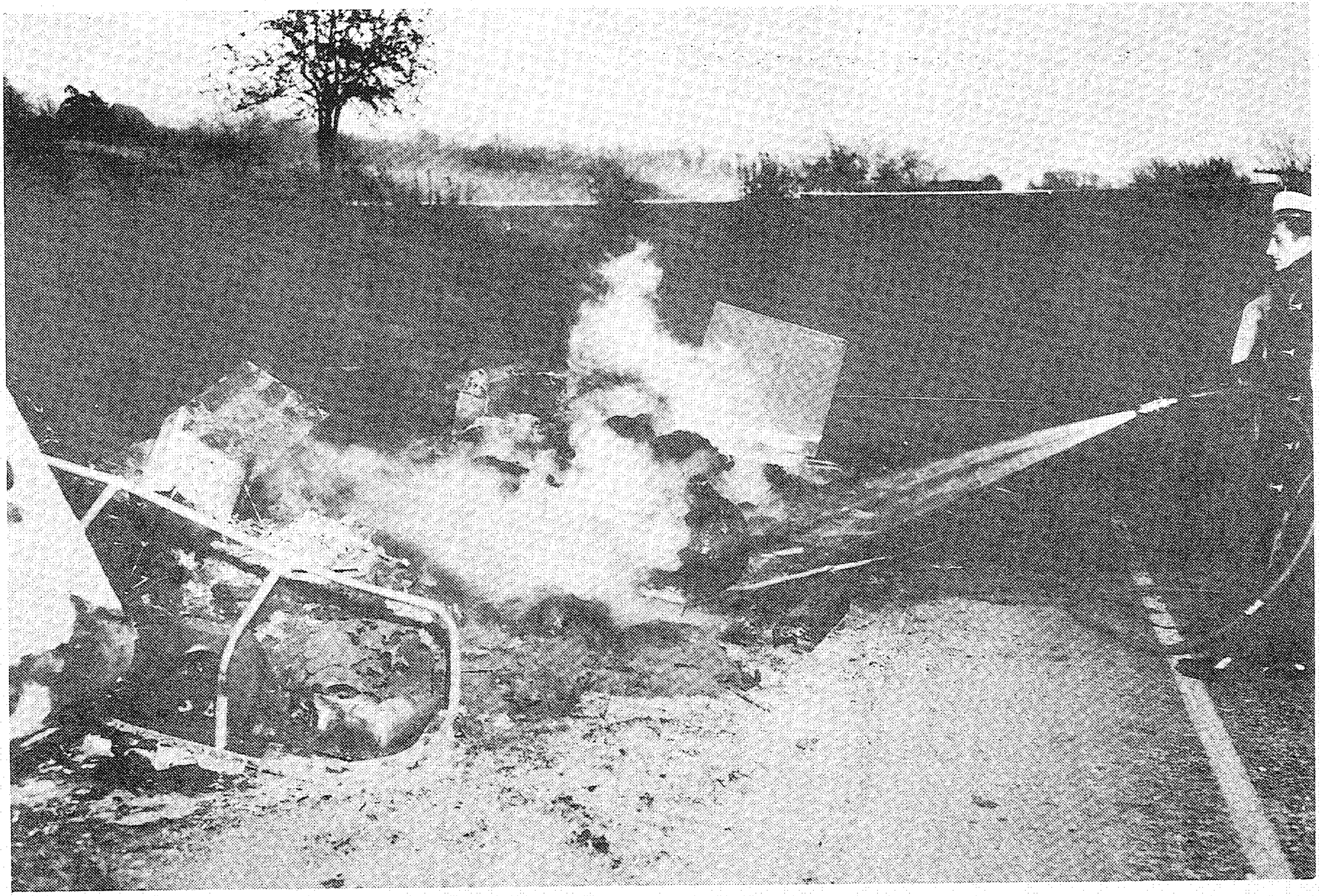
The truck was involved in a vehicular accident and fire resulted from rupture of the truck's gasoline tanks. The fire started to spread to the cargo which was in wooden crates. A local fire department responded but was instructed to use no water. The guards with the truck had received such instructions. At one time, it was thought that such a fire could not be fought with water. The instructions had been changed but the two men concerned had not yet attended the training class.

The fire spread through most of the cargo prior to the arrival of an AEC contractor fire department which extinguished the fire with water.

Remarks

It is well established that uranium in finely divided form or in small pieces such as machine scrap is pyrophoric. Research is underway to determine basic information in the field of uranium pyrophoricity. It is uncertain whether massive uranium metal will sustain combustion but this fire proves that massive uranium must be protected against exposure to external fire. In the case of both scrap and massive metal the "ashes" (uranium oxide) can be recovered for reprocessing. But the loss can be much higher in machined metal due to the fabrication steps which have taken place. Radiation contamination from a normal uranium fire is negligible.

Near Kansas City, Mo.
Oct. 29, 1952



Final extinguishment of uranium truck fire.

SLUG FAILURE INCIDENT

Nature of Incident

A fire occurred while removing a ruptured slug from a reactor.

Description of Operation

A ruptured slug was stuck in a tube. Mechanical pressure was used to move it with some success. This was followed with a high pressure stream of water.

Details of Incident

As the water washed the slug out of the tube, a flash of flame took place. The combustion products were picked up in the ventilation system and emitted from the stack.

Nature of Injuries or Loss

No one was injured. Decontamination work was necessary throughout the back of the reactor. Some of the surrounding countryside was slightly contaminated to a distance of several hundred feet.

Remarks

The exact cause of the fire is not known. It is suspected that a pocket of air ahead of the water picked up uranium dust.

Hanford
Nov. 1, 1955

PLUTONIUM FIRE*

Nature of Incident

A fire involving a quantity of plutonium turnings.

Nature of Operation

The turnings were loaded into combustible containers, which were placed in a plastic bag. The bag was then removed from the hood for heat sealing.

Details of the Incident

The plastic bag was positioned in an electronic heat sealing unit while one of the operators donned an assault mask. This operator returned to adjust the sealing bar and observe the sealing. The second operator, without a mask, moved about 8 feet away and energized the sealing unit control.

About half-way through the 6-second sealing cycle, the masked operator observed a growing brown spot on the plastic bag and white smoke inflating the normally deflated bag. He warned the other operator to shut off the sealer and they quickly left the immediate area of the burning material. The second operator donned a mask and warned five employees, working in the same area some distance away, of the hazards. The latter workers evacuated immediately.

The two operators returned to the turnings which were now burning on the floor (Note: It is not clear how the plastic bag dropped or fell to the floor, nor why the bag was not placed in a nearby hood) and tried to control the flame, using three small CO_2 extinguishers. Flames 2 to 3 feet high were observed. The extinguishers had little or no effect and in a matter of minutes the fire burned itself out. The operators evacuated the space and aided the sealing of the space to prevent further spread of contamination.

Operations in this space were discontinued for about 3 weeks while decontamination activities were completed by the operating forces.

Nature of Injuries or Loss

The direct costs incurred in the decontamination amounted to approximately $20,000.

---

*This is a typical example of the type of fire which occurs in plutonium operations. Several others have taken place.

Remarks

The cause of the fire was not definitely determined. Plutonium chips are pyrophoric and fires should be anticipated in the design and procedures of all plutonium chip operations. While the magnitude of the material loss may vary depending on recovery, the fire loss due to decontamination costs may be quite high, unless prior steps have been take to suppress general contamination in the event of a fire.

Among other steps taken in this case was the elimination of combustible containers and process rearrangement so as to make it unnecessary to remove the material from the hood.

Hanford
May 7, 1954

FIRE INVOLVING PLUTONIUM TURNINGS

Nature of Incident

A fire in plutonium turnings in a laboratory hood.

Nature of Operations

Some plutonium metal turnings were being dissolved in nitric acid in a stainless steel pot. All of the turnings were placed in the pot and 500 ml of 70 percent HNO_3 and 200 ML of water were added. The water was added by 20 ML at a time.

Details of Incident

The mixture was heated from 5 to 10 minutes on a standard laboratory hot plate, the hot plate was turned off, and the mixture had cooled for approximately 5 minutes when a flash and cloud of brown gas appeared within the hood. Sufficient pressure was exerted to force oxides of nitrogen and contamination to pass through the intake filters. Molten plutonium metal and/or oxide was scattered throughout the hood, starting a number of small fires. The pot containing the mixture was covered with a stainless steel cover. The cover was set on the pot with bolts in place, the bolts were not fastened, the cover was vented through a length of tygon tubing to the hood sink. The exerted pressure blew the cover off and the pot was found in the sink. The negative air pressure differential in the hood is approximately 1" of water. The air flow of the hood is such that a complete change is made approximately every 4 minutes.

Nature of Injuries or Loss

There were no injuries.

Remarks

The definite cause of the fire was not determined, but two possibilities exist:

1. The metal turnings were not completely immersed in the solution, and as the turnings were dissolved they settled causing a friction spark.

2. The exposed metal turnings may have oxidized so rapidly that ignition may have occurred.

Either of the two could have caused the flash in the presence of hydrogen gas given off by addition of water to the solution.

Hanford
July 27, 1954

FIRE IN PLUTONIUM CONTAMINATED WASTE

Nature of Incident

A fire occurred in the contaminated storage area of a research building and communicated to the chemical laboratory exhaust hood filters and attic.

Description of Operation

After the radiation burst, described on page 14, the entire building, with the exception of the test assembly room, had been successfully decontaminated and left in a neat and orderly fashion. Decontamination work was proceeding in the test assembly room and on the reactor control assembly.

Details of the Incident

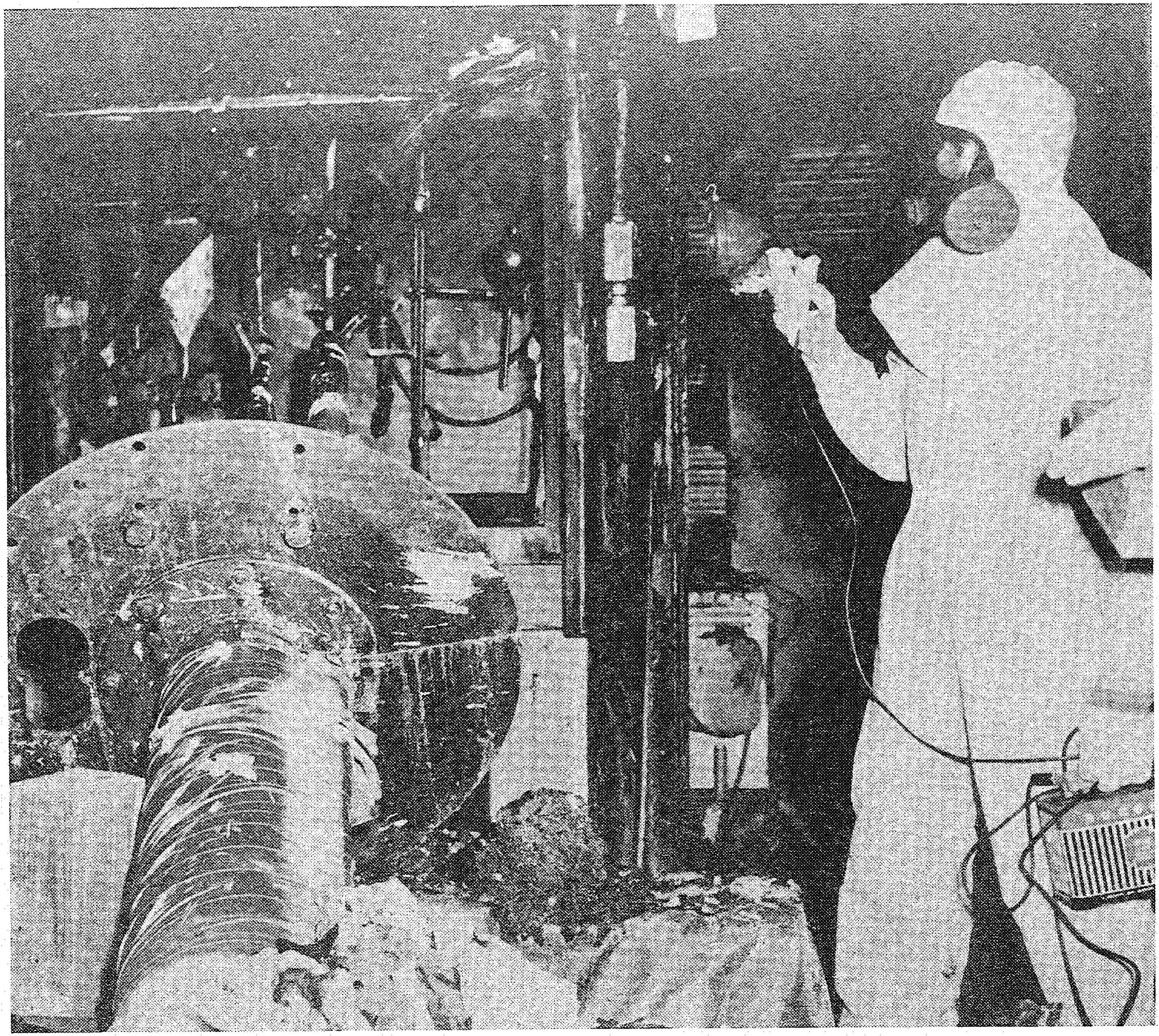
On the day of the incident the building was closed at 5:15 p.m. Approximately 4 hours later, a fire was discovered by the security patrol and reported to the emergency officer of the radiological monitoring unit, and the supervisor of the experiments. It was immediately apparent that the fire had originated in the contaminated storage room and that it had spread to the chemical laboratory exhaust hood filters and the attic.

(This building was remotely located and a careful emergency program had been worked out which required close coordination of the fire department and the radiation monitoring group for this and other buildings on the site containing operations with radioactive materials.)

Oxygen masks and other protective equipment were required due to the plutonium hazards. Qualified radiological monitoring personnel were present and took necessary measures to ensure that procedures devised for fighting fires involving plutonium were followed and that all personnel and equipment were thoroughly surveyed and decontaminated prior to release from the area.

Considerable difficulty was experienced in extinguishing the blaze in the hood filters. It was necessary to break open the filter unit and remove the filter elements to put out the flames and prevent further release of plutonium to the atmosphere.

The total amount of plutonium released was estimated to be between one and four grams. Most of this came from the burned hood filter and the remainder from the previously contaminated waste material. All surveyable surfaces inside the building gave positive alpha readings. A part of the released plutonium was washed from the building by the water used to extinguish the fire, and deposited on the ground outside the building. The contaminated ground was covered with sand to prevent the pickup of active particles from the ground by winds.



Fire damage in contaminated waste fire.

Nature of Injuries or Loss

There were no injuries. Several firemen and one patrolman were found to be slightly contaminated. Decontamination was effected by washing with soap and water. Urinalysis samples were taken of all personnel working within the roped-off firefighting area.

Fire damage had obliterated the cause of the fire. It was the opinion of members of the damage investigating group that the fire originated by spontaneous ignition in the contaminated waste boxed in cardboard cartons in the contaminated waste room. Large quantities of contaminated waste in the form of paper, nitric-acid laden glass wool, rags, and miscellaneous material known to be contaminated were packaged in this manner prior to accumulation of sufficient number of boxes to require burial. The exact number of boxes stored in this room is unknown but there were at least seven. No waste cartons were added to this accumulation during the 30 hours preceding the fire. During this period, several boxes were rearranged to obtain access to an electrical outlet.

Remarks

It should be noted that the building involved in this and the previous incident was built for the purpose of conducting critical mass experiments and thus was remotely located and of minimum value. It was, therefore, economically feasible to abandon use of the structure after the radiation burst and the later fire.

Experimental work which might release a high degree of contamination should be carried out at locations which can be abandoned, or in facilities carefully designed to cope with the decontamination problem.

A further lesson to be drawn is that the accumulation of radioactive waste prior to disposal should not be done in violation of the elementary principles of good fire protection. Specifically, good housekeeping, segregation of materials liable to spontaneous ignition (e.g., nitric acid-cellulose materials), and a storage location chosen with possible spread of water-borne or smoke-borne contamination in mind, are indicated. An ordinary inconsequential rubbish fire can be quite costly if all the elements of risk are not properly evaluated.

Hanford
Dec. 4, 1951

FIRE IN DRY CONTAMINATED WASTE

Nature of Incident

Fire in cellulose waste which had been used with nitric acid to clean up contamination.

Description of Operation

A metal mesh cage at the basement level was used for the storage of dry contaminated waste.

Details of Incident

Fire was discovered in the cage. Personnel from the building were evacuated to another building because of the possibility of airborne radioactive material.

Smoke spread through portions of the building and an indeterminate area was contaminated. The fire department was summoned to combat the fire. Upon arrival they donned respiratory protective equipment and protective clothing. The fire was brought under control by use of water in approximately 15 minutes. All firefighting equipment was left at the scene of the fire for decontamination.

Surface contamination resulting from the fire was limited to the service floor and the elevator shaft which formed a flue for the rising smoke. Negligible airborne activity was detected on the main floor of the building. Normal operations were resumed on the following shift (day).

Nature of Injuries or Loss

Including damage to building and equipment, cost of labor for clean-up, and wages of laboratory employees evacuated from building - $665.

Remarks

The fire was the result of spontaneous combustion of nitric acid and cellulose materials (paper).

Preventive Action Taken

1. All combustible contaminated waste is being stored outside buildings in metal dumpsters.

2. To eliminate time lost in assembling, equipping, and monitoring,

auxiliary firemen from the maintenance department before entering production buildings, employees in each major production building will be trained as auxiliary firemen and used for fighting fires in that particular building.

3. Emergency fire and respiratory equipment will be located in each major building for use of auxiliary firemen.

Savannah River
Dec. 14, 1954

RADIOACTIVE SODIUM FIRE

Nature of Incident

Fire involving radioactive sodium.

Description of Operation

Some radioactive sodium was in a "hot" cell for chemical tests.

Details of Incident

A leak developed in the apparatus and the sodium started to burn. The fire was extinguished with a special powder extinguishant which was sprayed into the cell. When the fire was discovered, the ventilation system was shut down and all personnel not essential to the operation were evacuated from the building.

Nature of Injuries or Loss

No one was injured and exposure was slight. Only one person received more than one roentgen.

Remarks

The possibility of such an incident had been anticipated and plans made accordingly. When this situation occurred, it was handled with a minimum of trouble.

Knolls Atomic Power Laboratory, Schenectady
June 11, 1955

EXPLOSIONS

NITRIC ACID REACTION IN EVAPORATOR

Nature of Incident

Chemical explosion involving radioactive materials.

Description of Operation

Chemical evaporator involving radioactive material dissolved in nitric acid.

Details of Incident

Explosion occurred during evaporation apparently from organic contamination.

Nature of Injury or Losses

There was severe physical damage but no personal injury.

Remarks

Recommendations bearing on the radiation hazards were as follows:

1. Health Physics should be called immediately if radioactive contamination is spread outside of a regulated area.
2. If noxious fumes or radioactive contamination are a possible result of an emergency in an area, a depot of protective clothing, gas masks, and other supplies should be established at a safe distance.
3. Areas covered by 2, above, should be so designated to the Fire and Patrol Departments and these groups should not approach closer than a predesignated distance without the express permission of the operating supervision.

Savannah River Plant
Jan. 12, 1953

PRESSURE RUPTURE OF DRUMS CONTAINING RADIOACTIVE WASTES

Nature of Incident

Rupture of drums containing radioactive waste.

Description of Operation

An AEC contractor had for some time concentrated medium and low level radioactive wastes in a vacuum evaporator. Since it was known that the normally acidic waste materials of this type generated gases, provision was made in the standard operating procedure for treating the concentrated (60-65% solids) evaporator slurry to render it alkaline (i.e., pH greater than 7) prior to placing the slurry in sealed stainless steel drums for storage.

Details of Incident

Operators entering the building containing the drummed waste noticed an unusual odor. Investigation revealed that one drum had "completely ruptured" causing widespread contamination; "slurry was spread over the surrounding area for a distance of 10-20 feet and splattered in other parts of the building for a distance of 30-40 feet." Following the rupture "the drum was blown up against the ceiling, . . ." causing, among other things, contamination of an overhead crane. The bulging heads on two other drums indicated that excessive internal pressure was present. To relieve the pressure, these drums were intentionally punctured from a distance of about 35 feet.

Nature of Injury or Losses

It was estimated that "the cleanup will require 4-5 weeks and it is doubtful whether it will be possible to reduce the degree of contamination to the levels existing before the incident."

Remarks

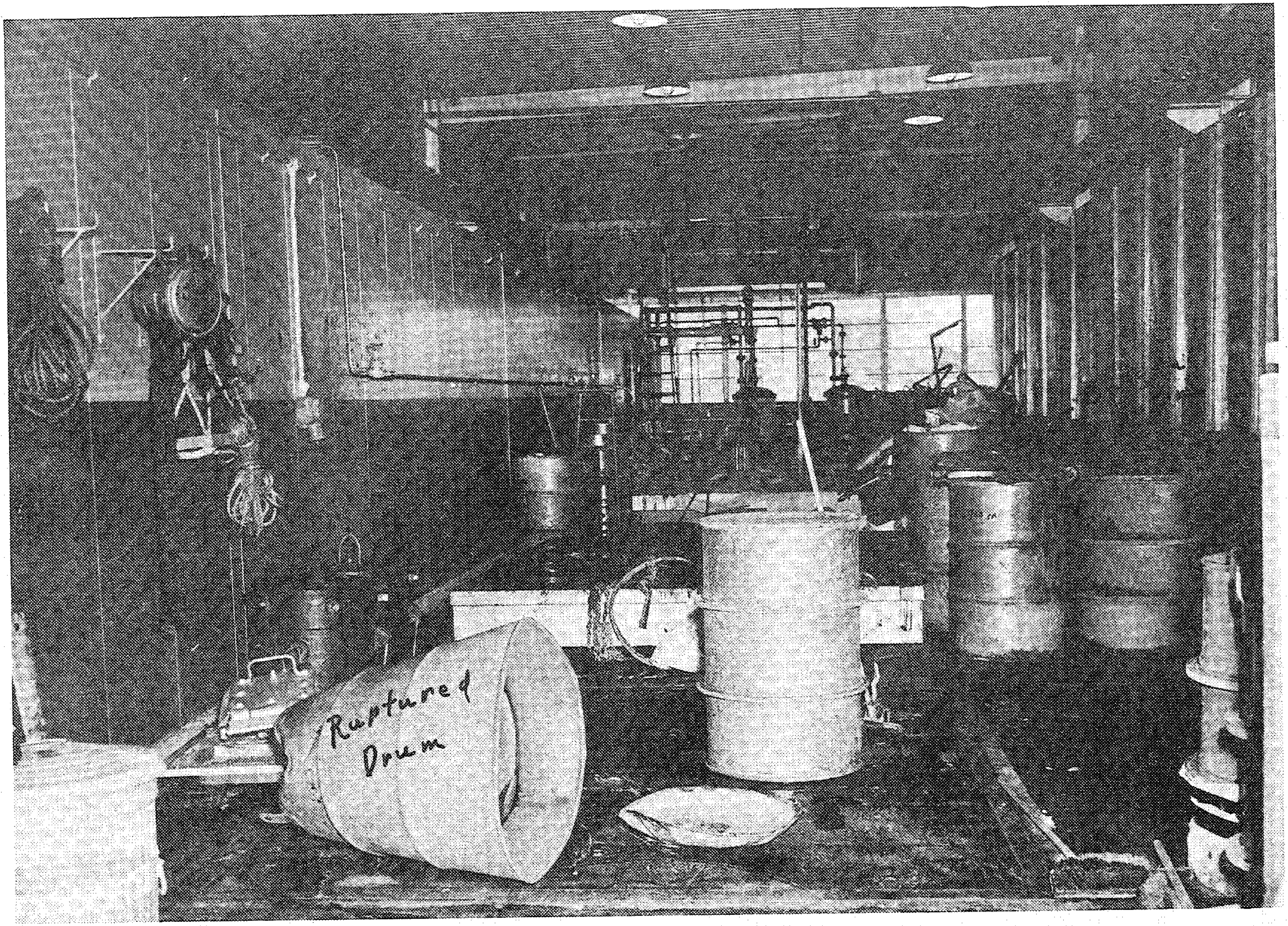
As a result of this incident, the contractor concluded that the operators had failed to check the slurry acidity and that supervision was also at fault for having allowed use of non-standard procedures.

The report covering this incident indicates that the following corrective action has been taken to prevent recurrence:

"1. Revision of existing operating procedures.

"2. Closer supervision of operations to ensure that procedures are followed.

"3. The pH of the evaporators must not go below 7 at any time during their operation.



Ruptured drum.

"4. To prevent any change of acidity during the operation, all evaporator feed tanks will be checked once a shift and will be maintained at a pH greater than 7, which in itself precludes the possibility of the evaporator becoming acidic.

"5. Approval for drumming must be given by the engineer in charge and must be based on a laboratory analysis.

"6. The Chemistry Section has been requested to study the nature of the reaction which generates gases in acidic slurries."

Knolls Atomic Power Laboratory, Schenectady
Feb. 15, 1953

MISCELLANEOUS

HIGH GAMMA DOSE TO HAND

Nature of Incident

Radiation over-exposure to the hand from grasping "hot" end of gamma source holder.

Description of Operation

A source holder with a 200 millicurie radium source was kept outside the laboratory building leaning against the building with one end on the ground. The holder was a piece of aluminum tubing 5 feet long and half-inch in diameter with a wire running inside the rod from a trigger at one end to a movable jaw at the other.

Details of Incident

The usual practice of setting down the source holder was to put the hot end on the ground and the handle end against the building. On the day the incident occurred, there was snow on the ground, so when the source holder was placed outside the door, the usual position was reversed.

A short time later, the employee reached out the door and grasped the holder in the customary way, forgetting it was upside down. Several moments past before he realized that he had hold of the hot end as there was very little to distinguish one end from the other.

Nature of Injury or Loss

There was no injury, although it was estimated that the gamma dose to the hand was about 40r.

Remarks

The source holder was provided with a handle similar to a file handle over the cold end and the hot end was painted a distinctive color. A description of the incident was widely circulated among all employees using a similar tool.

Los Alamos, New Mexico
Feb. 1949

BETA-RAY BURNS ON HANDS

Nature of Incident

Beta-ray burns of the skin of the hands of four individuals resulting from improper handling of fission samples.

Description of Operation

During an overseas operation in the spring of 1948, drone aircraft equipped with air filters were used to secure samples of the cloud resulting from the experimental detonation of nuclear devices. The drone planes were landed at the Eniwetok airstrip, the air filters removed from the planes, and the contained filter papers removed and packed in lead shields for immediate shipment by air for radio chemical study. The individuals who recovered the samples also acted as couriers in the return of the samples, and as there were short-lived activities of interest, the return flight took off immediately after the samples had been packaged and loaded.

Details of Incident

Injuries occurred following two separate detonations. During the procedures associated with an earlier detonation, tongs 2 feet in length had been used for handling the filter paper samples, but difficulties were experienced due to the wind. In the subsequent two experiments, the use of tongs was abandoned and the filter papers were handled with the hands protected by thin cotton gloves over rubber surgeon's gloves. In one operation, an individual used gloves for only a part of the procedure, and discarded them after they became contaminated. A monitor apparently made no objection to these departures from the established procedure for the operation. It is impossible to make any firm estimate of the radiation doses involved to the skin of the hands, although the body gamma doses as estimated by film badges and radiation meters which the individuals wore were 1.7 r, 4.5 r, 5.5 r, and 17.0 r.

Nature of Injuries or Loss

Four individuals received beta ray burns of the skin of the hands, of varying severity. On one man, the burn did not manifest itself until about 10 days had elapsed. The burn involved the thumb, index, middle, and ring fingers of the left hand. The lesion reached its maximum development in about 3 weeks and then began to subside. The other three individuals who received considerably greater exposure developed signs of injury much more promptly, noting pain and swelling within a few hours while on their homeward journey. Details of the management and clinical progress in the four cases were published in 1949.*

---

*Knowlton et al.: Journal of the American Medical Association, 141, pp. 239-246 (September 24, 1949).

One individual has no residual disability except for minimal changes in the skin of the left hand believed to be due to his radiation exposure. The other three individuals have had skin grafts of the hands. One individual has had some small areas of skin grafted as recently as June of 1955. This man has considerable disability of both hands consisting of flexion contractures, ankylosis of joints of the fingers, and subcutaneous tissue atrophy. One has similar changes but less severe. Another has essentially no residual functional disability, but does have extensive grafted areas on the hands.

Remarks

The injuries arose primarily from the failure of the monitor and the individuals concerned to recognize the potential danger from beta radiation. In the original design of the experiment, sufficient distance had been provided so that the contribution of beta radiation to dosage would be negligible.

To prevent a recurrence of such injuries the experiment has been completely redesigned. Changes have been made in the filter holder and associated equipment designed to permit completely remote handling and packaging of such samples in all subsequent tests.

Operation Sandstone
May 1948

RADIATION MACHINERY INCIDENTS*

Nature of Incident

Two cases of persons being irradiated by a linear accelerator.

Description of Operations

The incidents occurred at a university linear accelerator being operated for research purposes.

Details of Incident

Case I

Two graduate students, who were employed as research assistants were at work in a room closer to the target end of the machine than to the control panel. They had installed the target in the machine and were engaged in observing the recording of particular counts as reported in the counting equipment in the room. On two occasions they decided that the target was not properly installed and went from the room to the end of the machine to adjust the target. The first time both persons followed proper procedure in that they notified the accelerator operator by phone before leaving the room that they were going to the machine to adjust the target, and they also removed from the rack the high voltage interlock key, the absence of which from the lock makes it impossible to turn on the accelerator beam. They adjusted the target, returned to the room, replaced the interlock key, and informed the accelerator operator that all was well again.

After some time, they concluded that the target was not yet properly aligned and they left the room to adjust it. This time they failed to inform the operator of their intention, did not remove the interlock key, ignored warning lights and signs, and the sound of the accelerator klystron pulsers. They went into the target area, pushing aside a number of heavy coaxial cables which were in their way. One experimenter leaned over, adjusted the target by hand, and then bent over still more to make the alignment by eye. When he did so, he noticed a bluish irridescence in his eyeglasses. The other experimenter stood right behind him. Upon seeing the flash, the first immediately stood up. Both realized what had happened, and both left immediately and informed the operator of what had happened.

---

*Note: These incidents did not occur at an AEC site but are included because they represent the radiation hazard which is present with these machines.

The incident was immediately reported and a physician called in. A series of measurements and calculations were made to determine the probable exposure. The subject was studied intensively by the physician for several weeks. No signs of damage were found. After three weeks, the physician permitted him to return to the laboratory and he has continued service since then.

An unusual situation existed at the time of the accident which made it possible. An extension of the building was being constructed at the target end of the accelerator. Temporarily, a partition existed between the two sections and, as a result, the target end was not completely barricaded. On the other hand, both of the experimenters were experienced graduate students, well aware of the hazards and of proper safety precautions. The one who was exposed in particular had spent more than a year as a full-time accelerator operator, and it has been a part of his job as such to concern himself with the safety of persons in the building during operation. In addition, the requirement that experimenters work in tandem was made primarily to assure that safety precautions would be observed.

After this incident, operations were suspended until the target area had been enclosed.

Case II

The second exposure involved an inexperienced part-time worker, whose job it was to fill vacuum pump traps with liquid nitrogen on Saturday and Sunday afternoons. Three circumstances contributed to this exposure. First, the man had not been adequately indoctrinated and hence did not pay attention to warning devices or signs. Second, it was possible for him to enter the halfway station acrobatically from the top of the accelerator shielding instead of through the interlock gates at front and back end, and he did so in order to save time. Third, an unwarranted assumption was made by the accelerator operator that this person was no longer in the halfway station, and so the accelerator beam was turned on while he was still in.

The trap filler had told the operator that he was about to fill traps in the halfway station and the accelerator was put out of operation. The person was subsequently seen by an experimenter on the other side of the accelerator in a safe area, and the experimenter concluded that the halfway station traps had been filled. However, the trap filler was merely getting more liquid nitrogen to use, and he twice returned to the halfway station. Meanwhile, the operator was warming up the machine and putting it into operation.

In the experiment going on at the time, the electron beam was diverted from the accelerator into a magnet spectrometer in the station. After emerging from the spectrometer, the beam came out into the air in a direct line to intercept the trap filler at one of the traps. It was estimated that the trap filler was in this position for approximately one-half to one minute, and in the general area, but in a less exposed position, for another minute or so. The affect of the direct line exposure to the beam would undoubtedly have been more serious had it not been for a very fortunate circumstance, namely, that on that particular day a television camera had been installed on a home-made wood mount to monitor the beam as it came out of the spectrometer. The wood mount was located between the spectrometer and the trap in such a position as to stop the beam in some measure, but chiefly to spread it.

The subject was intensely studied by the clinic and no signs of any damage were found. He is presently at work for the laboratory but in a job which does not involve any exposure to radiation.

Following this incident, conditions were studied quite thoroughly and various measures taken. The halfway station was the only point at which acrobatic entry could be made to an area in which the electron beam emerges into air. The problem of providing a permanent roof for the station poses major structural problems which have not yet been solved, but a frame and wire top has been installed, operating procedures and discipline have been tightened, and a system for more adequate indoctrination of all laboratory personnel was initiated.

NITROGEN ASPHYXIATION

Nature of Incident

An employee was asphyxiated when he used an air-line mask which was accidentally supplied with nitrogen.

Description of Operation

Employees entering an area where there was a serious hazard with respect to inhalation of radioactive materials were required to use air-line masks. The air-line was also used to provide instrument air. A regular compressor and a standby compressor were provided on the air-line.

Details of Incident

Over the weekend, both compressors were out of service, so bottled nitrogen was manifolded into the line to maintain instrument air pressure. An employee working alone entered a radiation hazard area and was found dead due to asphyxiation because of the nitrogen substitution in the air-line.

Nature of Injuries or Loss

1 fatality.

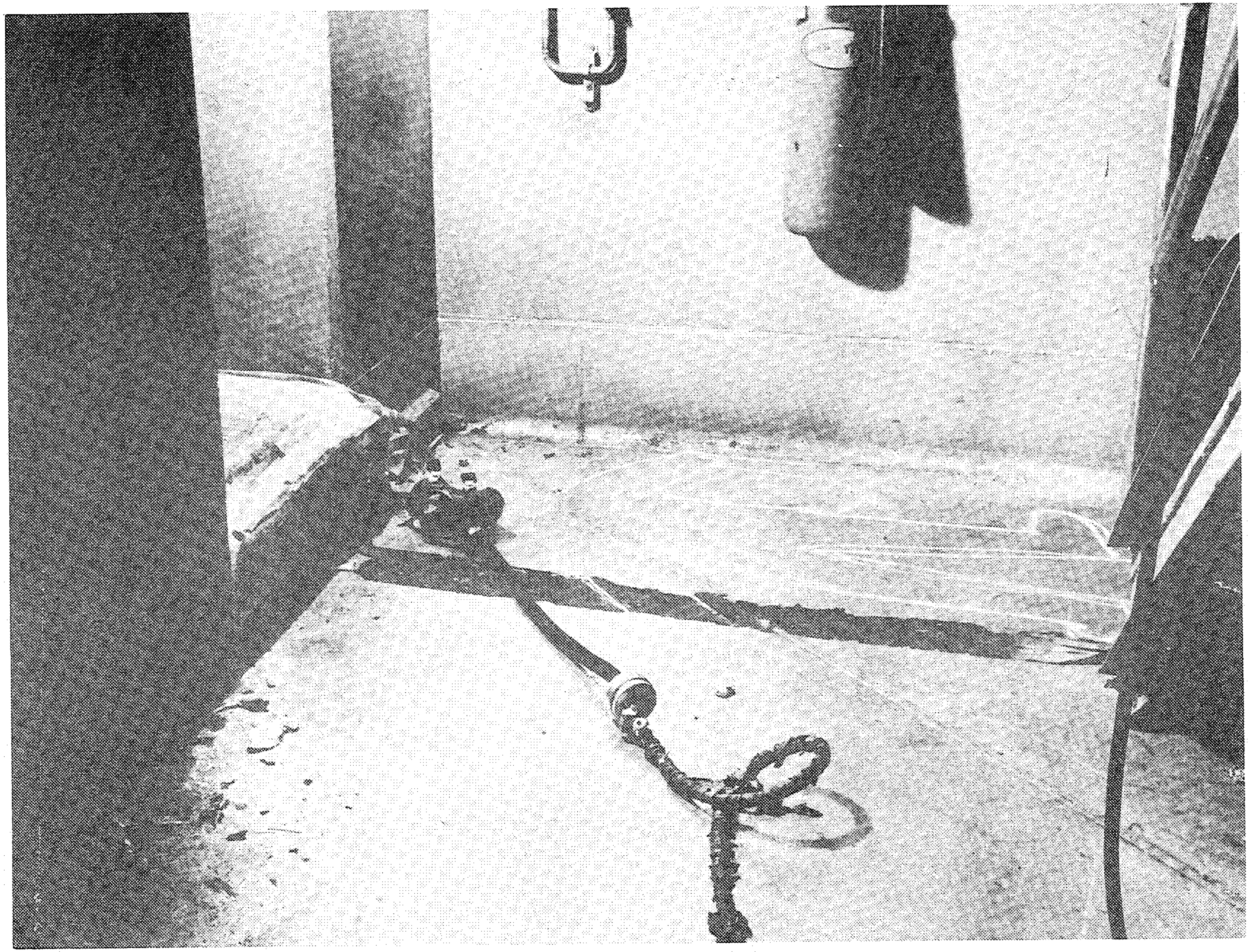
Remarks

No radiation was involved in this incident; the fatality was due indirectly to the fact that the area was one in which the precautions against exposure to radioactive materials made it necessary to use the air-line.

The closest control must be maintained over all operations involving the use of supplied-air or self-contained masks. Basic rules should include:

1. No employee should enter an area requiring such equipment unless tended from outside.
2. Breathing air systems should be used for this purpose only.
3. Air-line respirators should include a "self-rescue" air cylinder
4. Employees should be instructed in the difference between acute and chronic radiation hazard.
5. Where such equipment is used in a situation where the life hazard is not acute, employees should be instructed to remove the mask and leave the area if trouble develops with the mask.

Knolls Atomic Power Laboratory
March 18, 1951



Chalk marks show position of body when found.

UF_6 LEAKS

Nature of Incidents

A number of leaks of UF_6 (uranium hexafluoride) have occurred due to mechanical failures of equipment.

Description of Operations

UF_6 is the gas used in the isotopic separation of U-235 and U-238. It is handled through miles of piping and thousands of pumps and similar equipment.

Details of Incidents

From time to time leaks occur from the same causes as occur in any chemical plant.

Nature of Injuries or Loss

The radiation hazard is unimportant. UF_6 reacts with H_2O in the air to form HF, thus personnel exposed may receive HF burns. In heavy concentrations, the UF_6 may react directly with body tissues.

Remarks

Leak prevention control procedures parallel those for HF.

INADVERTENT EXPOSURE AT TEST

Nature of Incident

An overexposure of radiation was received by a security guard.

Description of Operation

The 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.

Details of Incident

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 safety point that had been set up. 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.

Nature of Injury or Loss

The guards film badge indicated he had received a dose of 39 r. However, continuing blood analyses and physical examination indicate no radiation symptoms.

Remarks

The radiation safety plan has been revised to prevent a recurrence of this incident.

Nevada Test Site
March 1, 1955

RADIATION EXPOSURE

Nature of Incident

Inadvertent handling of irradiated solid aluminum pieces.

Description of Operation

Three irradiated solid aluminum pieces were washed out of the front face end of a process tube on the 105-DR reactor. Two nearby employees, thinking that these aluminum pieces were "cold" pieces that they were in the process of charging, each picked up one of the irradiated pieces. One of these employees handed his piece to another employee who was to "charge" it before it was realized that these pieces were probably irradiated.

Nature of Injuries or Loss

Eleven people were nearby at the time of the incident, though it is believed that only six of them received exposure in excess of the permissible limit. Of these six, only three (those who had handled pieces) were believed to have received significant overexposure. Each was estimated to have received a hand dose of 100 r. The beta hand dose was estimated to range for the three employees from a possible minimum of 30 rad to a maximum of 330 rad. The maximum "whole body" dose was estimated to about 3.5 rad including 2 r.

Remarks

More adequate communications were established between the charge face and discharge face of the reactor to prevent one group from opening a tube while the other end of the tube was still under high water pressure.

More adequate pre-job planning measures were inaugurated.
Note: It was not realized prior to the incident that light weight (aluminum) pieces were upstream from the main charge. Also it was not known that the comparatively low water pressure that was on the tube could wash out such aluminum pieces under the conditions planned.

Hanford
May 11, 1953

RADIATION BURN

Nature of Incident

Employee received radiation burn.

Description of Operation

Employee was unpacking radioactive material.

Details of Incident

While unpacking material he allowed it to rest against his leg.

Nature of Injuries or Loss

The man received a radiation burn on his ankle. He lost 36 days from work. Compensation was paid. He made a full recovery.

Los Alamos
Sept. 1948