ANNOUNCEMENT

Federal Aviation Agency

ADVISORY CIRCULAR

FEDERAL AVIATION AGENCY · UNITED STATES OF AMERICA

AC NO: 150/5240-6A	AIRPORTS
EFFECTIVE: 3/7/66	

SUBJECT: RADIATION SAFETY FOR CIVIL AIRPORTS

1. PURPOSE. This advisory circular announces the availability to the public of the subject publication.

2. CANCELLATION. AC 150/5240-6, Radiation Safety for Civil Airports, is cancelled.

3. DESCRIPTION OF PUBLICATION. The subject advisory circular provides civil airport managers, safety personnel, and the public with information on the fundamentals of radiation and radioactive materials. It discusses the shipment of radioactive materials, methods of measuring the potency of radiation, and what to do following an accident when shipping radioactive materials.

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Cole Morrow, Director
Airports Service

Federal Aviation Agency

AC NO: AC 150/5240-6A

AIRPORTS

EFFECTIVE:

8/16/63

ADVISORY CIRCULAR

SUBJECT: RADIATION SAFETY FOR CIVIL AIRPORTS

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1. PURPOSE. This circular announces the availability of the subject publication.

2. DESCRIPTION OF THE PUBLICATION. The publication provides civil airport management and safety personnel with information and technical criteria needed to cope with accidents involving nuclear materials that might occur at or near airports. It discusses fundamentals of nuclear radiation, outlines the precautions taken in transporting radioactive materials by air, and suggests procedures for handling accidents involving radioactive material.

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RADIATION SAFETY FOR CIVIL AIRPORTS

FEDERAL AVIATION AGENCY

RADIATION SAFETY

FOR

CIVIL AIRPORTS

Revised 1965

FEDERAL AVIATION AGENCY
Airports Service

FOREWORD

Radiation Safety for Civil Airports was prepared by the Airports Service, Federal Aviation Agency, and is published as Advisory Circular 150/5240-6A.

This publication provides civil airport management, safety personnel, and the general public with basic information on the fundamentals of radiation and the technical criteria needed to cope with emergencies involving radioactive materials or nuclear weapons on aircraft should an accident occur on or near an airport. It describes the measures required by law to be taken to ensure maximum safety and the procedures to be followed at the scene of the emergency. Other forms of radiation that might be present on an airport, such as RF radiation from radar equipment, X-ray emitters, radioactive electronic tubes, and background levels associated with fallout air sampling, are not within the purview of this document.

The development since 1946 of peacetime use of radioisotopes has led to constantly increasing use of air transportation for shipping them. So much has been written about nuclear energy and radiation hazards since 1945 when the power of the atom was first publicized that many people look upon this power as a sinister force. The popular notion is that the effects cannot be combatted. An understanding of the basic fundamentals of nuclear radiation will help to lessen this fear.

This publication is divided into three major categories: "The Radiation Problem," "Nuclear Radiation," and "Emergency Operations at Civil Airports." The first category discusses the shipment of radioactive materials on civil aircraft and gives fundamental information about nuclear weapons on military aircraft. Radiation, methods of measuring and monitoring its potency and its biological effects, protection of personnel, and decontamination are covered in the second category. The third category outlines emergency operations to be set up following an accident involving shipment of radioactive materials on commercial aircraft and nuclear weapons carried on military aircraft; and tells how to obtain assistance for radiological protection. Public relations and news releases are mentioned to emphasize the need to prevent undue anxiety.

A glossary of specialized terms associated with nuclear radiation appears in the Appendix.

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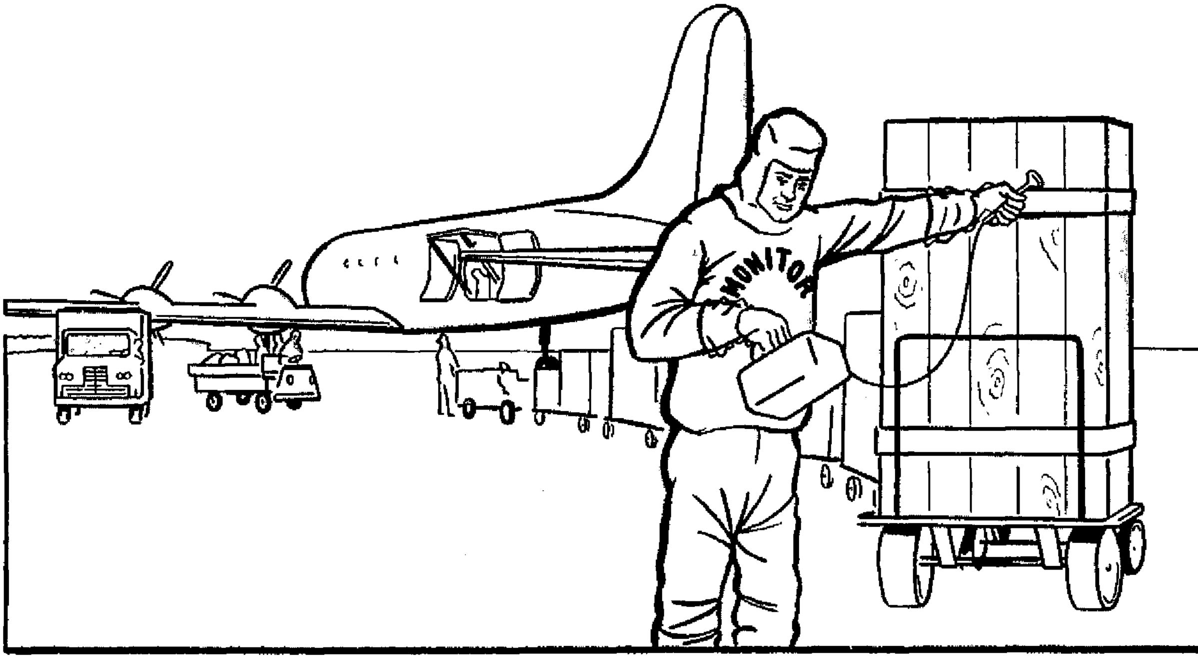


THE RADIATION PROBLEM

Section 1—Air Transportation of Radioactive Materials

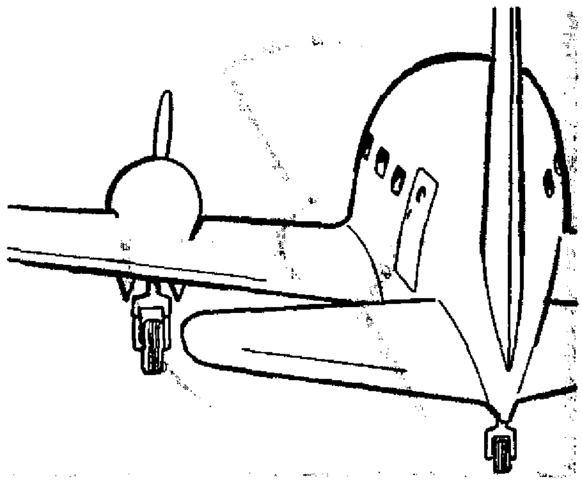
The possibility of disaster caused by accidents to aircraft carrying radioisotopes has been the object of much concern, especially of civil airport management and safety personnel. *This concern, for the most part, is unwarranted.*

Specialized procedures for handling radioactive materials are required. These procedures can be compared with those that a physician takes when dealing with a contagious disease; he is more careful in matters of personal sanitation. Similarly, safety personnel and crash crews who have been trained in specialized protective procedures and who are aware of the hazards involved should have little more difficulty with accidents to civil or military aircraft carrying radioactive materials than with other types of aircraft accidents.

Certain military aircraft, on the other hand, pose a completely different problem. Because the U.S. Department of Defense has a number of aircraft airborne at all times, some of which may be carrying nuclear weapons or components, it is conceivable that one of these aircraft might have to make a crash landing at a civil airport. It should be emphasized that the possibility of a nuclear explosion resulting from an accident of this kind is so remote that it can be ignored. However, the problem posed by military aircraft, as will be pointed out in Section 3, is that the hazards resulting from an accident involving a nuclear weapon would likely be due to the conventional high explosives contained in the weapon rather than to a nuclear detonation.

Nonetheless, the detonation of high explosives or the overheating of the weapon would create radiation dangers, and airport safety personnel must be prepared to cope with these conditions. In addition, any accident in which a nuclear weapon is involved creates security problems that, if improperly handled, may compromise the national defense.

Whether the accident involves a container of radioisotopes bound for some laboratory or industry, or whether a nuclear bomb is on board, a trained and equipped group of safety personnel can cope with the situation and can control the effects of it. It is the purpose of this publication to assist them in doing so.



Section 2—Radioactive Matter on Civil Aircraft

The loading and carrying of radioactive materials, including fissionable materials, in any civil aircraft in the United States and in civil aircraft of United States registry anywhere in air commerce, with certain exceptions, are governed by Part 103 of the Federal Aviation Regulations promulgated by the Federal Aviation Agency (FAA).

These regulations apply both to the shipper and to the civil aircraft operator who transports the materials, and both are required to be familiar with the regulations prescribing the safe transport of the materials. The basic requirements were drawn up initially by medical and other scientific experts, and they have remained constant and uniform for all modes of transportation.

The shipment of radioactive materials is no longer limited to the Atomic Energy Commission or one of its licensees. The quantity of radioactive material that can be transported on any one aircraft is quite small, being limited to 40 radiation units. The small amounts permitted, packaged in approved containers, are so shielded that surface radiation is held to a safe minimum. A shipper's certificate of compliance must accompany each package.

Under certain circumstances, a waiver may be obtained from the Administrator of the Federal Aviation Agency that will permit transporting larger amounts of radioactive material or materials. In such cases, the Administrator will specify the terms and conditions for the special shipment, including a requirement that the holder of the special authorization must notify and obtain the permission of the operators or managers of the airports to be used.

Radioisotope Shipments

The Oak Ridge National Laboratories (ORNL) is the largest single shipper of radioisotopes, and approximately 85 percent of the shipments from ORNL have been by air transportation. More than 50 percent of the air express and air freight shipments from the Knoxville (Tennessee) Municipal Airport have been radioisotopes from ORNL. Yet shipments by ORNL represent less than half of the total, the balance being shipped primarily by commercial firms licensed by AEC.

The popularity of air transportation for these materials is partially attributable to the short half-life of many of the radioisotopes which if held too long would render them useless on arrival. If shipped by slower surface transportation, the lapse of time could be too great.

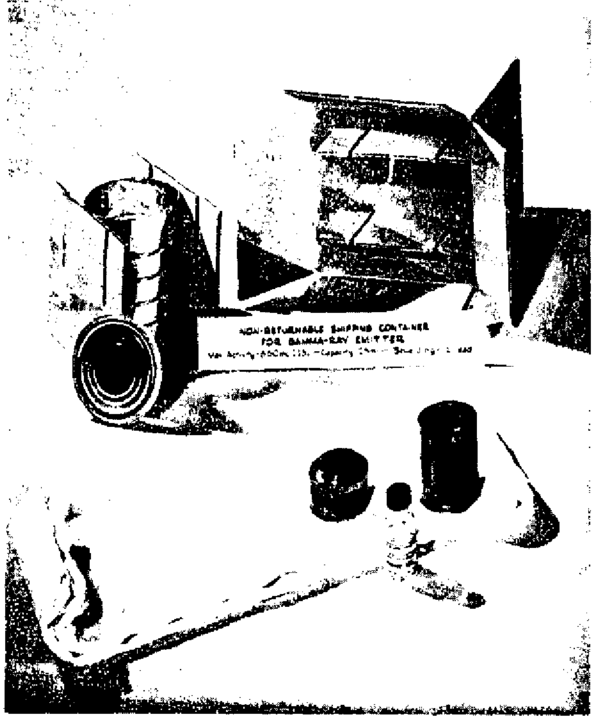
A quantitative analysis of the shipments of radioisotopes and correlation of the shipments to the hazard classification of the radioisotopes shipped is indicative of the relative safety of the operation. Radioisotopes may be divided into three groups according to their radiotoxicity:

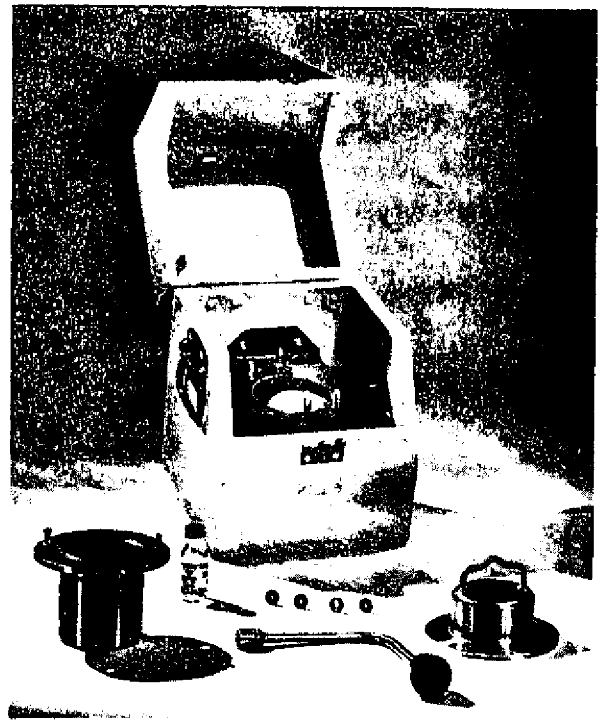
Group I—Very high radiotoxicity
Group II—High radiotoxicity
Group III—Moderate to low radiotoxicity

Radioisotope Containers

The great majority of radioisotopes shipped fall in Group III. Approximately 90 percent of them, consisting of Cobalt 60, Iridium 192, and Cesium 137, have been securely encapsulated to form sealed radiation sources in teletherapy machines, irradiators, radiographic cameras, and the like. (Sealed sources are designed to be highly resistant to leakage.) Less than 1 percent of the total materials shipped by all types of transportation warranted special attention beyond the regular packing and shipping requirements.

In addition to the categories listed above, radioactive materials are also grouped according to the type of radiation involved. Radioactive material, as defined by regulation,





is any one or a combination of materials that spontaneously emit ionizing radiation. They are treated as Class D poisons. The grouping is:

- Group I—Radioactive materials that emit gamma rays only or both gamma and electrically charged particles (alpha, beta, etc.).
- Group II—Radioactive materials that emit neutrons and either or both Group I types of radiation.
- Group III—Radioactive materials that emit electrically charged particles (alpha, beta, etc.) only, or any other material that is shielded so that gamma radiation does not exceed 10 milliroentgens for 24 hours at any time during transportation.

Under existing Federal Aviation Regulations, not more than 40 radiation units of Group I or Group II radioactive material may be carried on one aircraft. A "radiation unit" is the measurement of 1 milliroentgen per hour at 1 meter from any point on the surface of a container. These restrictions are imposed for the protection of human life, and as long as containers remain intact and the distance and time separation is maintained, a safe level of protection is assured.

An applicant for a special shipment waiver should submit the permit number of his container design which has been approved for the material and quantity thereof by the Bureau of Explosives. Special containers should be thoroughly tested and proven to be highly fire and crash resistant before approval is granted.

Shipping Labels

Federal Aviation Regulations require that radioactive material be identified by special shipping labels. The special labels, approved by the Atomic Energy Commission, are shown in the figure on page 4.

For Groups I and II radioactive materials, a white and red label is used to call attention to the characteristics of these radioisotopes that emit gamma rays or neutrons of considerable penetrating power. The red printing warns persons not to remain unnecessarily within 3 feet of the package, and to keep undeveloped photographic film at least 15 feet from it. In the blank spaces, the shipper must state the name of the material, the activity in

LABELS REQUIRED ON PACKAGES SHIPPED BY AIR curies, and the number of radiation units in the package.

Group III materials are identified by a white and blue label, used for shipments that emit principally alpha and beta particles of low penetrating power.

Shipping Compliance

The responsibility for compliance with packaging regulations rests primarily with the shipper. The regulations require that no shipper shall offer, and no air carrier or other operator of aircraft shall knowingly accept, radioactive materials for air shipment unless the shipper or his representative has certified that the shipment complies with Federal Aviation Regulations. Further, no shipment may be offered or accepted for transportation on passenger-carrying aircraft unless it bears a clearly visible statement that it is within the limitations prescribed for passenger operations.

An aircraft operator may accept such a certificate as *prima facie* evidence of compliance. The following statement is considered acceptable:

> *This is to certify that the contents of this package are properly described by name and are packed, marked and labeled and are in proper condition for transportation according to the Regulations prescribed by the Interstate Commerce Commission and the Administrator of the Federal Aviation Agency.*

For shipment on passenger-carrying aircraft, the following statement is considered acceptable:

> *This shipment is within the limitations prescribed for passenger-carrying aircraft.*

When radioactive material is carried on aircraft, the operator must inform the pilot-in-command of the name, label type, quantity, and its location on the aircraft. The cargo manifest must be conspicuously marked to indicate the presence of radioactive materials.

Special Shipments

Larger amounts of radioactive materials may be shipped by air only upon issuance of a waiver by the Federal Aviation Agency. Such issuance is limited to emergencies or when other modes of transportation are found to be impractical. Examples of the latter are: the destination of the shipment inaccessible except by air; or the characteristics of the material such that the decay rate would make the radioisotope unusable upon arrival at the destination if shipped by surface transportation. If the large shipment is solely for the convenience of the shipper no waiver will be granted.

Shipments of radioactive materials by the Atomic Energy Commission (or under its direction or supervision and escorted by specially designated personnel) are covered by special arrangements approved by the FAA Administrator.

Exempted Articles

Some materials are so mildly radioactive that they present no significant hazard. An example of this is the use of radium compounds on watch and clock dials. These and various other radioactive materials are exempt from packaging regulations if they meet *all* of the following requirements:

1. The package is so designed and constructed that there can be no leakage of radioactive materials under conditions normally incident to transportation.
2. The package shall contain not more than 0.1 millicuries of Radium or Polonium, nor of the amount of Strontium 89, Strontium 90 or Barium 140 that disintegrates at a rate of more than 5 million atoms per second; or not more than that amount of any other radioactive substance that disintegrates at a rate of more than 50 million atoms per second.
3. The package shall be such that no significant alpha, beta or neutron radiation is emitted from the exterior of the package, and the gamma radiation at any point on the surface of the package shall be less than 10 milliroentgens in 24 hours.

Manufactured articles other than liquids (of which radioactive materials are a component part) and luminous compounds when securely packed in strong outside containers are exempt from the packaging requirements, provided the gamma radiation at any point on the package surface is less than 10 milliroentgens in 24 hours.

Radioactive ores and residues are also exempt from packaging requirements if they are placed in strong tight containers, and the per-plane load does not exceed 10 milliroentgens per hour of gamma radiation or equivalent. Loose material and leaky containers are not permitted.

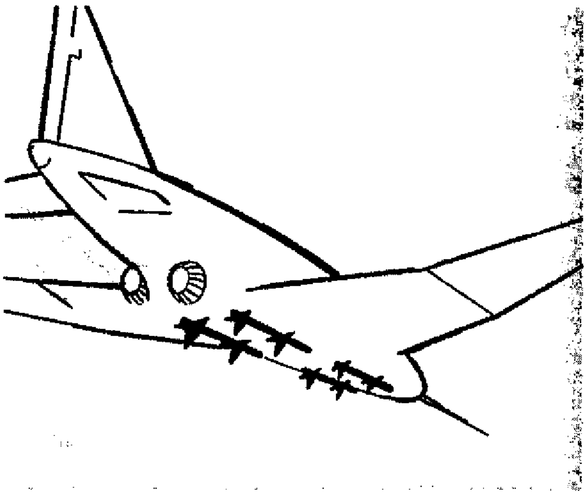
Safety Analysis

It will be obvious, after reading this chapter, that the shipment of radioactive materials by air transportation is circumscribed by all safeguards possible. Regulations put rigid restrictions on the amounts that can be shipped on any one aircraft. All shipments must be carefully and conspicuously labeled so as to call attention to their presence.

The containers are so sturdy that they have been dropped from moving vehicles and even run over by taxiing aircraft without being broken open. In fact, it is not too farfetched to say that, in the event of an aircraft accident, they may survive better than many components of the aircraft.

There is *absolutely* no possibility of a nuclear explosion being caused by radioactive materials in civil air transport. This will be explained in Section 3.

The hazard stems from that isolated instance when the packaging may be broken in a crash or be burned so that radiological contamination is released. It is to control the effects resulting from such contamination that airport safety personnel must be prepared. The techniques and procedures for doing this are described in Sections 8 through 10.



Section 3—Nuclear Weapons and Components

In the defense of our country, there are daily shipments of nuclear weapons and their components by rail, naval vessel, and military aircraft. In its alert and dispersal program, the U.S. Department of Defense has a number of aircraft in the air at all times; some of these have nuclear weapons aboard. In the event of an emergency, it is possible that some of these aircraft would land at civil airports. If a normal landing is effected, there is no hazard. If the aircraft crashes or burns, hazards may be created with which it is essential that airport management and safety personnel be familiar.

There is nothing exotic or mysterious about the appearance of nuclear weapons. They look like what they are—bombs, rockets, etc. Each bomb contains two principal components: radioactive materials and high explosives. If the weapon is involved in a crash or fire, these are the components that will be of primary concern to airport personnel. The odds against a nuclear detonation are astronomical, but detonation of the conventional high explosives and scattering of radioactive contamination may occur.

Bomb Theory

Details of the construction of nuclear weapons are highly classified, but the basic principles are simple. To understand why a nuclear weapon cannot explode accidentally, it is first necessary to know how it is detonated deliberately.

All matter is composed of atoms, and atoms in turn are composed of a nucleus and one or more electrons in orbit around the nucleus. Hydrogen has 1 electron and uranium has 92. The nucleus is composed of a combination of protons and neutrons, depending on the particular element or isotope. When particles are spontaneously emitted from the nucleus of an atom, the element is said to be radioactive.

There are two ways in which nuclear interactions can be caused, resulting in a tremendous release of energy in a very short time, producing an explosion. They are known as "fission" and "fusion."

In fission, a free (or unattached) neutron enters the nucleus of a fissionable atom (certain isotopes of uranium or plutonium) and splits the nucleus into two smaller parts. The combined weight is less than that of the original atom, and the difference in weight, or mass, is converted into energy. The complete fission of *1 pound* of uranium or plutonium can produce as much energy as the explosion of *9000 tons* of TNT.

In fusion, a pair of light nuclei fuse (or unite) to form a nucleus of a heavier atom with the release of a large amount of energy. Such fusion reactions can be brought about by the application of extremely high temperatures. Weapons using this process are often referred to as "thermonuclear weapons." The fusion of all nuclei present in *1 pound* of the hydrogen isotope deuterium can release as much energy as *26,000 tons* of TNT.

Stray neutrons are always present in radioactive material; therefore, there are definite limits to the amount of material that can be assembled without producing a nuclear reaction. If the amount or shape of material is such that the stray neutrons can escape after only a few fissions, the mass is said to be "subcritical," because the release of nuclear energy in amounts sufficient to be usable is dependent on the ability of the fission process to continue in what is known as a "chain reaction."

If the shape or amount of radioactive material does not allow one neutron from each fission to escape, but to go on to fission a new atom, chain reaction is created and the mass is said to be "critical." In nuclear reactors the chain reaction is controlled so that energy is released but an explosion does not occur.

To cause a nuclear explosion, the mass must become "supercritical," and to make it so, *the mass must be compressed with great force in a few millionths of a second.*

Mechanics of Detonation

To compress the nuclear material in a bomb, the material is completely surrounded by high explosives, commonly referred to as "HE." The principle is known as "implosion" because the force is *inward.* When the HE is detonated by the absolute simultaneous firing of many detonators around the surface of the charge, the wave from each detonator moves inward, compressing the nuclear material and squeezing the atoms closer together. Thus the mass becomes "supercritical."

On the other hand, if even one of the detonators fails to fire, or if it fires even microseconds later than the others, the implosive force escapes *through* the mass, and the nuclear material is not compressed. Therefore, the mass cannot become supercritical and no nuclear detonation will result. This point is so important that tremendous effort has gone into the design of the electrical system to ensure that all detonators will be fired *exactly* at the same time, and to ensure that *this cannot happen accidentally.*

Safety Measures

One might reasonably ask how—since all the components needed to fire a nuclear weapon are present in the aircraft on a readiness mission—the possibility of an accidental nuclear detonation can be termed "negligible."

Although full nuclear technical information is classified, we can present the information that civil airport management and safety personnel will need to cope with a possible nuclear accident.

Four procedures for the safe handling of nuclear weapons are designed for the prevention of:

1. Accidents.
2. Unauthorized acts.
3. Human error.
4. Faulty security.

Each of these four safety systems interlock and so make the chances of a nuclear explosion negligible. In addition to these four systems, further controls are provided.

A nuclear weapon can be completely armed (that is, made ready for firing) only at the direct order of the President of the United States; unless the weapon is so armed it *cannot* "go nuclear." To preclude the possibility of premature arming, a series of safety switches that prevent the flow of electrical current from reaching the nuclear component is incorporated in the design of the weapon. For added operational safety, a set of switches separate from those used during transportation are provided. These switches are so concealed that no one member of the operational team knows where all of them are.

To avoid detonation of a weapon by psychotics or saboteurs, the complexity and concealment of the switch systems are backed up by periodic and rigid mental, physical, and security checks. Finally, at least two persons must be present whenever access to a nuclear weapon is granted.

Following is a tabulation of some of the safeguards that protect the nuclear weapon from unauthorized or accidental detonation:

Area of Concern	*Safety attained by:*
Accidents	1. Bomb design. 2. Inert storage. 3. Switching systems. 4. Detailed safety procedures.
Unauthorized Acts	1. Safety switches concealed. 2. Two or more controls. 3. Presence of two or more persons. 4. Personnel screening.
Human Error	1. Switches locked or sealed. 2. Two or more controls. 3. Presence of skilled technicians.
Faulty Security	1. Armed guards. 2. Personnel identification. 3. Security clearance. 4. Physical barriers. 5. Alarm devices.

The High Explosives Hazard

As stated above, the unintentional detonation of the nuclear component in a weapon is virtually impossible. However, in the event of an accident involving a nuclear weapon, two characteristics of the weapon may create a serious hazard both for safety personnel and for the surrounding community.

Basically, a nuclear weapon consists of two components: (1) the high explosive material that, upon detonation, creates the implosion or "squeeze" that causes the mass of nuclear material to become supercritical, and (2) the nuclear material itself. The latter and its concomitant hazards will be treated in the next Section of this chapter. Accidents or fires involving nuclear weapons are similar in effect, and require handling similar to incidents involving conventional high explosives, *plus* added precautions made necessary by the potential radiation hazard.

The high explosives contained in a nuclear weapon are of several types, depending on the weapon, but may be categorized generally into three classes: slow- and fast-burning components used to shape the implosion wave, and an initiator (which is similar in use to that of a dynamite cap).

To determine the extent of hazard associated with a nuclear weapons accident, the AEC and the Department of Defense have conducted tests in which nuclear weapons were dropped, burned, and otherwise mishandled. The results of these tests were used to develop the guidance presented in Section 9.

The detonation of the high explosives component may take the form of small, large, or a series of small explosions. The breakup of the weapon as a result of hard impact or explosion will probably result in the scattering of fragments of unexploded HE and/or radioactive material. Sensitivity of the HE used may be increased by powdering, temperature changes, and exposure to sunlight. Some types of HE will melt at comparatively low temperatures and resolidify to form a mass extremely sensitive to shock, and may detonate if stepped on. Exposure to sunlight will often change the color of the material so as to render it almost invisible against a runway surface or natural surroundings.

For these reasons, the clearing of an aircraft accident scene in which a nuclear weapon has been involved should be undertaken only by specially trained Government demolition teams.

In addition to the blast hazard, burning high explosives emit toxic and caustic gases, and many leave highly toxic residues; special care must be taken to ensure that the gases are not breathed. The presence of other flammable matter in any aircraft accident, such as gasoline, other volatiles and explosive fuels, may cause the weapon to be enveloped in flame. If the HE is ignited, "torching" may be observed, in which a brilliant white, orange, or bright red flame will issue from the weapon. Visible white or yellow smoke may or may not be present. Both ignition and detonation may be controlled, however, if the explosive's temperature can be kept below 300° F.

Radiation Hazards

The other hazard involved in a nuclear incident is that caused by nuclear radiation. If the weapon remains intact with only superficial damage, there will be no radiation hazard. If, on the other hand, the weapon is broken open, or if the HE has burned or detonated, it is probable that a radiation hazard will exist.

The radioactive materials contained in a nuclear weapon are, primarily, either uranium or plutonium or both. In general, the hazard arises from alpha particles emitted from both elements. Since alpha particles cannot penetrate the skin, the hazard is not serious as long as the particles are not ingested by way of the respiratory or alimentary tracts. Particles can enter the body through an opening in the skin, but they would, in that case, be sufficiently localized that they could be removed.

Uranium acts mainly as a chemical poison; plutonium, on the other hand, tends to concentrate in the bone and bone marrow, where the continuous emission of alpha particles may cause significant injury.

Both elements react readily with oxygen and may become dispersed in the form of oxides as smoke particles. Some fissionable materials will melt and be left on the ground as slag, to become airborne or otherwise dispersed if disturbed. Tests by the Atomic Energy Commission have indicated, however, that the amounts of plutonium oxide received from contaminated smoke or otherwise at distances greater than 1,500 feet from the incident will probably not exceed the accepted Radioactivity

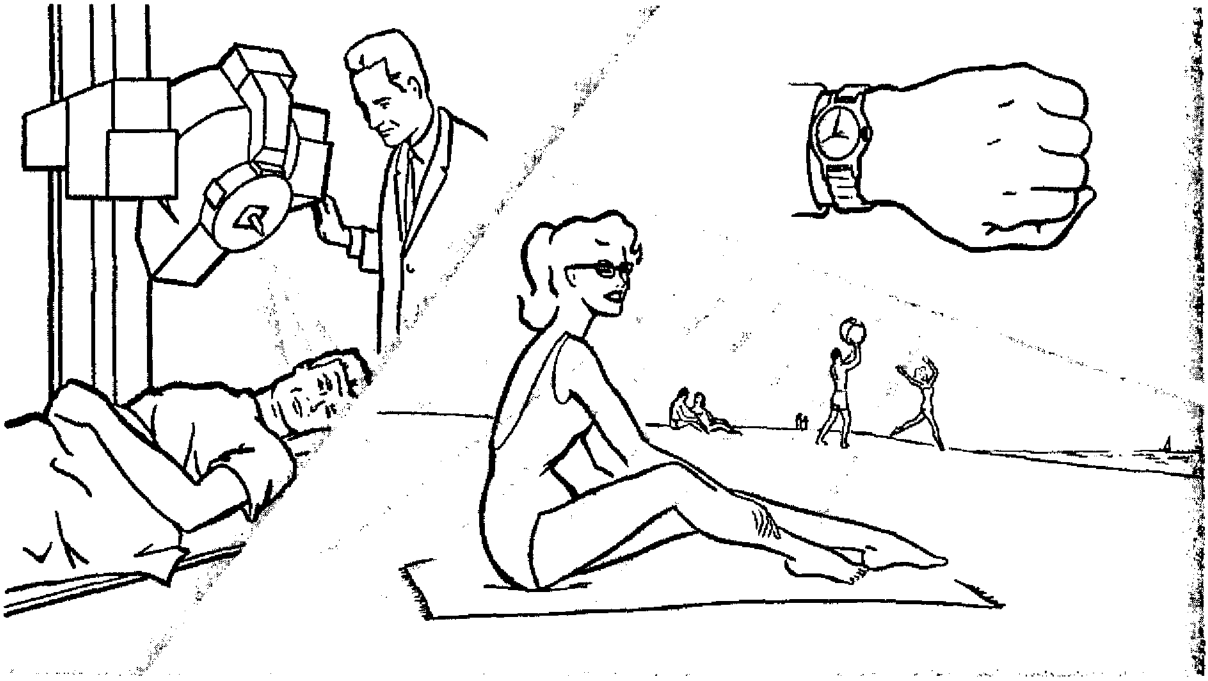
Concentration Guide values established by the Federal Radiation Council.

In short, the best defense against radiation from uranium or plutonium is to prevent ingestion, either by filter masks or self-contained breathing apparatus. Persons not so equipped can minimize the hazard by remaining at least 1,500 feet from the incident.

The other element that may present a radiation hazard is the hydrogen isotope, tritium. In air, tritium becomes an analogue of water, T_2O or HTO. Where it can concentrate it can easily be absorbed through the unbroken skin, the lungs, or the alimentary system. However, once inside the body it dissolves in the body water and is excreted at the same rate as body water, with no concentration in the bones or organs. Precautionary measures against other radioactivity are more than adequate against tritium.

Fission products, emitting beta particles and gamma rays, would be produced only if there were a nuclear reaction. Both beta and gamma radiation are easily detectable with a radiological monitoring device, and the precautionary measures would be those taken in the presence of fallout, scaled down to the actual fission yield in the accident. As a general rule, a radiation dose from fission products delivered in the open at a distance of 1,500 feet from the incident will be negligible.

Because the area surrounding a nuclear accident may be highly radioactive, efforts by airport safety personnel should be concentrated on rescue of personnel, fire containment and control, and preventing the HE components from exploding. Under no circumstances should the safety personnel undertake to clean up the area in the absence of a special Government radiological team. The area of the accident should be roped off to prevent entry by other than members of the survey team.



NUCLEAR RADIATION

Section 4—Radiation Fundamentals

Nuclear radiation and its effects sometimes seem extremely confusing and frightening to the average person. Memory of the devastating destruction and violent deaths that were the aftermath of the use of the atomic bomb near the end of World War II is still very vivid. People understand nuclear radiation as a threat of destruction but do not always realize that with proper precautions radioactive material may be handled safely.

Radiation, *per se*, is not something just discovered. Since the universe was created, the earth and everything on it have been bombarded with background radiation. We think nothing of wearing a watch on which hands and numbers have been painted with radium. Dentists X-ray our teeth and physicians X-ray thoracic cavities. Sunshine is a form of radiation. The danger from any kind of radiation lies in getting too large a dose of it.

Countless generations of humanity have adapted to cosmic radiation. People at higher altitudes receive more than those at lower ones, but the effect is hardly measurable. The radium dials on watches are of such low energy levels as to produce no hazard. X-radiation used in diagnosis or therapy is carefully controlled. The big difference, therefore, lies in the fact that exposures to nuclear radiation, except for the use of radioisotopes in therapy, are usually accidental, uncontrolled overdoses from fairly high energy sources.

There is nothing mysterious about nuclear radiation. A clear understanding of what it is, what it does, and how to avoid injury if exposed to it is essential for airport management and safety personnel. It is the purpose of this Section to discuss the fundamentals of radiation in nontechnical terms.

Atomic Structure and Radiation

All substances are made up of one or more of about 90 natural and several more artificial simple materials known as elements. The smallest particle of any element that retains the characteristics of that element is called an "atom."

The atom is similar to the solar system in many ways; it has a central nucleus analogous to the sun, and one or more electrons that are comparable to the planets in their orbits. What distinguishes one element from another is the composition of the nucleus, which is made up of a definite number of particles known as "protons" and "neutrons." Protons are *positively* charged particles, electrons are *negatively* charged particles, and neutrons have no charge as the name implies. The particular element is determined by the number of protons in the nucleus; hydrogen has one proton, helium has two, uranium has 92 and plutonium has 94. (The elements with more than 92 do not occur in nature, but are "manufactured" artifically from uranium.) The positive charge of the nucleus (due to the protons) is balanced in the normal atom by the negative electrons.

Isotopes of elements are differentiated from their elements by the number of neutrons in the nuclei; the number of protons remains constant. For instance, "deuterium" and "tritium" are isotopes of hydrogen; hydrogen ($_1H^1$) has one proton in the nucleus; deuterium ($_1H^2$) has a proton and a neutron forming the nucleus; tritium ($_1H^3$) has one proton and two neutrons. All have one negative electron to balance the positive proton.

All but about 20 of the elements occur naturally in isotopic forms; scientific advancements have created others.

Certain elements (notably uranium, thorium, and plutonium) are called "radioactive" because their nuclei are naturally unstable; they emit particles or rays due to the spontaneous disintegration of their nuclei. This emission is known as "radiation" or "radioactivity," and the elements or their isotopes are known as "radioactive materials."

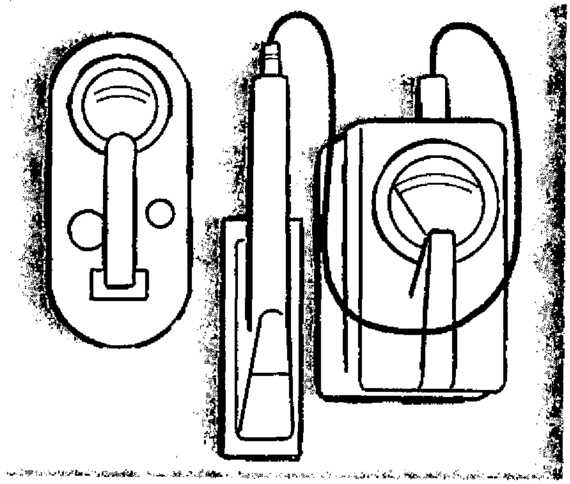
Types of Radiation

There are four forms of radiation with which airport management and safety personnel will be concerned: alpha particles, beta particles, neutrons, and gamma rays. The first three are actually particles of matter with measurable mass. Gamma rays have no mass, but are pure rays of electromagnetic energy.

Alpha and beta particles do not pass readily through solid matter and are, therefore, not a serious problem *as long as they are kept out of the body;* alpha particles will not penetrate even the dead external layer of human skin, and beta particles will not penetrate foil sheets or protective clothing.

Neutrons, being solid particles of matter, present a more serious problem in protection because they travel faster and farther, and are of a higher energy level. It is safe to say, however, that practically all neutron emissions occur as a result of either the fission or fusion process and, as has been pointed out, the possibility of such reaction resulting from an accident involving a nuclear weapon is next to impossible. In general, precautions taken against other forms of radiation will suffice for the neutron hazard.

Gamma radiation, being pure energy without mass, penetrates solids readily. The only protection is in an adequate thickness of dense material, or in maintaining an adequate distance from the source, or both.



Section 5—Measurement and Monitoring

It is axiomatic that the effects of radiation ınd the degree of protection required will de›end on how much of it there is. Measurenent and monitoring are practically synonynous; the subject of this Section is the detecion of the presence of radiation and the deternination of radiation doses.

Jnits of Measurement

It will be recalled that, in Section 1 which leals with the transportation of radioactive naterials by air, the term "curie" was used, either with or without certain prefixes. A curie is that quantity of any radioactive matter n which the atoms are disintegrating (or givng off their excess energy) at the rate of 37 billion disintegrations per second. A "millicurie" is a thousandth of a curie, and a "microcurie" is a millionth of a curie. The term has no relation to the weight of the material; a curie of a slightly radioactive material may be quite heavy, and a curie of a highly radioactive substance may be very light. For instance, one curie of Cobalt 60 would weigh about 880 nicrograms, but a curie of Thorium 232 would weigh about 10 tons.

A curie is not a measurement of the radiation hazard. It tells us how many disintegrations per second are taking place. *What happens* when an atom disintegrates deternines the hazard and depends upon the type of radiation emitted. To indicate the *amount* of energy (or radiation), and as a measure of dose rate, the term "roentgen" (usually pronounced rent-gen, with a hard "g") is used. The amount of radiation (or the number of roentgens) will vary with the material. For example, a curie of Cobalt 60 will emit about twice as much radiation as a curie of radioactive iron; a survey meter will indicate about twice as many roentgens from the Cobalt 60 source.

The gamma radiation per hour, measured at 3 feet from 1 curie, of some of the more commonly transported radioisotopes is as follows:

Source	*Roentgens per hour*
Sodium 24	2.31
Gold 198	0.30
Iodine 131	0.28
Iron 59	0.77
Iridium 192	0.61
Cobalt 60	1.59
Zinc 65	0.36
Cesium 137	0.43

Measuring Instruments

Radiation cannot be detected directly by the senses; instruments are necessary, therefore, to detect and measure it. The types of instruments described below are those of greatest interest and use to airport personnel.

Geiger Counter.—The average person thinks of all radiological survey meters as "geiger counters." The geiger counter is but one kind of radiation detection device. It is essentially a low-level-intensity dose rate instrument, limited in most cases to maximum readings of 40 or 50 milliroentgens per hour. Most geiger counters detect both beta and gamma radiation. A shield can be closed over the Geiger-Mueller tube to screen out the beta and the gamma can be read directly. To determine the level of beta radiation, the total is read, then the gamma, and the difference represents the beta radiation.

Ionization Chamber.—This is a higher level meter, reading usually to 50 roentgens per hour (r/hr) and sometimes as high as 500 r/hr. It is, therefore, especially useful to fire service and other emergency personnel.

Alpha Meter.—As the name indicates, this instrument measures only the short-range alpha radiation. The radiation levels are generally stated in disintegrations per minute per 100 square centimeters of surface. When an area has been contaminated with a pure alpha emitter, the detector is held very close to the contaminated surface (the range of alpha radiation is a matter of inches) and the surface gone over inch-by-inch to locate the contamination. If the surface is very uneven, it should be wiped with a piece of cloth or tissue over a measured area, and the cloth or tissue monitored.

Dosimeters.—The meters described above are rate meters; that is, they indicate the rate of radiation at the time the meter is read. When the instrument is removed from the contaminated area, the needle swings back to zero, and there is no indication of the radiation to which the meter was exposed. Individuals require instruments that will indicate the total accumulated dose received during the time of exposure. The dose can be calculated roughly by multiplying the rate by the length of exposure; but this is somewhat inexact because the actual dose received may vary with several factors. Contamination is not always uniform; some persons in the same area may be more shielded than others, etc. Instruments to indicate accumulated dose are called "dosimeters," and are of two types:

1. *Film Badges* are pieces of X-ray film carried in special holders and worn on the person. Radiation darkens the film in proportion to the amount received and, when developed and compared with film calibrated to known doses, indicate the dose received by the wearer. Their weakness lies in the time required for development and comparison.
2. *Pencil Dosimeters* are pencil-shaped devices that can be read directly by observation of a hair-line across a calibrated scale inside the instrument. They require periodic charging to ensure that the hair-line is on the zero mark before the instrument is exposed to radiation. There is, however, no waiting time; the readings are instantaneous. They may give false readings if dropped or damaged by electrical leakage; and film badges are often worn with them for a double check in areas of critical intensity.

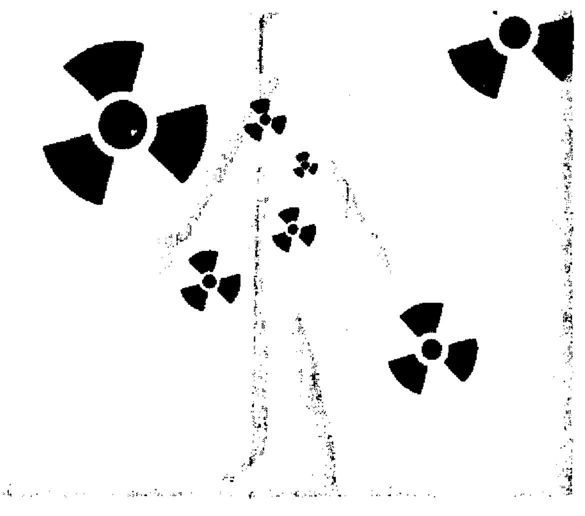
Dosimeters do not record alpha radiation, but this is of no consequence since external alpha exposures are not harmful.

Monitoring

Monitoring of the area following an accident involving radioactive materials is necessary for several reasons:

1. It helps to determine how long persons may be exposed without receiving an injurious dose.
2. It determines the need for masks or self-contained breathing apparatus.
3. It assists in avoiding the spread of contamination by monitoring of clothing, etc.
4. It indicates the degree of success in decontamination.

Emergency rescue efforts, however, should never be delayed in order to wait until monitoring is accomplished. Except for possible ingestion of alpha or beta particles, the staytime for rescue operations is usually short enough that injurious doses will not be received.



Section 6—Biological Effects

A knowledge of the effects of exposure to radiation on the human being engaged in emergency operations will help in determining how big a dose of radiation safety personnel may safely receive and, consequently, how long they should be allowed or required to stay and work in a contaminated area.

Bomb Fallout and Nuclear Incidents

Since this publication is concerned with incidents that involve radioactive materials rather than the effects of residual radiation from fallout resulting from the detonation of a nuclear weapon, the radiation levels that would result from fallout are of academic interest only. The form of radiation of primary concern in fallout is gamma, and the levels may range, in the early period immediately following a detonation, up to several thousand roentgens per hour.

The only way in which safety personnel might be presented with the problem of gamma radiation would be if a fission reaction were started, and this is extremely unlikely. In any accident involving a nuclear weapon, monitoring for gamma radiation should, of course, be carried out; even in that event, it is unlikely that radiation levels comparable to fallout would ever be met. What we are concerned with here are things like spillage from a container of radioactive materials, or plutonium oxide particles in smoke from a fire involving a nuclear weapon. The radiation forms that are most likely to be encountered will be alpha and beta particles, especially the alpha. The radiation levels and tolerances will be more nearly those that are associated with industrial accidents than those encountered in wartime.

These statements are not to be taken as minimizing in any way the hazards of radiation from nuclear accidents. But airport safety personnel should realize that, with the taking of proper precautions, the hazard is no greater than that of any other kind of accident. Firemen who are at a nuclear weapons accident scene will find that there is more hazard from the possibility of an explosion from the HE in the weapon or from gasoline.

External and Internal Radiation

In this publication, we shall use the term "external radiation" to mean that which is emitted from radioactive matter outside the body; "internal radiation" is that emitted from radioactive matter inside the body.

Gamma radiation, as has been said before, is high level electromagnetic energy, with considerable penetrating power. A great deal of damage can be done to the human body by this penetration of external radiation.

Both alpha and beta radiation are relatively low in penetrating power. Alpha particles cannot penetrate the skin, and ordinary protective clothing will turn away beta particles. There is no hazard from external radiation emitted by alpha or beta particles.

The hazard associated with nuclear accidents, therefore, comes from *internal* radiation, brought about by alpha or beta particles entering the body. This can happen in several ways: by breathing contaminated matter into the lungs; by ingesting contaminated matter into the digestive system; and by getting contaminated matter into open wounds where it may enter the blood stream.

Biological Effects

There is no rigid standard by which one can say that such-and-such a dose will produce this or that effect on all persons exposed to it. Personal reaction to radiation doses—until one gets up into the "positively lethal" bracket—will depend in good measure on the individual's age, build, and current physical condition. Generally, his reaction will be analagous to his ability to recover from injury, disease, poison, etc. The human body has the ability to slough off some of the material and to recover from some of the effects.

Certain radioisotopes have an affinity for certain portions of the body. For instance, plutonium (Pu 239), which is a major constituent in nuclear weapons, and Strontium 90 are deposited predominantly in the bones, and bone cancer may result. Pu 239 is also deposited in the liver.

Some parts of the body are more sensitive to radiation than others. Lymphoid tissue, bone marrow, genital organs, and the lining of the small intestine are said to be radiosensitive. Muscles, nerves, and full-grown bone are called radioresistant. The skin, liver, and lungs lie between these extremes.

The precise mechanism by which radiation attacks the organs of the human body is not known in detail. Cells are destroyed, and the dead cells and other biological debris tend to clog the capillaries and obstruct the flow of blood; the products formed may act as poisons. High-dose rate exposures (which are unlikely in accidents) may result in epilation (loss of hair), soreness and swelling of the throat, anemia, ulcers, and leukemia if particles are absorbed by the bone marrow.

If beta particles adhere to the skin and remain for an appreciable length of time, "beta burns" may result, having the appearance and effect of burns received from fire.

Two rules, therefore, develop from these biological effects: (1) do not let beta particles enter the body and, (2) keep them away from the skin. How to do these will be discussed under "Protection and Personal Decontamination."

One point cannot be overemphasized: *Persons who have been exposed to radiation do not themselves become radioactive!* Even when a person is exposed to the most massive doses this is true, and safety, medical, and recue personnel need have no fear in handling them.

Allowable Doses

Radioactivity Concentration Guides (commonly known as RCG) have been developed and published for the more important radioisotopes in air and water. These will be found useful to persons whose occupations cause them to be exposed frequently to radioactive substances. They are to be found in the National Bureau of Standards Handbook 59, "Permissible Dose from External Sources of Ionizing Radiations." The RCGs and recommendations of the Federal Radiation Council, approved by the President, were published in the Federal Register of May 18, 1960, pages 4802–3.

It should be noted, however, that the Guides are intended for general use and not specifically for those persons engaged in emergency operations. The values set forth may be exceeded if the emergency requires it to save life, but the overdose should not be repeated. A good rule of thumb is that *every* exposure to radiation must be followed by a compensating period of time to allow for the radiation deterioration. This is true whether one is having a tooth X-rayed or a cancer treated, or is saving a life in a crash fire.

An Acceptable Guide for Emergency Exposure, Measured in Rems*

EXPOSURE	CONDITION
	Single Dose
25 rem in one day ----	When accomplishing extremely important tasks.
100 rem in one day ---	During extreme emergency.
150 rem in one week ---	During extreme emergency.
	Repeated Dose
25 rem per day for a total of 200 rem ----	During extreme emergency.

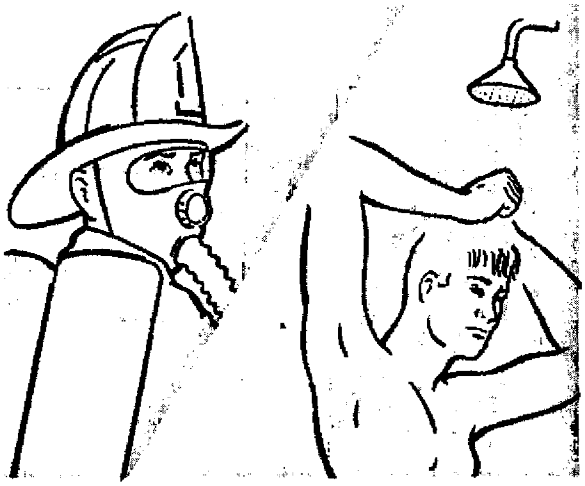
*A unit of biological dose of radiation.

The term "rem" is a unit of biological dose of radiation; the name is derived from the initial letters of "roentgen equivalent man." Dosimeters read in roentgens or milliroentgens. A "rem" is actually the absorbed dose in roentgens adjusted by a factor representing the biological recovery; for the purposes of this publication, however, the terms rem and roentgen are considered synonymous.

Exposure Determination

Exposure to external radiation will be determined by the use of radiological monitoring equipment such as dosimeters. A reasonably accurate estimate can be obtained, if personal dosimeters are not available, by the use of survey meters (see Section 5) and multiplying the dose rate by exposure time.

Internal radiation hazards may be detected by taking nose wipes and urine samples. Nose wipes can be taken with cotton swabs and should be taken of all persons involved in the accident and rescue effort. Urine samples should be taken of all persons with nose wipes exceeding 1,000 disintegrations per minute per nostril. When nose wipes cannot be evaluated immediately, urine samples should be taken on all persons within 1,000 feet of the accident, and stored for later processing if required.



Section 7—Personnel Protection and Decontamination

From the standpoint of airport safety personnel engaged in accident or crash operations, two things are important in regard to radiation hazards: protection from radiation and personal decontamination. The latter serves two purposes: it gets rid of radioactive matter on the individual that might continue to cause damage after the person has left the scene of the accident; and it prevents the spread of radioactive materials to clean areas and uncontaminated persons. Area decontamination will be covered under "Emergency Operations at Civil Airports."

Personal Protection

Whether the accident involves spillage of radioisotopes from broken containers or the burning or breakage of a nuclear weapon, the radiation hazard will be primarily from alpha or beta radiation. The alpha and beta particles may impinge on or become mixed with dust, be stirred up by the feet of the people in the area or carried by the wind, and be respired or ingested. A burning weapon would probably produce clouds of highly contaminated smoke that would contain not only radioactive matter but toxic gases as well. It is extremely important that these do not enter the body.

It is also important that beta particles are not allowed to reach and remain on the skin where beta burns may result; neither alpha nor beta particles should be allowed to enter an open wound.

Safety personnel and crash crews should, if possible, be equipped with self-contained breathing apparatus which, in effect, carries its atmosphere with it. If it is known that radioactive material, whether as radioisotopes in commercial shipment or as a nuclear weapon, is involved the breathing apparatus should be taken to the scene and used from the beginning. If self-contained breathing apparatus is not available, some protection can be obtained by covering the mouth and nose with several layers of dry turkish or terry-cloth toweling or with not less than 8 layers of a cotton handkerchief.

If a life is at stake, any material that will serve as a filter will suffice—even the hair normally found in the nostrils will filter out a considerable amount of dust—provided there is no extended stay in the contaminated area. In short, go in and get out quickly, keeping the exposure time as short as possible. Whether the exposure is justified will depend on whether there is a compensatory gain—a sufficient justification would be a life saved.

The kind of impermeable clothing normally issued to firefighters will be ample protection against external beta radiation. In the absence of such clothing or when there is no fire, ordinary clothing will suffice, provided it can be thoroughly cleaned of all dust and radioactive matter that may lodge on or in it.

Despite recent advertisements for "fallout clothing," *there is no clothing that is protective against gamma radiation*, which is the chief constituent of residual fallout radiation. If gamma radiation is present, don't expect any kind of clothing to afford protection. Rapid movement into and out of the area for rescue purposes, with strictly limited stay-time, is the only reasonable protection.

Because of the high level of the energy of gamma radiation and its power of penetration, mobile shielding for use in rescue operations is impractical.

Firefighting Operations

A crash fire involving a nuclear weapon presents two principal hazards: the high explosive (HE) material in the bomb and the radioactive material. Properly trained firefighting personnel will know the proper method of handling fires involving high explosives. The presence of highly toxic gases resulting from the burning HE, and the presence of radioactive (plutonium oxide) particles in the smoke underlines the desirability of approaching the fire from the upwind side—a standard procedure in any event.

It is, of course, possible that the process of keeping a water spray on the bomb to hold the temperature down may dislodge some radioactive material, particularly if the bomb casing has been broken. If so, the spray and runoff should be regarded as radioactively contaminated.

Personal Decontamination

All personnel leaving contaminated zones must be monitored and decontaminated as required. Such monitoring will give the measurement of the radiation exposure.

Monitoring should be done with both alpha and beta/gamma survey meters. The probes should be passed *as closely as possible* over the surfaces to be monitored, without actually touching. (The probes should be protected from becoming contaminated.) Special attention should be given to clothing that is not rubberized, to the hair, and to body orifices (nostrils, ears, etc.). It is advisable to use the earphones for this purpose because the slow response of the meter may cause areas to be missed, and the control of distance between the probe and the surface makes it difficult to read the meter simultaneously.

Rubberized clothing may be hosed off while still on the wearer. If nonrubberized garments are worn, it will be necessary to remove and discard the outer clothing as soon as possible (or leave behind for removal to a cleaning and decontamination area). Fabrics that are loosely woven will be more likely to retain contaminated particles than will hard-surface materials.

The person should then take a shower, paying special attention to the hair, ears, nostrils, and other parts of the body in which dust might collect. He should then be monitored and the bathing process repeated if necessary, until monitoring is negative. Clean clothing may then be donned.

Equipment Decontamination

In handling any nuclear incident or accident on an airport, it is quite likely that some motorized equipment, such as firetrucks or ambulances, will be used. It is probable too, that these vehicles will be taken into the contaminated area and will, in turn, become contaminated. They must be decontaminated so the contamination will not be spread to clean areas.

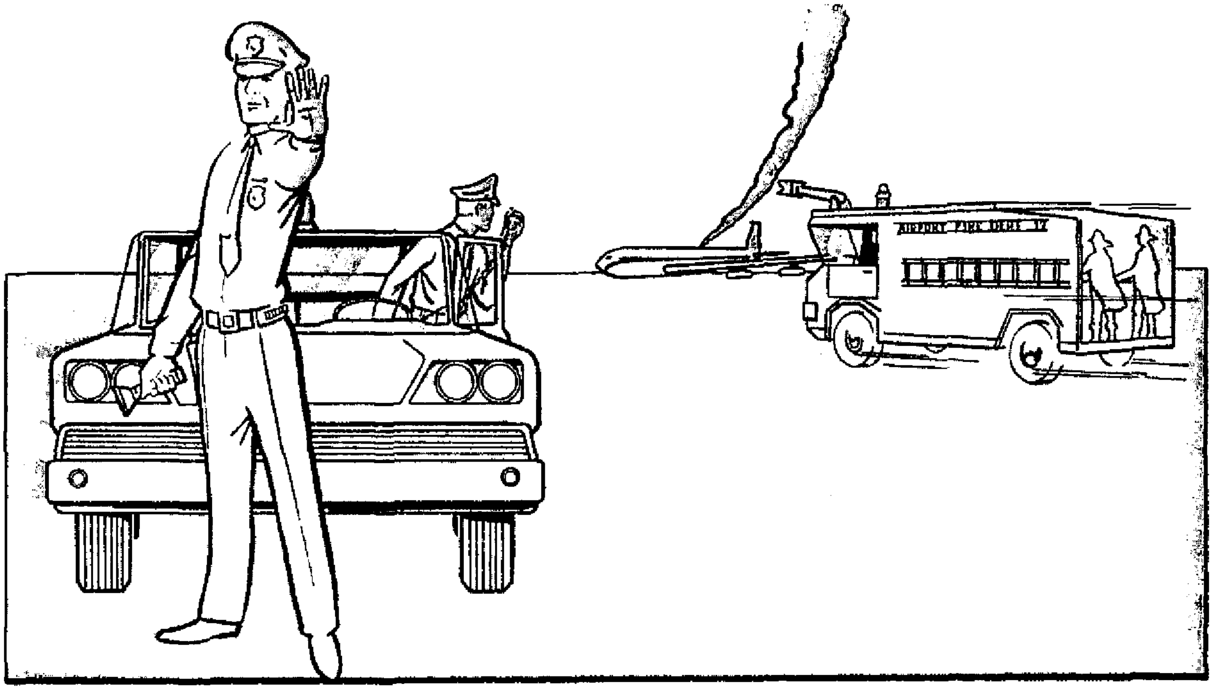
Remember that decontamination does not destroy radioactivity. It merely removes it to another place where it can be further rendered innocuous by burying, conveying it to a remote area away from people, or by some other way. The areas, therefore, where equipment is decontaminated will become contaminated, and must, in turn, be cleaned up. Use paved areas that can be hosed down if possible.

Exteriors of most objects can be hosed down. However, water should never be applied to upholstery, because the radioactive matter may simply be forced deeper into the material. Vacuum cleaners will effectively remove debris—and then they must be decontaminated. Undercarriages that are coated with grease will tend to retain a great deal of contaminated matter and may be steam cleaned to decontaminate.

Equipment should be monitored after each pass. If radioactivity is still detected it may be necessary to resort to detailed cleaning of parts with detergents.

To prevent, as far as possible, the contamination of the interior of vehicles the following suggestions are made: Persons who have entered contaminated areas and walked about should not reenter vehicles until decontaminated. Have one person remain in each vehicle to hand out needed equipment. Do not return contaminated equipment to the trucks. Casualties should be carried to ambulances and there received by attendants who have remained in the vehicle.

It is probable that the casualties' clothing will be contaminated and their physical condition will not allow the time nor handling needed for decontamination. In such cases the patients can be wrapped in blankets to help keep the inside of the ambulance clean. Do not, however, let contamination problems stand in the way of giving prompt medical attention. Medical personnel should always be told of the presence of contamination.



EMERGENCY OPERATIONS AT CIVIL AIRPORTS

Section 8—Incidents Involving Commercial Shipments

Of the two types of incidents discussed in Section 1—(1) those involving commercial shipments of radioactive material on civil or military aircraft, and (2) those involving nuclear weapons or their components on certain military aircraft—the first presents by far the lesser problem. In the former case, the amount of radioactive material that may be transported on any one aircraft is limited; the design and strength of the containers is such that breakage is unlikely, and there are no explosives either to do their own damage or to scatter radioactivity. The second type, because nuclear weapons are involved, contains much larger amounts of radioactive material accompanied by varying amounts of high explosives.

If a container does break and spillage occurs, the possible spread of contamination by vehicles moving through the radioactive area or by people tracking about are primary control problems. If the radioactive material is disturbed, or if winds or a thermal column from an aircraft fire are present, the radioactive material could become airborne and be carried some distance. The important control actions are to keep unauthorized persons out of the area, to protect personnel working at the accident scene, and to prevent the spread of the radioactive material by decontaminating the personnel and the area.

Contamination Control Perimeter

The first step to take after an accident involving a civil aircraft carrying radioactive isotopes is to establish a cordon around the aircraft to prevent the entry of unauthorized persons to the scene. If the accident has occurred without resulting in fire, the perimeter may be small. The safety personnel should set the area boundary so that no spillage from containers will be tracked about.

If the aircraft burns, the fire chief will locate the perimeter and set it as far away from the scene as is necessary to afford protection from exploding fuel tanks. It is always possible that radioactive materials may be released through impact or by the melting of the lead container and be carried some distance downwind. Other than this, it is extremely unlikely that radioactivity would be detected at any distance from the accident.

Rescue Operations

Rescue of persons on the aircraft should never be delayed solely because of the possible presence of radioactivity. Discretion dictates that rescue workers, firemen, and others at the accident scene should, even before they know whether containers have been broken, take steps to ensure that they do not breathe or ingest radioactive particles by wearing self-contained breathing apparatus if available or by using toweling or cotton handkerchiefs. If smoke is blowing toward buildings, doors and windows should be closed and personnel not helping with rescue should stay inside.

In general, the presence of radioactivity will change very little the rescue operations ordinarily used in any crash in which radioactivity is not present. If monitoring conducted simultaneously with rescue operations indicates dangerous levels of radioactivity, exposure will be governed by limiting the stay-time of any one individual.

Monitoring

If the radioisotope container is found unbroken, airport management's problems are over as far as radiation is concerned. The material should be held in custody by security forces until disposal instructions are issued by the AEC. (See Section 10, "Radiological Assistance.") Some shipments are, for security reasons, accompanied by a courier designated by AEC; he, in effect, "owns" the material and is responsible for it. If he survives the accident, he will retain custody.

If the container is not intact, or if the aircraft is on fire, monitoring should be started as soon as possible. Alpha monitoring can be delayed, generally, until the beta/gamma monitoring is completed, because the shorter range and lower penetrating power of alpha particles make them less dangerous *as external radiation.*

When monitoring for beta radiation, one process will show both beta and gamma. The same instrument is used for both; a reading is taken with the shield open, which detects both beta and gamma; then with the shield closed for gamma only. The difference between the two readings is the beta radiation. If gamma radiation is found, airport safety workers should wear dosimeters and their stay-time in the contaminated area should be regulated to prevent overexposure.

Protective clothing, such as firemen usually wear, will protect also against alpha and beta radiation, and should be worn by persons at the accident site if radioactive matter has been released. While the range is short, scuffling about in radioactive dust, carrying of particles in smoke and possible contamination from spray from firehoses may cause apparel to become contaminated and increase the danger of radiation ingestion.

Radiological monitoring around the site of the accident should be emphasized, and monitoring downwind from the accident (especially if there is a fire) should not be neglected. Radioactive smokeborne or wind-carried particles may be found as far as 1,500 feet or more downwind. It is probable that the percentage of contamination so carried will be quite small. However, a very small amount of ingested radioactive matter can do a great deal of harm.

As stated in Section 7, all personnel and equipment that have been inside the control perimeter should be monitored. Nose wipes and/or urine specimens should be taken of the personnel before they leave the area.

Aircraft parked downwind or that may have received smoke from the fire should also be monitored. Other aircraft should not, if at all possible, be allowed to land, takeoff, or taxi through the contaminated area; on the ground their tires can pick up and spread contamination and, if airborne, their passage may cause clouds of contaminated dust to be kicked higher and spread the contamination.

Radiological Assistance

All air transportation of radioisotopes on civil aircraft are, at present, made by AEC or a contractor licensed by them. In the event of an accident in which such materials are involved, the AEC should be notified so that they *may issue instructions for handling the material* and give assistance in decontamination and with other radiological problems. Full details are given in Section 10, "Radiological Assistance."

Decontamination

Personnel and equipment decontamination is covered in Section 7. However, spillage of radioactive materials from broken containers can be spread and the area must be decontaminated before such spreading can take place.

Decontamination, as has been said, does not destroy radiation. It removes the dangerous material to a safe place so that the processes of radioactive decay will reduce the radioactivity to a point where it is no longer hazardous. Fire has no effect; you might burn some of the material that carries the radioactive particles, but the particles (or emitters) themselves remain or are airborne to spread farther.

Structures

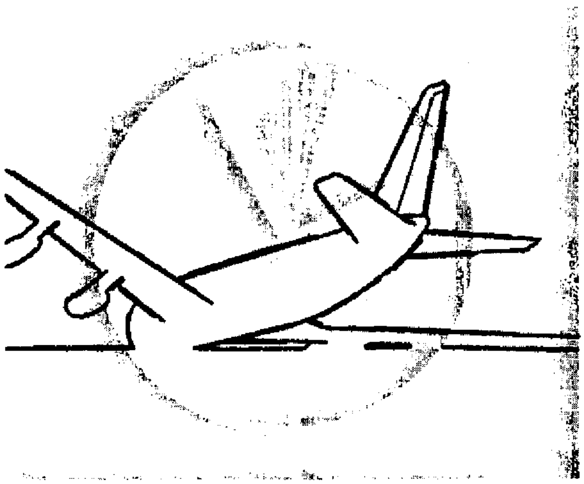
If radioactivity is detected by monitoring of structures downwind from an accident, these structures should be decontaminated. The most common methods are firehosing and hot-liquid cleaning. Firehosing is especially useful on buildings constructed of materials (brick, stone, stucco, etc.) that provide numerous crevices in which contamination may lodge. In hot-liquid cleaning, a mixture of hot water and detergent is forced through a nozzle to provide a cleaning and washing action.

Paved Areas

Paved runway and taxiway surfaces may be firehosed, hosed and scrubbed or, in the case of asphalt material, flame-treated. The first method uses water only to push the contaminant off the area. The second uses street sweepers, water and a detergent. In the third method, the surface is softened and a thin layer removed.

Unpaved Areas

When unpaved areas are contaminated, the surface may be scraped off and removed, filled over, or plowed under. If contaminated by alpha or beta emitters, the fill need not be thick; with gamma emitters the fill thickness should be determined by radiation levels.



Section 9—Incidents Involving Nuclear Weapons

In an aircraft accident involving a nuclear weapon, several hazards may be present that do not occur in the commercial shipment of radioisotopes. Blasts of varying degree may occur as a result of detonation of the high explosives in the weapon; toxic or caustic fumes may be given off by burning high explosives; larger quantities of radioactive materials may be scattered and radioactive plutonium oxide may be carried over considerable distances by smoke. *But the odds against a nuclear explosion are astronomical!*

Detonation of the high explosives and the presence of toxic or caustic gases are things with which the well-trained firefighter should be thoroughly familiar. This Section, therefore, will deal primarily with the radiological aspects of the problem.

Notification

An aircraft carrying a nuclear weapon will not normally land at a civil airport unless absolutely necessary. If this necessity should arise, the aircraft commander will use air-to-ground radio transmission, either through the airport traffic control tower or relayed through an FAA Flight Service Station, to alert appropriate authorities to the emergency conditions. The procedure has been established and is illustrated in the following example of an unclassified transmission:

> EXPLOSIVE CARGO WINGS OF AIRCRAFT. IF EXPLOSIVE BECOMES ENVELOPED IN FLAMES, DETONATION MAY BE EXPECTED IN FIVE MINUTES. APPLY EMERGENCY PROCEDURES ACCORDINGLY.

This is interpreted as follows:

1. EXPLOSIVE CARGO. The cargo is hazardous and can be conventional high explosive bombs, nuclear weapons or components, or other cargo that may explode when exposed to fire or impact.
2. WINGS OF AIRCRAFT. This phrase indicates the location of the explosive cargo. In bombers, bombs are usually carried in the bomb bay; in transport aircraft, in the fuselage; in fighter-bombers or interceptors, under the wings, and/or in or under the fuselage.
3. FIVE MINUTES. This is the aircraft commander's best estimate, based on the type of explosives and the thickness of the bomb casing, of the time available for fighting the fire and withdrawing before detonation.

The High Explosives Hazard

It was mentioned in Section 3 that the nuclear components in a weapon are surrounded by high explosives needed to produce the implosion required to make the mass become supercritical. Some of the HE may be sensitive both to impact and temperature changes. The sensitivity of some is increased by powdering and, if scattered, may detonate if stepped on. Others change color if exposed to sunlight, and become difficult to see on pavement. For these reasons, once the fire is extinguished or contained, cleanup of the area should be left to especially trained teams of Government personnel.

In drop and fire tests conducted by the AEC and the Department of Defense, it was found that detonation of the HE components by impact alone is not likely. The bomb casing, however, may break on impact, resulting in the scattering of the HE, with the hazards described above.

In the case of fire, it has been determined that detonation can usually be avoided if the temperature of the weapon can be held below 300° F by application of water spray or foam.

If the HE begins to burn "torching" (bright jets of white, orange, or red flame) may be seen especially if the casing has been broken. However, torching does not necessarily occur. The burning of the HE may result also in the liberation of toxic and caustic gases. For this reason and because of the presence of oxides in the smoke, personnel should not be allowed to remain downwind without proper respiratory apparatus.

The Radiation Hazard

If the bomb casing remains intact there will be no radiation hazard. If the casing breaks, the nuclear materials may be scattered with the resulting radiation being almost completely alpha. If the weapon explodes or burns the plutonium oxide (again alpha) will be carried in the smoke cloud. Gamma radiation and neutrons will not be released unless some fission reaction takes place (which is a very remote possibility).

Controlled Area

As soon as the aircraft has come to a stop, a controlled area not less than 1,500 feet in radius should be established around it. Unauthorized persons should be denied entrance to this area. The controlled area has been set at the 1,500-foot distance because:

1. It has been determined a safe distance for personnel in the event the entire charge of HE is detonated.
2. The hazard of smokeborne plutonium oxide will be insignificant at this distance, even on the downwind side.
3. The interests of the national security may be adequately protected at that distance.

The perimeter of the controlled area should be guarded by airport police with such additional assistance by other police and security forces as may be required.

Buildings within 1,500 feet of the scene of the accident, especially on the downwind side, should have all windows and doors closed and ventilation system intakes shut down to avoid contamination of their interiors.

Firefighting

If the accident results in an aircraft fire, the techniques used should be the same as those used for any fire involving explosive materials and toxic chemicals. The weapon should be kept as cool as possible—below 300° F—by the application of a water stream, water fog or foam. Care should be exercised to ensure that the application of water to the weapon does not break down the foam applied to the aviation fuel.

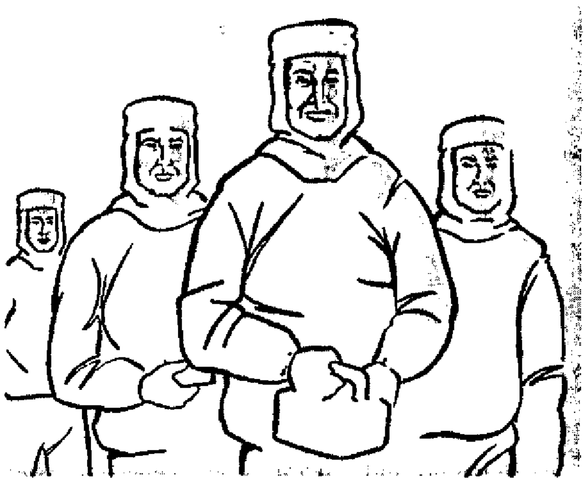
Actions

When the notification of a possible crash landing is received from an aircraft commander or pilot in command, the sequence of actions should be generally as follows:

1. The airport traffic control tower should alert the crash, safety and security personnel of the anticipated accident. Information received from the aircraft commander—location of the weapon, time before detonation, etc.—should be passed on to them.
2. The airport manager should notify the Joint Nuclear Accident Coordinating Center (JNACC) in accordance with the procedures described in Section 10 and ask for radiological assistance.
3. As soon as the aircraft has come to a stop, the controlled area should be marked off and security guards posted. Do not allow souvenir collecting. Preserve the accident scene intact for the review of Government authorities.
4. Rescue operations take priority over everything else.
5. Locate the weapon and keep it cool as described above, while extinguishing the fire. If the weapon becomes engulfed in flames the fire chief may, at his discretion, order the withdrawal of all personnel to the 1,500-foot perimeter.
6. If AEC or military special teams have not arrived by the time the fire is controlled, all personnel who have been engaged in the operation, including aircraft crew members, should be held at the perimeter, unless they require immediate medical attention, until the arrival of the teams. Do not admit anyone to this area except authorized personnel.
7. *Do not try to clean up the site of the accident!* This can be dangerous.

Special teams have been trained for doing this. Let them do it.

8. If first aid is required, it should be minimal pending the arrival of the special teams and physicians especially trained in radiation medicine.
9. Upon the arrival of the teams, all personnel and equipment held at the controlled area perimeter will be monitored and decontaminated as required.
10. The special teams may call on airport management for assistance and will advise on the cleanup and decontamination jobs. If so, do it their way! They are the experts.
11. Section 11, "Public Relations," offers suggestions for dealing with the public and news media representatives.



Section 10—Radiological Assistance

In the event of an incident at or near a civil airport, whether involving the shipment of radioactive material on civil or military aircraft or a nuclear weapon on a certain tactical military aircraft, radiological assistance can and should be obtained through the Radiological Assistance Plan.

The Radiological Assistance Plan

The Radiological Assistance Plan is maintained jointly by the Atomic Energy Commission and the U.S. Department of Defense. It is an organized means of making available manpower, instrumentation, and trained personnel who are experienced in evaluating and handling radiological incidents, wherever and whenever they may occur.

It is important to stress that this is an *assistance* program. It is not intended that assistance teams will perform all actions connected with a radiological incident. When called, the teams will be dispatched immediately; however, it is unlikely that they would arrive in time to participate effectively in the first or emergency phase. Airport personnel must be prepared to act during the emergency phase without outside assistance.

Who May Apply for Assistance

Assistance and advice may be requested by any person, organization, local or State official cognizant of an incident or accident involving radioactive materials or ionizing radiation injurious to the health and safety of the community or of individuals.

Where to Apply for Assistance

To get help from the Radiological Assistance Teams, call immediately the AEC Operations Office nearest the scene of the accident or incident involving the radioactive material. AEC offices, their telephone numbers and addresses, and the area for which each office is responsible are given in the Appendix. The special telephone numbers will be answered 24 hours a day.

Calls may also be placed to the AEC-Department of Defense Joint Nuclear Accident Coordinating Center (JNACC), Albuquerque, New Mexico, telephone number 505-264-4667, if a nuclear weapon is or is suspected to be involved. The nearest AEC office or military installation may be called and requested to relay the message.

Kind of Assistance Available

When a request for radiological assistance is made, give all of the information possible concerning the incident. From this information, the initial determination is made as to what capabilities should be drawn upon and sent to the scene. AEC has available capabilities for: alpha, beta, and gamma monitoring; sampling and monitoring of air, water, and food; radiation decontamination advice and assistance; radiation medical services; radiochemical sample analysis; and specialists in nuclear weapons accidents.

The military services radiological assistance capabilities include most of those listed above, plus a special capability for explosive ordnance disposal operations.

The person or persons responsible for the site and facilities involved may provide for the necessary radiation cleanup from other sources. AEC teams, however, will not be withdrawn until appropriate steps have been taken and there is reasonable assurance that the public health and safety will not be adversely affected.

Assistance From Other Sources

Assistance may be sought from the following sources:

1. State and local officials may contact the Office of Civil Defense, U.S. Public Health Service, and FAA airport traffic control towers and Flight Service Stations. Information concerning their policies and capabilities should be obtained from them and made a part of the airport emergency operations plan.
2. Several States have organized Radiological Emergency Teams, usually under the direction of the State board of health. Their services may be obtained by notifying the State police or highway patrol, the local sheriff's office or the local police department.

Section 11—Public Relations

Accidents involving aircraft that are carrying commercial shipments of radioisotopes are no more newsworthy than accidents to aircraft that are not. Rescue and airport safety personnel will need to take some special precautions, but the general public is in no danger. Unnecessary alarm, however, may follow upon an accident to an aircraft carrying a nuclear weapon, and this Section is concerned primarily with that problem.

Unhappily, experience has shown that a large segment of the public is morbidly fascinated by aircraft accidents and will throng to the scene even at the risk of jamming roads so that emergency equipment cannot get through. If, under these conditions, it becomes known that a nuclear weapon is involved and the HE detonates, panic will probably spread rapidly. Some people may be exposed needlessly to contaminants. Calm decisive direction will be required. The national security may also be endangered by misinformation being circulated about a nuclear weapon.

Each airport manager should have, as a part of his disaster control program, a preplanned public information program to enable him to cope with these problems.

News Releases

A statement on radio or television that a disabled aircraft is circling the airport and will attempt to land in "x" minutes is sure to bring out a crowd. Agreements should be reached with representatives of news media that such announcements will not be made. The crowds not only hamper rescue efforts but endanger themselves.

Postaccident announcements must be factual, with no speculation as to the probable cause of the accident.

If a commercial shipment of radioisotopes is involved, there is no objection to disclosing this information, provided that such an announcement is necessary:

1. To provide necessary public protection and assistance.
2. To prevent needless alarm if rumors start.
3. To ensure an accurate presentation to the public.

If a nuclear weapon is involved, the national security must be considered basic. Official confirmation of the presence of the weapon should be forthcoming *only* when it will have significant value in maintaining the public safety and in keeping people out of the danger area.

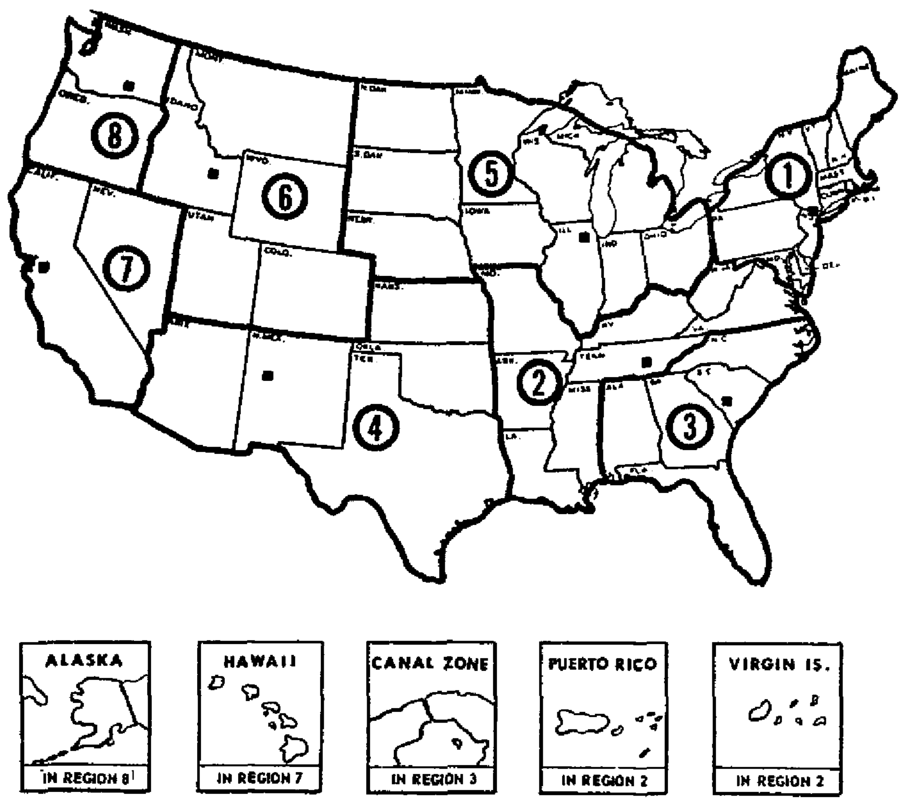
If a courier accompanies a shipment, he will be responsible for issuing all announcements. In nuclear weapons incidents the aircraft commander will have that responsibility. If the courier or aircraft commander is incapacitated, the person in charge of emergency operations must use his best judgment about news releases until the special Radiological Assistance Teams arrive. If an information announcement *must* be made to allay fears or in the interests of safety, it is suggested that the announcement be patterned on those shown in the Appendix. Forms similar to these are carried by all couriers for use in emergencies. They have been approved in format by proper authorities.

Annoucements, if made at all, should be complete enough to prevent the spread of speculation and unfounded rumor. They should allay concern and warn people to stay away from hazard areas. They must *never* disclose classified information. Requests for further information should be referred to the AEC or the U.S. Department of Defense.

Appendix

U.S. ATOMIC ENERGY COMMISSION

REGIONAL OFFICE AREAS OF RESPONSIBILITY FOR RADIOLOGICAL ASSISTANCE IN INCIDENTS INVOLVING RADIOACTIVE MATERIALS



REGION NO. and OPERATIONS OFFICE	POST OFFICE ADDRESS	TELEPHONE for ASSISTANCE	DDD AREA CODE
1 NEW YORK	376 HUDSON STREET NEW YORK, NEW YORK 10014	989-1000	212
2 OAK RIDGE	P. O. BOX E OAK RIDGE, TENNESSEE 37831	483-8611, Ext. 3-4510 or 483-7486	615
3 SAVANNAH RIVER	P. O. BOX A AIKEN, S.C. 29802	N. AUGUSTA, S.C. 824-6331, Ext. 3333 AIKEN, S. C. 649-6211, Ext. 3333	803
4 ALBUQUERQUE	P. O. BOX 5400 ALBUQUERQUE, NEW MEXICO 87115	264-4667	505
5 CHICAGO	9800 S. CASS AVE. ARGONNE, ILLINOIS 60439	739-7711 Ext. 2111 duty hrs. Ext. 4011 off hrs.	312
6 IDAHO	P. O. BOX 2108 IDAHO FALLS, IDAHO 83401	522-4400 Ext. 2345	208
7 SAN FRANCISCO	2111 BANCROFT WAY BERKELEY, CALIFORNIA 94704	841-5620	415
8 RICHLAND	P. O. BOX 550 RICHLAND, WASHINGTON 99352	942-1111 Ext. 6-5441	509

Revised: January 1965

Information Announcement No. 1

A United States ______(type)______ aircraft carrying ______(cargo description)______ accidentally crashed (or other circumstance) at approximately ______(time)______ at ______(location)______

Against any remote danger (from the crash, or an atomic[1] or high explosive detonation), in the interest of national security and to facilitate removal operations, visitors are asked to stay out of the area that is under surveillance by guards. There is no need for evacuation.

[1] Use the terms "nuclear" and "atomic" only when less specific terms will not serve.

Information Announcement No. 2

A United States ______(type)______ aircraft accident has occurred at ______(time and location)______ It involves conventional high explosives and radioactive materials. There is no danger of an (atomic[2]) explosion. However, the high explosives in the weapon ______(have detonated, are burning, may detonate)______

In the interest of public safety, visitors are asked to stay out of the area now under surveillance by guards (or indicate area). (If true:) There is no need for evacuation. An experienced explosive ordnance disposal team has been ordered to the scene of the accident as a precautionary measure.

If scattering of fission fragments is possible, the following may be added to the release:

The greatest potential danger in an accident of this kind is the effects of blast caused by denotation of the conventional high explosives in the weapon. Local scattering of nuclear material in the form of finely divided dust may have resulted nearby and downwind from the explosion (fire). It would have no significance to health unless taken into the body as by breathing or swallowing, and it is considered unlikely that any person would inhale or swallow an amount that could be hazardous to his health. Spectators have been (are) warned to remain at least a half mile—6 or 7 city blocks—from the accident scene (and if true) until a monitoring team, now enroute to the site of the accident, can survey the ground and verify the safety of adjacent areas.

Decontamination is a simple washing procedure and, therefore, evacuation (of the type to cause public concern) will not be necessary.

[2] Use the terms "atomic," "weapon," and "nuclear" cautiously and only when other wording will not serve.

GLOSSARY

ABSORBED DOSE. The amount of energy imparted by nuclear (or ionizing) radiation to unit mass of absorbing material. The unit is the "rad."

ALPHA PARTICLE. A particle emitted spontaneously from the nuclei of some radioactive elements. It is identical with a helium nucleus, having a mass of four units and an electric charge of two positive units. It consists, in short, of two protons and two neutrons.

ATOM. The smallest (or ultimate) particle of an element that still retains the characteristics of that element.

BACKGROUND RADIATION. Nuclear (or ionizing) radiation arising from within the body and natural surroundings. The main sources are Potassium 40 in the body, Potassium 40, Uranium, Thorium and Radium in the rocks, and cosmic rays.

BETA PARTICLE. A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. It is identical physically with an electron moving at very high speed.

CONTAMINATION. The accidental presence of radioactive materials.

CRITICAL MASS. The minimum mass of a fissionable material necessary to maintain a fission chain reaction under precisely specified conditions.

CURIE. A unit of radioactivity; the quantity of any radioactive material in which 3.700×10^{10} nuclear disintegrations occur per second.

DECAY. The decrease in activity of any radioactive material with the passage of time.

DECONTAMINATION. The reduction or removal of contaminating radioactive material from a structure, area, object or person.

DEUTERIUM. An isotope of hydrogen of mass 2 units; sometimes used in fusion-type weapons.

DOSE. A total or accumulated quantity of nuclear (or ionizing) radiation. The *exposure dose*, expressed in roentgens, is a measure of the total amount of ionization produced. The *absorbed dose*, given in rads, represents the energy absorbed per gram of specified body tissue.

DOSE RATE. The amount of radiation that an individual would receive or to which he would be exposed per unit of time. Commonly used to indicate the level of radioactivity in a contaminated area.

DOSIMETER. An instrument for measuring and registering total accumulated exposure to radiation.

ELECTROMAGNETIC RADIATION. A traveling wave motion resulting from oscillating magnetic and electric fields. Gamma rays are an example; others are X-ray, radio and radar.

ELECTRON. A particle of very small mass, carrying a unit negative or positive charge. The electrons surrounding the nucleus of an atom are negative.

ELEMENT. One of the basic varieties of matter occurring in nature which, individually or in combination, compose substances of all kinds.

FALLOUT. The contaminated particulate matter resulting from a nuclear explosion.

FILM BADGE. X-ray film worn or carried in a special frame, as a dosimeter.

FISSION. The splitting of the nucleus of a heavy element into (generally) two nuclei of lighter elements, with an accompanying release of energy.

FUSION. The combination of the nuclei of light elements to form the nucleus of a heavier element, with an acccompanying release of energy.

GAMMA RAYS. Electromagnetic radiation of high energy originating in atomic nuclei; physically identical with X-rays except in their source.

IONIZATION. The separation of a normal electrically neutral atom or molecule into electrically charged components, especially as used in this publication, the removal of an electron from the atom or molecule, leaving a positively charged ion.

ISOTOPE. Forms of the same element having identical chemical properties but differing in their atomic masses and nuclear properties. A radioisotope is one in which the nuclei are unstable.

MEGACURIE. One million curies.

MICROCURIE. One-millionth part of a curie.

MILLICURIE. One-thousandth part of a curie.

MILLIROENTGEN. One-thousandth part of a roentgen.

MONITORING. The procedure of locating and measuring radioactivity with survey instruments.

NEUTRON. A neutral (i.e., with no electrical charge) particle present in all atomic nuclei except ordinary hydrogen.

NUCLEAR RADIATION. Radiation (alpha, beta, gamma and neutrons) emitted from atomic nuclei.

NUCLEAR WEAPON. A weapon in which the explosion results from the energy released by reactions involving the atomic nuclei; may be either the so-called A-Bomb or H-Bomb.

NUCLEUS. The small, central, positively charged mass of an atom. In ordinary hydrogen, it consists of a single proton; in all others it is made up of both protons and neutrons.

PROTON. A positively charged particle, identical with the nucleus of ordinary hydrogen.

RAD. A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of radiation per gram of tissue.

RADIATION UNIT. 1 milliroentgen per hour at 1 meter distant from any point on the surface of a container.

REM. A unit of biological dose of radiation.

ROENTGEN. A unit of exposure dose of gamma radiation or X-rays.

SHIELDING. Any material that absorbs or attenuates radiation, thus protecting persons behind it.

SUPERCRITICAL. The state of a given fission system when the quantity of fissionable material is greater than the critical mass; a highly supercritical system must exist for a nuclear explosion to occur.

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