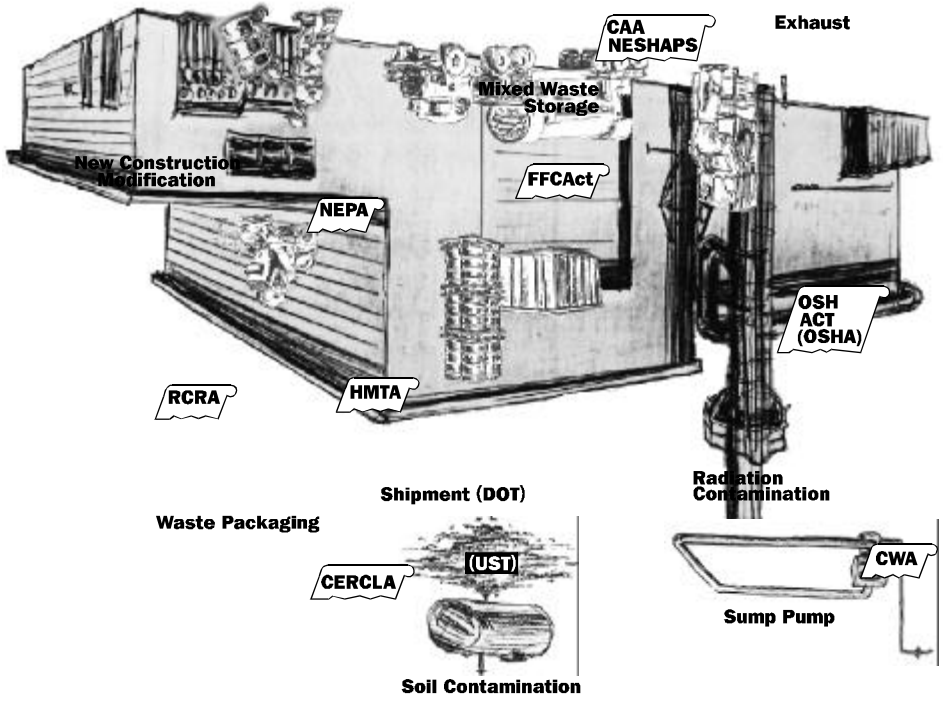
THE ATOMIC ENERGY ACT (AEA)



TERMINAL OBJECTIVE

Given the Environmental Laws and Regulations Course Manual as a reference, you will be able to:

- Explain the scope of the Atomic Energy Act (AEA) and its impact on the DOE.

ENABLING OBJECTIVES

- Define the following terms: source material, special nuclear material, and by-product material.
- Describe the impact on the Atomic Energy Commission (AEC) and the Energy Research and Development Administration (ERDA) by passage of the Energy Reorganization Act of 1974 and the DOE Organization Act.
- Explain how the Resource Conservation and Recovery Act (RCRA), DOE O 435.1, and "Standards for Remedial Action at Inactive Uranium Processing Sites" (40 CFR Part 192) relate to the Atomic Energy Act.
- Summarize the provisions of the following AEA amendments:
  - 1954 amendments, 1959 amendments (Section 274), 1964 amendments (PL 88-488), 1988 (PL 100-408 - Price-Anderson Amendments), 1988 (Defense Nuclear Facilities Safety Board - 100-456)
- Describe the waste types for which EM has management responsibility under DOE O 435.1.

Environmental Management
Time line of Significant Events

December, 1938	Fission of uranium is observed
August 2, 1939	Einstein letter to Roosevelt warning the chain reactions observed could lead to developing powerful bombs
December 7, 1941	Japan attacks Pearl Harbor/U.S. enters World War II
January 19, 1942	Roosevelt approves production of the atomic bomb
August, 1942	Seaborg produces a microscopic sample of pure plutonium
September, 1942	Army Corps of Engineers establishes Clinton Engineer Works (later, Oak Ridge) as the uranium production pilot plant
November 25, 1942	Los Alamos is selected as "the bomb laboratory"
December 2, 1942	The first human-induced self-sustained nuclear criticality takes place at Stagg Field, University of Chicago
January 16, 1943	Hanford is selected at the plutonium production site
September, 1944	The first nuclear reactor begins operation at Hanford
February, 1945	Hanford sends the first plutonium to Los Alamos for experiments
June, 1945	Scientists from the Metallurgical Lab (Site A) advocate international control of atomic bomb research and propose an atomic bomb demonstration prior to use in combat
July, 1945	A test of the atomic bomb (code name Trinity) was conducted at White Sands Missile Range, NM
August, 1945	A uranium bomb is dropped on Hiroshima (8/6); two days later, a plutonium bomb is dropped on Nagasaki (8/8); six days later, Japan surrenders (8/14)
August 1, 1946	Truman signs the Atomic Energy Act
January 1, 1947	The Atomic Energy Commission is established
1954	The AEA is amended to enable commercial use of nuclear materials
1963-1967	Project Sale Vault studies a salt mine near Lyons Kansas for suitability for permanent disposal of high level radioactive waste
1974	Energy Reorganization Act established the Nuclear Regulatory Commission (with responsibility for licensing the commercial use of nuclear materials) and the Energy Research and Development Administration (with responsibility for developing and refining additional sources of energy, including improvements in the nuclear fuel cycle, disposal of waste, and production of materials for the Nation's nuclear weapons stockpile)
1977	DOE established
1989	EM established

OVERVIEW

The Atomic Energy Act (AEA) of 1946 was passed to ensure that the development of nuclear energy was conducted in a manner that was consistent with the security of the United States. Congress gave the Federal Government control of the production and use of fissionable material and vested control through the inception of the Atomic Energy Commission (AEC), which was established by the AEA.

REGULATORY HISTORY

It soon became apparent that accelerated technical and scientific advances in nuclear energy research and development were exceeding the scope of the AEA's provisions. In 1954, Congress revised the AEA to keep pace with nuclear development in the United States and other countries.

The 1954 amendments removed the monopolistic Government control over nuclear energy development and utilization as long as private enterprise complied with the AEC's licensing requirements. Additionally, these amendments ensured Federal regulation for the processing and use of source, by-product, and special nuclear material through comprehensive licensing processes.

Prior to 1954, nuclear energy activities were largely confined to the Federal Government. The AEA amendments made it possible for private commercial firms to enter the nuclear energy field for peaceful purposes, if an operating license was obtained from the AEC.

Because the amendments did not specify how the States would be involved, this commercial influx presented a conflict between the 1954 amendments and the historical role the States had undertaken to ensure public health and safety protection. This issue was not addressed until 1959 when Section 274 was added to the AEA to provide a statutory role and basis for States under which the Federal Government could relinquish portions of its regulatory authority to them. These amendments also made it possible for the States to license and regulate by-products, source materials, and small quantities of special nuclear materials, which, according to the AEA, are defined as the following:

- **Source material**—(1) uranium, thorium, or any other material which is determined by the [Nuclear Regulatory] Commission pursuant to the provisions of Section 61 of this Act to be source material, or (2) ores containing one or more of the foregoing materials, in such concentration as the Commission may, by regulation, determine from time to time. [AEA, Section 11(z)]

- **Special nuclear material**—(1) plutonium, uranium enriched in the isotope 233 or the isotope 235, and any other material which the Commission, pursuant to the provisions of Section 51 of this Act, determines to be special nuclear material, but does not include source material, or (2) any material artificially enriched by any of the foregoing, but does not include source material. [AEA, Section 11(aa)]

- **By-product material**—(1) any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to radiation incident to the process of producing or utilizing special nuclear material, and (2) the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. [AEA, Section 11(e)]

In 1959, the AEA was further amended to define the respective responsibilities of the States and the AEC, which include the following:

- The control of source, by-product, and special nuclear materials.

- The establishment of an orderly regulatory system for State and AEC use to regulate radiation hazards associated with source, by-product, and special nuclear materials.

- The establishment of procedures for the transfer of AEC regulatory responsibilities to the States upon approval of a State program. However, provisions were maintained that prohibited the AEC from turning over to the States the responsibility for regulating the discharge of radioactive effluents from any facilities.

These amendments established a formal role for the states (now known as the "agreement state" concept).

Additionally, Section 161 of the AEA provides the authority to establish "by rule, regulation, or order, such standards and instructions to govern the possession and use of special nuclear material, source material, and by-product materials as the . . . AEC . . . [Atomic Energy Commission (AEC), now the Nuclear Regulatory Commission (NRC)], . . . may deem necessary or desirable to promote the common defense and security or to protect health or to minimize danger to life or property." This and Sections 2, 3, and 41 of the AEA allow the DOE to set radiation protection standards for itself and its contractors. Furthermore, the AEA defined the licensing powers (Sections 101-111) granted to the NRC and itemized any licensing exclusions for defense production facilities (Sections 91 and 110).

In 1964, Congress amended the AEA (Public Law 88-488) to allow private ownership of special nuclear material by AEC licensees.

AEC, ERDA, AND DOE

In the early 1970s, Federal energy efforts were redirected when the Energy Reorganization Act of 1974 was passed. Its intent was to establish efficient energy utilization while enhancing environmental protection. Congress decided that the public's interests would best be served by separating AEC licensing functions from those of energy development and other related activities. Congress achieved this by abolishing the AEC and replacing it with two organizations: (1) the NRC, and (2) the Energy Research and Development Administration (ERDA), which later became the DOE when the DOE Organization Act passed in 1977. The Energy Reorganization Act of 1974 authorized the NRC to license ERDA facilities according to the following classes:

- Demonstration liquid metal fast breeder reactors when operated as part of the power generation facilities of an electric utility system or when operated in any other manner to demonstrate the suitability of such a reactor for commercial application.

- Other demonstration nuclear reactors, except those in existence on the effective date of the Act, when operated as part of the power generation facilities of an electric utility system or when operated in any other manner to demonstrate the suitability of such a reactor for commercial application.

- Facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under the Act.

- Retrievable surface storage and other facilities authorized for long-term storage of high-level radioactive wastes generated by ERDA, which are not used for, or part of, research and development activities.

The DOE Organization Act of 1977 further clarified congressional intent as it pertained to the DOE's environmental functions. It states:

> The DOE, by consolidating environmental considerations and procedures now within the separate purview of the Federal Energy Administration (FEA), Energy Research and Development Administration (ERDA), Federal Power Commission (FPC), and part of the Department of Interior (DOI), should provide an effective vehicle for identifying potential environmental, health, safety, socioeconomic, institutional, and control technology issues associated with technology development. It will provide a single, coordinated mechanism for determining necessity and timing of environmental impact statements in order to respond to the needs of specific technologies or resources. It will ensure a complete and fully integrated program with respect to environmental, health and safety impact research, and engineering applications.

Other AEA amendments have been passed by Congress that deal largely with commercial licensing by the Nuclear Regulatory Commission (NRC). Some of these include the following:

- Public Law 97-415 (1983) amended many sections of the AEA. The law authorized the NRC to implement a resident inspector program for quality assurance purposes. A study of commercial nuclear power plant construction was also required to improve quality assurance and quality control. A limitation was placed on the use of special nuclear material and penalties were set for the sabotage of nuclear facilities or fuel.

- Section 148 of the Act was amended to require the Secretary of Energy to prepare a quarterly report regarding DOE information with respect to nuclear defense programs.

- Public Law 99-399 (August 27, 1986) added three new sections to the Act:

  - Section 132 provides the authority to suspend nuclear cooperation with nations that have not ratified the Convention on the Physical Security of Nuclear Material.

  - Section 133 requires consultation with the Department of Defense (DoD) concerning certain exports and subsequent agreements.

  - Section 149 requires fingerprinting for criminal record checks.

- The Price-Anderson Amendments Act (Public Law 100-408, August 20, 1988) amended the Price-Anderson provisions of the AEA to extend and improve procedures for liability and indemnification for nuclear incidents.

The DNFSB

- Public Law 100-456 (September 29, 1988) added Chapter 21 to the Act, which established the Defense Nuclear Facilities Safety Board (DNFSB). The Board has five members, appointed by the President, who are respected experts in the field of nuclear safety. The functions of the DNFSB are as follows:

  - Review and evaluate the standards relating to the design, construction, operation, and decommissioning of DOE's defense nuclear facilities.

  - Investigate any event or practice at a DOE defense nuclear facility that the DNFSB determines had adversely affected, or may adversely affect, public health and safety.

  - Analyze design and operational data.

- Review new facilities' design and construction.
- Provide recommendations to the Secretary of Energy that pertain to DOE defense nuclear facilities, including operations of facilities, standards, and research needs.

EM'S RESPONSIBILITY FOR WASTE MANAGEMENT

DOE O 435.1 provides the requirements for EM's waste management activities.

EM is responsible for management of: High-Level Waste, Low-Level Waste, Transuranic Waste, Mixed (low level) Waste, Uranium Mill Tailings, Hazardous Wastes, and Sanitary Wastes. In addition, spent nuclear fuel is sometimes considered a waste. Hazardous and sanitary waste will be addressed in the module on the Resource Conservation and Recovery Act (RCRA). The other types of waste will be discussed here.

TRANSURANIC WASTE

Transuranic Waste is defined as: without regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100nCi/g at the time of assay.

Transuranic waste (also referred to as TRU waste) results from work with americium, plutonium, or other transuranium (greater than element 92) elements. Typical TRU waste contains used laboratory glassware, coveralls, lab coats, booties, failed equipment, and other incidental laboratory wastes. It results from reactor fuel assembly, weapons fabrication, and chemical processing operations.

Waste from facilities (laboratory, canyon, processing plant, etc.) where transuranics are used is assumed to be contaminated at greater than 100 nCi/g until it is assayed, at which point it is either confirmed to be TRU waste, or shown to be low-level waste (by virtue of containing less than 100 nCi/g transuranic contamination). Further, TRU waste is assumed to contain hazardous waste (RCRA) constituents unless the waste generators can prove that no RCRA constituents are in the waste; therefore, TRU is occasionally referred to as TRU mixed waste.

TRU is proposed to be disposed of in the Waste Isolation Pilot Plant (WIPP), a deep geologic repository located 26 miles from Carlsbad, NM.

High-Level Waste

High-Level Waste (HLW) is defined as: the highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid, that contains a combination of transuranic waste and fission products in concentrations requiring isolation.

HLW contains relatively short lived radionuclides such as ^{137}Cs and ^{90}Sr in concentrations that prohibit contact with the waste. In addition, HLW also contains long lived transuranic radionuclides. HLW must be handled remotely from behind shielding to protect workers.

The largest volume of HLW is stored as liquid in underground storage tanks at Hanford, the Savannah River Site (SRS), Idaho National Engineering and Environmental Laboratory (INEEL), and the West Valley Site. Much of the liquid waste at the INEEL has been converted to a dry granular solid known as calcine and is stored in stainless steel "bins" inside concrete encasements.

The high-level liquid wastes at West Valley and SRS are currently being vitrified into borosilicate glass, the final waste form. Hanford is also proposing borosilicate glass for its high-level liquid wastes. The final form for the Idaho wastes is not yet determined. HLW may contain hazardous (RCRA) constituents; the RCRA-approved treatment method for HLW is Vitrification.

Immobilized HLW will be disposed of in a deep geologic repository. Congress has directed DOE to study the Yucca Mountain site in Nevada to determine if it is technically qualified to serve as the final repository.

Low-Level Waste

Low-Level Waste (LLW) is defined as: waste that contains radioactivity and is not classified as HLW, transuranic waste, or spent nuclear fuel or by-product material as defined by this order.

LLW often contains small amounts of radioactivity dispersed in large amounts of material. It is generally made up of rags, papers, filters, tools, equipment, discarded protective clothing, dirt, and construction rubble contaminated with radionuclides.

To dispose of LLW, the generator must certify that the waste does not contain any hazardous (RCRA) constituents. LLW is disposed of via shallow-land burial.

Radioactive Mixed Waste

Radioactive Mixed Waste is defined as: waste containing both radioactive and hazardous components as defined by the AEA and the RCRA, respectively.

A large portion of DOE's mixed waste is mixed low-level waste (MLLW) found in soils. No MLLW can be disposed of without compliance with RCRA's requirements for hazardous waste and meeting RCRA's Land Disposal Restrictions, which require waste to be treated before disposal in appropriate landfills. DOE has several MLLW treatment facilities which enable this waste to be disposed of in compliance with RCRA requirements.

In 1987, DOE issued a final rule (10 CFR 962) that defines by-product material as it applies to DOE-owned or DOE-produced radioactive material that has a hazardous waste component (i.e., mixed wastes). Under 10 CFR 962, the term *any radioactive material* as described in part (1) of the AEA's definition of by-product material refers only to the actual radionuclides suspended or dispersed in the material, not to the nonradioactive hazardous component of the waste. This means that although the DOE retains authority under the AEA for the actual radionuclides in by-product material, any nonradioactive hazardous component of the material is subject to regulation by the Environmental Protection Agency (EPA) or its Agreement States under the RCRA. However, the new rule does not apply to by-product materials as defined by part (2) of the AEA definition or substances not owned or produced by the DOE.

Spent Nuclear Fuel

Spent Nuclear Fuel (SNF) is defined as: fuel that has been withdrawn from a nuclear reactor following irradiation but has not been reprocessed to remove its constituent elements.

SNF is thermally hot and highly radioactive. It is usually stored underwater for shielding and worker protection. It will be disposed of with the HLW in a deep geologic repository.

Uranium Mill Tailings

Uranium mill tailings are naturally occurring, radioactive, sand-sized particles of crushed rock and soil that are by-products of uranium milling operations. Mill tailings contain residual radium and other radioactive elements, and radium produces radon gas when it undergoes radioactive decay.

Radon and its decay products are believed to increase lung cancer risk. Although radon generally disperses harmlessly when released into the atmosphere, long-term exposure to high concentrations of radon gas has been shown to be harmful to humans.

Uranium mill tailings are isolated in disposal cells designed to meet the requirements of "Standards for Remedial Action at Inactive Uranium Processing Sites" (40 CFR Part 192). The standards established guidelines for the control of mill tailings piles and the cleanup of buildings and open land. These standards are prescriptive rather than risk-based standards (i.e., quantitative standards are imposed regardless of the absence of nearby communities or populated areas). The requirements in the standards cover long-term stability of mill tailings (long-term isolation and stabilization), radon emission (reduction/control), and ground water (protection of water quality).

The standards require that tailings be effectively stabilized for a period of at least 200 years (control measures must be designed to be effective for up to 1,000 years). Radon emission limits and alternative concentration limits for radon-222 released into the air from the stabilized tailings were also established. Additionally, the standards set limits for the allowable concentration of radium-226 in the soil. For cleanup of vicinity properties, limits were established for radon decay products, as well as gamma radiation emission limits in buildings.

After closure of the disposal cell, it is licensed by the Nuclear Regulatory Commission, and long-term monitoring is provided by DOE.

RADIATION HAZARDS

Radiation was discovered just 100 years ago.

In the 100 years since it's discovery, much as been learned about both the sources and properties of radiation. This includes the development of fission and fusion weapons, commercial nuclear power, medical diagnostics and treatment, power sources for space craft, and a variety of industrial applications.

It also includes the generation of wastes that remain hazardous for many thousands of years.

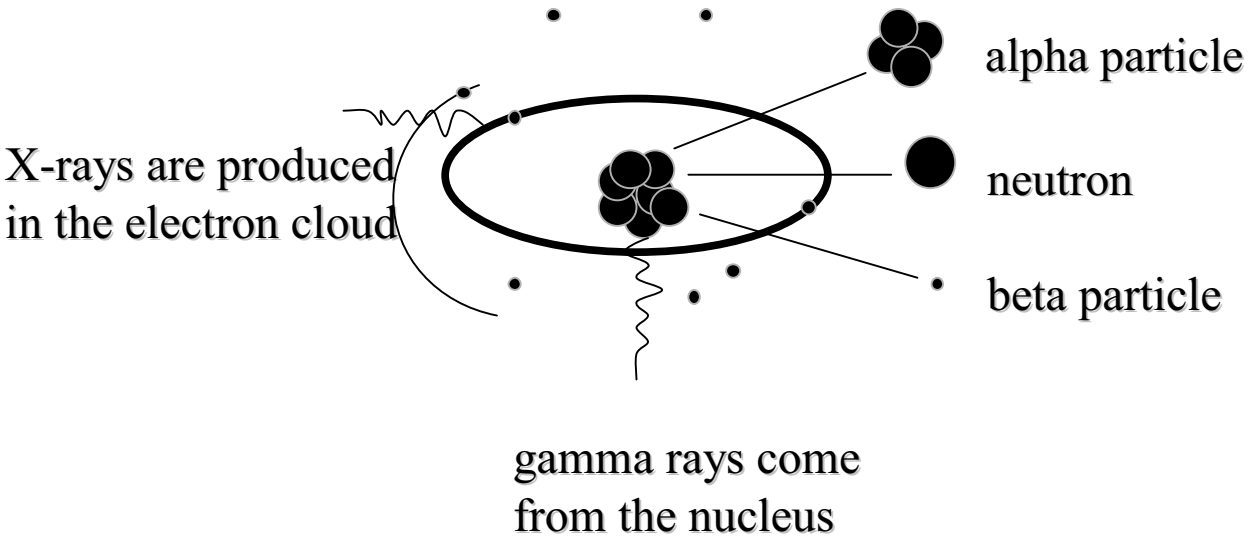
This module will provide a brief history of the discovery of radiation, and radioactivity, describe the evolution and definition of terms associated with radioactivity, discuss the hazards of and precautions for working with radioactive materials, and define the types of wastes generated by the EM program.

The safety procedures and legal requirements associated with radioactive materials and radiation have evolved along with the growing use of such agents. The concurrent development of regulations and safety procedures with the military and commercial application of nuclear science enabled safety practices to be continuously updated as more knowledge has been acquired. This, in turn, has produced an excellent safety record for both military and commercial nuclear activities.

The Atomic Energy Act of 1946 established the Atomic Energy Commission, to control nuclear energy development and to explore the peaceful uses of nuclear energy. The Atomic Energy Act was amended in 1954 to permit and encourage the participation of private industry in the development and use of nuclear energy and other radioactive materials.

Under the authority of the 1954 amendments, 10 CFR 20, Standards for Protection Against Radiation, was issued in November, 1960. This regulation established the standards for protecting against ionizing radiation resulting from activities conducted under licenses issued by the Atomic Energy Commission (later the Nuclear Regulatory Commission).

Current radiation protection standards are recommended by nationally and internationally recognized authorities such as the International Commission on Radiological Protection (ICRP) and the U.S. National Council on Radiation Protection and Measurement (NCRP). These standards and the evaluations provided by the National Academy of Sciences Committee on Biological Effects of Ionizing Radiation (BEIR) and the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) are used by the Department of Energy (DOE) for determining radiation standards to be used by its contractors.



HISTORY

WILHELM KONRAD ROENTGEN (1845-1923)

Wilhelm Roentgen was a German physicist who discovered X rays ("X" for unknown radiation) in the fall of 1895. X rays were immediately useful to medical science and subsequently led to new insights into the structure of the atom. Based on his discovery and research on X rays, Roentgen was awarded the first Nobel Prize in physics in 1901.

While experimenting with conduction of electricity through gases in spent vacuum tubes, Roentgen became interested in the luminescence that cathode rays (speeding electrons) caused in certain chemicals. Roentgen noticed that paper coated with barium platinocyanide glowed when the cathode ray tube was turned on, even though the cathode rays could not possibly be reaching the paper because he had shielded the tube with thin black cardboard. Roentgen concluded that a highly penetrating yet invisible radiation from the cathode ray tube could penetrate substances that blocked ordinary light. This newly discovered radiation could pass through thick paper, flesh, and even thin sheets of metal, but was stopped by other materials, such as thicker pieces of metal and bone.

Roentgen continued to experiment to gather as much information on X rays as possible. When he published his first paper on X rays on December 28, 1895, he was able to report all the fundamental properties of X rays, such as their ability to ionize gases (i.e., strip electrons from the gas molecules) and their failure to respond to electric or magnetic fields. On January 23, 1896, at his first public lecture on the new phenomenon, Roentgen took an X-ray photograph of the hand of a volunteer from the audience. This demonstration caused a sensation in the scientific and medical communities, and interest in X rays swept across Europe and America. X rays were immediately recognized as a new tool for medical diagnosis. By 1900, the British Army was using mobile X-ray units in the Sudan to locate bullets and shrapnel in wounded soldiers.

Scientists later determined that X rays were generated as a result of the slowing of fast electrons by the nuclei of heavy atoms. In honor of Roentgen's discovery, the unit of X- or γ-radiation exposure is called the roentgen (R). The unit of radiation dosage that is used in radiation protection is the roentgen equivalent man (rem).

ANTOINE HENRI BECQUEREL (1852-1908)

Henri Becquerel was a French physicist who, in 1901, showed that radioactivity was property of uranium and that radioactivity did not depend on the nature of the substance in which the uranium was present (i.e., solid, liquid, gas). For his discovery of radioactivity, Becquerel shared the 1903 Nobel Prize in physics with Marie and Pierre Curie.

Intrigued by Roentgen's discovery of X rays, Becquerel experimented to determine whether penetrating rays similar to X rays were emitted from a fluorescent material, such as a pure specimen of uranium salt (potassium uranyl sulfate). In February 1896, Becquerel wrapped a photographic film plate in black paper and put the wrapped film in sunlight with a uranium salt crystal on it. He hypothesized that if sunlight induced fluorescence, and if the fluorescence contained X rays, then the X rays would penetrate the paper and expose the film. When he developed the film, Becquerel found that it had been exposed. Therefore, he believed that X-ray radiation had penetrated the black paper and the X rays were produced in fluorescence.

At the time, Becquerel thought that sunlight was essential for the success of his experiment. Since the skies were cloudy for several days after the initial experiment, he could not continue his studies. Becquerel decided to put the experiment (the covered photographic plate with the uranium crystals sitting on it) away in a desk drawer. He later took the plate out of the drawer an developed it, looking for any delayed fluorescence, but not expecting any positive results.

However, the photographic plate showed strong fogging, indicating that some type of radiation had penetrated the covered plate. Becquerel concluded that the fluorescence of the uranium salt did not depend on sunlight, and therefore some new, unknown type of radiation was being emitted by the uranium salt.

Becquerel studied this radiation further and found that it was similar to X rays. He learned that the rays penetrated matter, ionized the air, and were given off by the uranium salt in an unending stream that radiated in all directions. Over the next two years, Becquerel determined that the radiations from radioactive substances could be deflected by a magnetic field (unlike X rays).

From this, he deduced that at least part of the rays consisted of small, charged particles. He later concluded that these were negatively charged particles (i.e., speeding electrons) coming from within the atoms of uranium.

In honor of Becquerel's discovery, the unit of radioactivity is termed the becquerel (BQ), which is one radioactive disintegration per second.

Marie Sklodowska Curie (1867 - 1934) and Pierre Curie (1859 - 1906)

Marie Curie was a Polish-French chemist who, intrigued by the discoveries of X rays and uranium radiations, studied the radioactive properties of uranium. Curie and her husband, French chemist Pierre Curie, conducted an intensive systematic study of uranium and discovered two new elements in the process (polonium in 1898 and radium in 1902). The Curies shared the 1903 Nobel Prize in physics with Henri Becquerel. The Curie's Nobel Prize was awarded for their studies of radioactive radiations. Marie Curie was later awarded the 1911 Nobel Prize in chemistry for the discovery of polonium and radium (Pierre had been killed in 1906). She is the only person to win two Nobel Prizes in science.

The Curies had tons of waste ore, which was rich in uranium, shipped from abandoned mines to the physics school where they conducted their research of the radioactive radiations in uranium. From this ore, the Curies isolated small amounts of the new, intensely radioactive elements polonium and radium. The Curies purified tons of ore for four years to produce a small sample (0.1 grams) of pure radium. Eventually, after purifying eight tons of pitchblende (a uranium-containing ore), they extracted a full gram of radium salt. In addition to uranium, polonium, and radium, the Curies determined that thorium was also radioactive. Their work laid the foundation for new discoveries in nuclear physics and chemistry, as well as the discovery of other radioactive elements.

It was Marie Curie who coined the term "radioactivity" for the process in which uranium gives off rays. The curie (Ci) is a unit of radioactivity originally based on the disintegration rate of one gram of radium (which emits α particles), but is now defined as the quantity of any radioactive nuclide undergoing 37 billion disintegrations per second (i.e., the amount of a radionuclide that emits any type of particle at the same rate as does one gram of radium).

Ernest Rutherford (1871-1937)

Ernest Rutherford was a British physicist who contributed to the theory of the basic structure of the atom. Rutherford formulated the theory of radioactive disintegration of the elements, identified α and β particles, and devised the theory of the nuclear structure of the atom. In 1908, Rutherford won the Nobel Prize in chemistry for his investigations of the chemistry of radioactive substances.

Continuing Becquerel's work with radioactivity, Rutherford discovered that there were several different kinds of rays given off by radioactive substances. He determined that some of the rays (actually particles) were positively charged (α particles), some were negatively charged (β particles), and he proved that some rays that were not affected by a magnetic field consisted of electromagnetic waves (γ rays). Rutherford's discovery that there were three different kinds of rays coincided with those of Becquerel and Curie.

Beginning in 1902, Rutherford studied radioactive disintegration. He believed that, starting with uranium or thorium, each radioactive element broke down (decayed) into a series of different intermediate elements until lead was formed. Rutherford observed that each intermediate element broke down at a particular fixed rate and that half of any quantity of a radioactive element disintegrated in a fixed period of time, which he named the half life.

Rutherford also showed that an α particle was a helium nucleus (i.e., a helium atom minus its electrons), and he studied β particle scattering using thin sheets of gold foil. Rutherford's nuclear theory of the atom evolved from this research. He believed the atom contained a small nucleus at its center. He further believed that the nucleus was positively charged and contained all of the protons of the atom and therefore almost all of its mass. In addition, he thought the negatively charged electrons were relatively light and made up the outer regions of the atom.

It was Rutherford who determined that one gram of radium emitted 37 billion particles per second (later to be known as one curie of radiation). While not commonly used in the EM program, a rutherford of radioactivity represents that amount of material that yields one million breakdowns per second.

Skipping ahead in time to some historical highlights after the 1930's that are relevant to DOE and the EM program:

- In the mid to late 1930's, there was great concern by many of the scientists who had fled Europe that Germany could develop an atomic weapon.

- In August, 1939, Albert Einstein wrote a letter to President Roosevelt urging support of research on uranium chain reactions. (*A copy of the letter is at the end of the module*)

- On September 17, 1942, the Atomic Project, which included scientists from the Universities of Chicago and Virginia, Columbia University, and the University of California at Berkeley was established, with General Leslie Groves, of the Army Corps of Engineers in charge.

- On December 2, 1942, the world's first self-sustaining nuclear fission chain reaction was achieved in a demonstration reactor [Chicago Pile 1 (CP-1)], which was located in a laboratory in an abandoned squash court beneath the stands of Stagg Field at the University of Chicago. In the meantime, the scientists at Columbia University had been developing the theory of gaseous diffusion to enrich uranium, the scientists at Berkeley were looking at enrichment through application of electromagnetics, and the scientists at the University of Virginia were exploring centrifuge technology for uranium enrichment.

- Less than four weeks after the first criticality, President Roosevelt authorized spending $500 million to build a full-scale uranium-enrichment gaseous diffusion plant and plutonium and heavy water production facilities.

- Also in late 1942, the government acquired 59,000 acres west of Knoxville on the Clinch River. In February 1943, 500,000 acres on the Columbia River near Hanford, Pasco, and White Bluffs, WA, were purchased.

- By mid 1945, a plutonium bomb had been fabricated; it was detonated on July 16, 1945 on the White Sands Missile Range in New Mexico.

- On July 29, 1945, Japan rejected the Potsdam Proclamation's demand to surrender unconditionally or face "prompt and utter destruction". In response, the "Little Boy" uranium bomb was dropped on Hiroshima on August 6, 1945. Three days later, the "Fat Man" plutonium implosion bomb was dropped on Nagasaki. Japan surrendered on August 14, 1945.

- After the first nuclear weapons were developed, congressional debate ensued on whether a military or civilian agency should have control of the atom. Many Manhattan Project scientists objected to continued military control over nuclear research. While tolerable during war, they advocated free scientific interchange.

- In 1946, Congress passed the Atomic Energy Act, which established the Atomic Energy Commission (AEC). The AEC was created "to foster the peacetime development of nuclear science and technology, as well as to produce sophisticated weapons for defense and develop nuclear energy and nuclear power plants for out Nation's electrical needs".

- The AEC developed "Manual Chapters," which governed AEC operations, including nuclear safety policies and the management of radioactive waste.

- In 1974, out of concern that the AEC could not effectively both regulate and promote nuclear energy,Congress passed the Energy Reorganization Act, establishing the Nuclear Regulatory Commission (to license commercial uses of radioactive materials) and the Energy Research and Development Administration (which became the Department of Energy under President Carter).

BASICS OF RADIATION

Radioactivity is the spontaneous disintegration of an atomic nuclear accompanied by the emission of energy or particles. Radiation is the energy travelling in the form of electromagnetic waves or photons (such as (γ or x-rays), or the stream of particles (α, β, or η) from a radioactive source.

There are many sources of radiation in the environment that people are exposed to on a daily basis, such as cosmic radiation and naturally occurring radioactive isotopes of potassium, carbon, oxygen, or other elements.

There are three types of radiation that are of major concern to EM workers:

ALPHA particles consist of two protons and two neutrons bound together with an electrical charge of +2. Alpha particles are identical to the helium nuclei.

Alpha (α): large mass (4 amu) - large charge (+2) very energetic - shallow penetrating

Alpha particles cannot penetrate the top layer of skin. Therefore, alpha radiation is an internal hazard—a hazard only when alpha emitters are deposited in the body and are directly in contact with living cells.

BETA particles contain a single negative electrical charge, and are identical to electrons.

Beta (β): small mass (0.00055 amu) - charged +/- 1, shallow penetrating

Many light elements and fission fragments decay by the emission of an electron (a beta particle). Higher energy beta particles can penetrate to the living cells of skin. Beta radiation is an eye, skin, and internal hazard.

GAMMA rays are high energy, short wavelength, electromagnetic radiation. Other types of electromagnetic radiations include visible light, ultraviolet light, and radar.

Gamma (γ): no mass - no charge

Gamma rays and x-rays are photons (like light) but high enough energy to produce ions in the material they travel through. X-rays and gamma rays are penetrating radiation, and are an external hazard.

A fourth type of radiation, neutrons, primarily occur in cyclotrons, nuclear reactors, and nuclear weapons.

Neutron (η): mass 1 amu - no charge highly penetrating - very energetic

Neutrons can be released when an atom splits (or fissions). Neutrons are penetrating and are an external hazard. They can travel through space and through living tissue. They are a hazard even when the source is located outside your body.

IDENTIFYING CHARACTERISTICS OF RADIONUCLIDES

Radionuclides have three distinct characteristics that are useful for identification purposes.

Half-life - the amount of time it takes for ½ of the original number of atoms of a specific radionuclide to decay. For each radionuclide, it is always the same.

Type of Radiation - the types of radiation (α, β, γ, η) emitted by a specific radionuclide. For each radionuclide, it is always the same.

Energy - whether low or high energy or particles, the energy of the radiation emitted by a specific radionuclide is always the same.

UNITS OF RADIATION

Radiation may be divided into two classes: ionizing and non-ionizing.

X-rays, for example, are classified as an ionizing radiation by virtue of their energy. Microwaves are non-ionizing radiation because they are lower energy. Ionizing radiation, however, includes many types of radiation in addition to X-rays. The International Committee on Radiation Protection has divided ionizing radiation into two categories:

- Directly ionizing particles or charged particles (electrons, protons, α particles, etc.) that have sufficient kinetic energy to cause ionization by collision; and

- Indirectly ionizing particles or uncharged particles (neutrons, γ-rays, X-rays, etc.) that can interact and liberate directly with ionizing particles.

Ionization is the major process by which radiation deposits energy in, and causes damage to, human body tissue. Ionization is defined as the process by which a neutral atom or molecule undergoes structural change to become a charged particle. This results in the formation of positive ion and energetic free electrons.

Activity

The most widely used unit of activity in the EM program is the curie (Ci). It is the quantity of radionuclide that disintegrates at the rate of 37,000 million disintegrations per second. The activity of one gram of Radium is approximately equal to one Ci.

The unit of activity in the Systeme Internationale (SI) system is the Becquerel (bq).

1 Becquerel (bq) = 1 disintegration per second.

1 Curie (Ci) = 37 Gigabecquerel = 37 (Gbq).

Exposure and Absorbed Dose

Historically, the most important term associated with radiation exposure has been the roentgen. However, the roentgen measures photon (x- and γ-rays) ionization effects on air, and this is very limiting.

In addition to photons, radiation can also consist of α or β particles or neutrons. In addition, the material of interest in which interaction occurs in most cases is not air.

Absorbed dose is a more general quantity. Any type of ionizing radiation (directly or indirectly ionizing) is included. Any material (not just air) may be used in making the measurement.

1 rad = 0.01 joule/kilogram = 100 ergs/gram.

The SI unit of absorbed dose is the Gray (GY).

1 Gy = 1 joule/kilogram (100 Rads).

Dose Equivalent

The unit of greatest interest to EM is the dose equivalent measurement Roentgen Equivalent to Man (rem). The rem is a measure of the dose of any ionizing radiation to body tissues in terms of its estimated biological effect.

The SI unit of dose equivalent is the Sievert (Sv) (1 rem = 0.01 Sv).

The roentgen, Ci, rad, and rem are rather large units of measurement. Smaller and more convenient units are:

- Milli...(one thousandth). 1 millirem = mrem = 0.001 rem
- Micro...(one millionth). 1 microcurie = 0.000001 ci

Any employee whose work assignment involves work with radioactive materials or radiation-generating machines must receive adequate radiation safety training and be familiar with the processes and equipment to be used.

The Biological Effects of Ionizing Radiation

The degree of hazard associated with a particular radioactive material is based on the nuclide and the type of radiation being emitted. All radioactive particles are ionizing to some extent. As the particles pass through human tissue, the particles eject electrons from the atoms they strike thereby leaving ions in their path. This may result in damage or death to the cells in the tissue.

The human cell is comprised of three things:

1. Cytoplasm: mostly water and the site of most of the chemical activity in the cell.
2. Nucleus: contains the chromosomes, and is separated from the cytoplasm except during the final stages of cell division.
3. Chromosomes: made up of DNA, the carrier of genetic information. Damage here by direct

or indirect ionization is of most concern.

The factors affecting a cell's susceptibility to DNA damage are: rate of cell division; time that the cell spends dividing; cell's chemical activity; and the function of the cell (i.e. blood, food or oxygen processing). This is why bone marrow (blood production) is more sensitive to exposure than, say, your fingers and toes.

The effects of ionizing radiation on an organism can be divided generally into three groups: the acute effects, the later effects, and the genetic effects. They clearly depend on the dose received to the whole body, but a high dose rate is also important. A dose delivered over a period of hours or days is generally less damaging than the same dose delivered in an exposure lasting only seconds or minutes.

Late Effects of Ionizing Radiation

Effects to human beings from exposure to nuclear radiation may not appear for several years. Among these are the formation of cataracts, leukemia, and other forms of malignant disease, as well as the retarded development of fetuses irradiated in the uterus and an overall shortening of the life span. Data on these effects for human beings are necessarily limited. Studies are continuously conducted on survivors from Hiroshima and Nagasaki, and on workers who were irradiated in the course of their employment before the dangers were understood.

Genetic Effects of Ionizing Radiation

Each of the 46 (23 pairs) of chromosomes in the human body are made up of several thousand genes. Genes are not completely stable and are constantly undergoing changes known as mutations. Only very rarely do mutations improve the species and it can be generally assumed that most mutations are harmful. The rate at which genes mutate is called the spontaneous mutation rate, and it is this rate that leads to over 2 percent of the worlds population suffering from one or another of the 500 or more defects or diseases of known genetic origin.

Radiation can cause mutations, as can other agents.

RADIATION SAFETY

Standards have been established for permissible radiation exposures to various parts of the body. Certain tissues and organs (e.g., reproductive organs) are more sensitive to radiation than others, thus protection requirements vary. Exposure limits for radiation workers are higher than those allowed for the general public. One of the underlying assumptions of the radiation industry, and a basis for the recommendations of the International Committee on Radiation Protection, is the cautious assumption that any exposure to ionizing radiation may carry some risk of negative effects. This implies that there is no wholly safe dose of radiation. However, unless society wishes to dispense with activities involving exposures to ionizing radiations, it must recognize that there is a degree of risk, and must limit the radiation dose to a level at which the assumed risk is deemed to be acceptable to the individual and to society in view of the benefits derived from such activities.

CONTROLLING EXPOSURE

RADIATION PROTECTION STANDARDS FOR INTERNAL AND EXTERNAL EXPOSURE FOR OCCUPATIONAL WORKERS

The exposure of an occupational worker to radiation resulting from routine DOE activities shall not exceed the standards established in DOE Order 5480.11.

- Whole Body: the location of most of the vital and blood producing organs.
  - 5 Rem/year not to exceed 3 Rem in any quarter
  - 5 (N-18) Rem cumulative life time (N = age)
- Extremities: < 50 Rem/year
- Lens of eye: < 15 Rem/year
- Unborn child: < 500 mrem/gestation not to exceed 50 mrem/month
- Visitors, General Public: < 100 mrem/year

DOE facilities may set “Local Levels” more stringent that these levels. However, in no case may the facility-specific levels exceed the standards established in DOE Order 5480.11.

Continued exposure of any worker over a substantial portion of a working lifetime at or near these limiting values should be avoided.

Radiation doses to an individual are derived from two sources: external exposure to radiation and internal exposure resulting from inhalation, injection (puncture wounds), ingestion of radioactive materials, or absorption of contamination on the body.

External Exposure

Whatever the source of the ionizing radiation, a radiation safety program must be designed to minimize the possibility that an employee could be exposed to harmful doses of radiation through routine work or by accident.

Planned exposure for either repetitive or occasional maintenance type operations may be controlled by utilizing one or more of the following practices:

Time - Limiting the time that a worker is exposed to a source of radiation is probably the most useful for activities where the work steps can be carefully planned and timed, or the assignment can be shared by two or more persons, one acting after another.

Distance - Work should be performed at as great a distance from the radiation as is practicable to reduce the radiation dose. For compact sources, dose rate is inversely proportional to the square of the distance. (Simply stated, if you double the distance from the source of radiation, you quarter the dose). For extended sources, the dose rate may decrease more slowly with distance. In the manipulation of radiation sources, for example, the use of small tools (e.g., forceps), can considerably reduce the finger dose received. It is very important for individuals not to place themselves in a direct beam of radiation.

Shielding - Where it is not possible to give personal protection by distance only, it is necessary to introduce a shield between the source of radiation and the individual. Where radiography is performed in an enclosure, the wall acts as shielding material.

Normally the walls are made of brick or concrete, but if the natural shielding is not sufficient, it can be increased by adding layers of barium plaster to the wall, or thin layers of lead to both the walls and the doors. In general, the more dense the material used, the greater the shielding effect.

Internal Exposure

When a radioactive source is outside the body, the dose to which the body is subjected may be controlled by any or all of the three factors, namely control of exposure time or by placing distance and shielding between the source and the body. However, the situation is different when the source has entered the body and is being carried around within it. The ultimate dose that the body will receive is now dependent on two factors: the amount and type of radioactivity in the body, and the speed of

elimination from the body. The latter may be very difficult to influence. Therefore, health physicists (or other controlling authorities) institute policies and practices to minimize intake.

RADIATION EXPOSURE

To summarize, to implement the ALARA (As Low As Reasonably Achievable) Concept, management relies on the following three basic protective measures:

1. Time: minimize the time spent in a radiation field by planning your work, use mock-ups (for training) and checklists to prepare (RWP).

2. Distance: know where the hot spots are and stay away; during work delays, move to a low dose area.

3. Shielding: permanent and/or temporary shielding can be installed

   - Radiological Work Permits (RWP): a process to ensure that all appropriate measures have been taken to ensure maintenance is accomplished with the least amount of exposure and risk to workers.

   - Postings and Signs: clear warnings of potential hazards according to type of hazard and levels of contamination:

     1. Black or magenta trefoil on yellow background

     2. Contamination (airborne/underground/soil)

     3. High/very high (with range readings)

   - Contamination Area Entry and Exit - clearly marked

   - Radiological material handling and disposal requirements.

The following are practical radiation safety considerations:

- Lead shielding and remote control devices should normally be used by the facility to handle and store radioactive materials. Gloves, coveralls, shoe covers and respirators can shield α and β particles. However, there is no personal protective equipment that protects against gamma radiation. The most effective safety measure is to separate yourself from the source

by distance or shield the source.

- Keep a lifelong listing of your exposure to even low levels of radiation. The effects of radiation exposure may be cumulative.

- All waste handlers should have an ongoing program of radiation monitoring through which exposure is assessed. Seek the advice of a health physicist if you have concerns about a facility's monitoring or protection program.

- Mixed wastes present both chemical and radiation hazards. For chemical hazards, seek the advice of the facility representative, industrial hygienist, or consult the Material Safety Data Sheets contained in file records. Select the appropriate respiratory or dermal protection based on the potential for exposure to chemicals handled at the facility.

- Mixed waste handlers may be exposed to extensive contamination of soils, ground water, or surface water. Avoid contact with or exposure to contaminated environmental media. Implement and monitor appropriate decontamination procedures. Wash your hands and face before eating to avoid ingestion of contaminated dust particles.

- Radioactive material uptake and accumulation occur in plants growing in contaminated soil. Animals grazing on radioactively contaminated plants may further concentrate the radioactive material.

CONTAMINATION

Types:

- Fixed contamination: embedded in a material and cannot be removed by normal cleaning methods.

- Transferrable (smearable) contamination: easily spread via dust and soot

- Airborne contamination: gaseous or particulate

Sources:

- Leaks in radioactive systems.

- Maintenance on radioactive system - e.g. grinding or chipping.

- Full enrichment process (via diffusion)

Control Methods

- Proper use of adequate protective clothing, anti-contamination (anti-c's).
- Containments (glove boxes or bags, hot cells, tents).
- Posting and control of radiological boundaries.
- Radiation detection and monitoring equipment.
- Radiological controls program.
- Training

PERSONNEL MONITORING EQUIPMENT

The requirements for the conditions requiring individual monitoring of external and internal occupational dose are described in DOE Order 5480.11.

EXTERNAL RADIATION

Personnel dosimetry programs shall be adequate to demonstrate compliance with the radiation protection standards provided in paragraph 9b of DOE Order 5480.11 Personnel dosimeters shall be routinely calibrated and maintained and shall meet the requirements of the DOE Laboratory Accreditation Program for Personnel Dosimetry as specified in DOE 5480.15. Personnel dosimeters shall be provided to radiation workers who have the potential to exceed in a year any one of the following from external sources:

- 100 mrem (0.001 Sv) annual dose equivalent to the whole body.
- 5 rem (0.05 Sv) annual dose equivalent to the skin.
- 5 rem (0.05 Sv) annual dose equivalent to any extremity.
- 1 1/2 rem (0.015) Sv) annual dose equivalent to the lens of the eye.

Note that these are 10% of the level with which a worker may be exposed under the standards defined in DOE Order 5480.11. In other words, Doe requires all workers with the potential to receive 1/10th of the permitted dose to have a personal dosimeter.

Radiation Monitoring

Radiation stationary and/or portable radiation instruments shall be available and used to measure dose rates for the purpose of controlling exposure to radiation. These instruments shall be routinely calibrated and maintained. The combination of instruments used shall provide the capability to measure radiation types (neutron, gamma, beta, or x-radiation) and dose rates characteristically encountered at that facility.

None of the ionizing radiations are detectable by any of the five senses; therefore, all indications of their presence and intensity must be obtained by instruments. Radiation detection devices, like other measuring instruments, operate because of some effect the phenomenon being measured has no matter. In the case of radiation, this effect is ionization.

It is extremely difficult to measure the absorbed dose or energy deposition in tissues from the different types of radiation. The conditions under which one must work are generally complex, ill defined, and irregular. Normally the best one can hope for is an estimate of the exposure dose to X and γ radiations. This usually requires not one instrument or method, but several.

A variety of devices collectively known as dosimetry are used to measure each individual's exposure to internal and external sources of radiation. There is no one method available that is suitable for measuring exposure to all of the different types and sources of radiation.

There are several types of dosimeters used. One of the most common types is the Thermoluminescent Dosimeter, commonly referred to as a TLD.

Thermoluminescent Dosimetry

The TLD is used as an official record of exposure and consists of a holder, filters, and thermoluminescent material. The filters allow the health physics personnel to distinguish between beta and gamma radiation.

After exposure to ionizing radiation, the material gives off light when heated. The amount of light is proportional to the amount of radiation to which the TLD (and therefore the wearer was) exposed.

Each person is assigned two TLDs, but only one is issued at a time. TLDs are exchanged and read by HP once a month, at which time the other TLD is worn.

Albert Einstein

Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd 1939

F.D. Roosevelt
President of the United States
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia. while the most important source of uranium is Belgian Congo.

In view of the situation you may think it desirable to have more permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with y private persons who are willing to make contributions for this cause, and perhaps also by obtaining the cooperation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,

A. Einstein

(Albert Einstein)