ALUMINUM COMPANY OF AMERICA

ALCOA TECHNICAL CENTER

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BASIC PRINCIPLES OF COMPANY RADIATION PROTECTION TRAINING PROGRAM

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INTRODUCTION

Radioactive material has a wide range of uses extending from basic investigation in the laboratory to production applications in plants. Gauging devices containing a radioactive sealed source have become accepted tools of industrial production. Industrial management is utilizing one aspect of radioactive gauging devices, in order to reduce production costs and assure product quality. A vital factor in the growth of the radiation gauging program is informing the personnel involved of the capabilities, advantages and safety limitations of gauging devices containing radioactive sealed sources.

Most persons have very little information and experience related to ionizing radiations and its properties and interactions with matter. Though much publicity has been given to A-bombs and H-bombs, their destructive forces and their hazards to the human body, relatively little information has been disseminated on the useful applications of radiation.

STRUCTURE OF MATTER

To understand the nature of radioisotopes and their use, one must start with the nature of matter. All matter is made up either of elements or combinations of elements called chemical compounds. An element is a substance such as iron or carbon or aluminum which cannot be broken down into other substances by chemical methods. There are 92 naturally occurring elements. In addition to these, modern science has increased the number to more than 100 by artificially producing elements. An atom is the smallest unit of an element.

An atom consists of a relatively heavy core called a nucleus, surrounded by a sufficient number of negatively charged particles called electrons, spinning in orbit much as the planets move in orbit around the sun. In the nucleus of each atom are two kinds of particles--positively charged ones called protons, and ones without charges called neutrons. There is normally one proton in the nucleus for each electron whirling around it.

The space in the atom outside the nucleus is large compared to the size of the nucleus or the electrons orbiting around the nucleus. To illustrate this, the hydrogen atom with its single electron revolving about a nucleus has a diameter about 1/200,000,000 of an inch. If the nucleus were enlarged to the size of a baseball, the single electron would be nearly half a mile away.

ISOTOPE

The atomic number of an element is the number of protons in the nucleus which serves to identify each element. The number of protons plus the number of neutrons in the nucleus of the atom determines the physical properties and the atomic weight of the atom. But two atoms of the same element, each having the same number of protons, may have a different number of neutrons. They have the same chemical properties but different physical properties. They are known as isotopes of the same element. An isotope can be defined as one of two or more species of an element, each having the same number of protons and electrons in its atom, but differing in the number of neutrons contained in its nucleus.

There are, for example, these naturally occurring aluminum isotopes:

$^{27}_{13}Al$ 13 protons in nucleus, 13 electrons outside nucleus
14 neutrons in nucleus

$^{26}_{13}Al$ 13 protons in nucleus, 13 electrons outside nucleus
13 neutrons in nucleus

The number of isotopes for each element varies, while hydrogen has 3 isotopes, tin has 25 isotopes. When an isotope becomes radioactive, it is called a radioisotope.

RADIOACTIVITY

Certain arrangements of the component parts of the nucleus of an atom appear to be preferred by nature. In these preferred isotopes, the atom is said to be stable. If the order of the particles within a stable atom is disturbed, however, the atom may become unstable. This may happen, for example, if the nucleus of a stable atom is invaded by a stray neutron. When this happens, the particles in the penetrated atom attempt to rearrange themselves and return to their preferred or stable condition. In doing this, the atom releases energy which is given off in the form of radiation and the atom is said to be radioactive. As an example: If a bullet strikes a metal target, energy is added to the target--it is excited. This energy is then radiated away in the form of waves which carry off the noise and heat of impact. There may also be a particle radiation if the bullet knocks some pieces out of the target. In the same way, a bullet of atomic dimensions (neutron) excites an atom when it strikes.

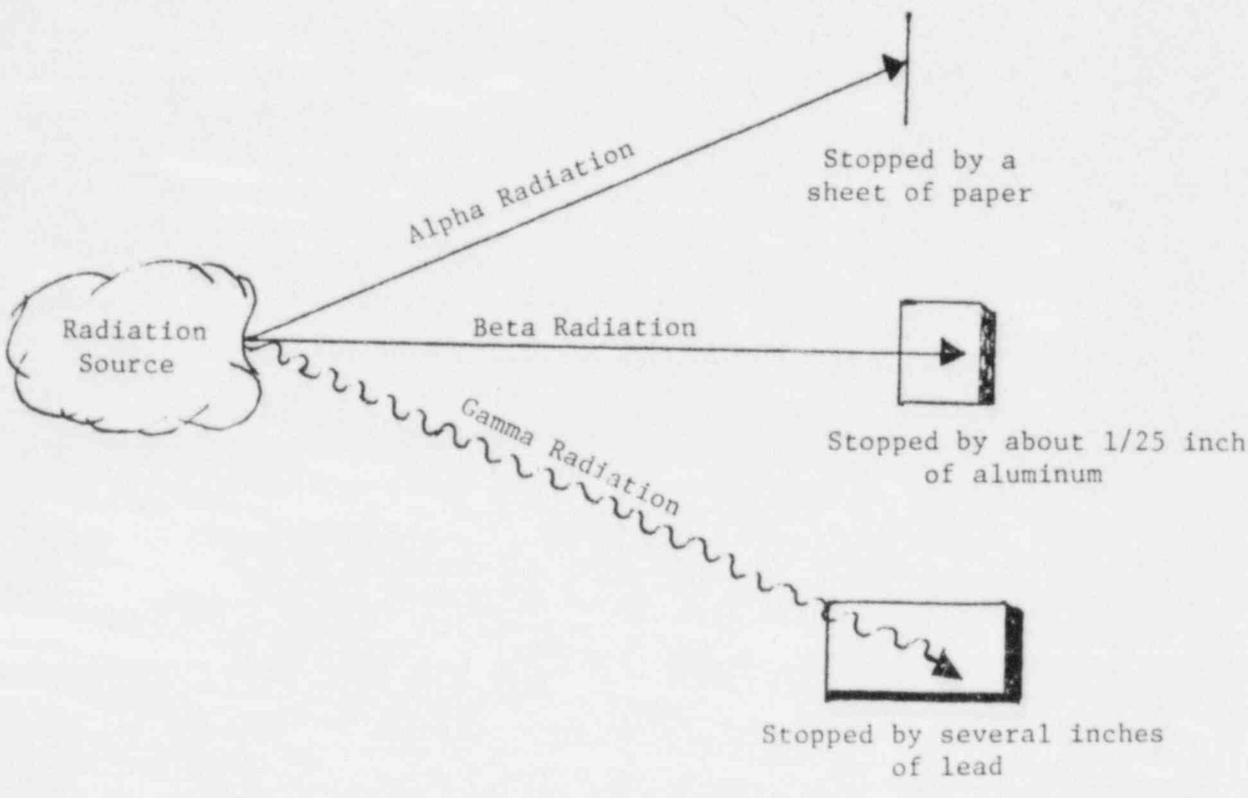
KINDS OF RADIATION

Three types of radiation are emitted by unstable atoms: alpha particles, beta particles and gamma rays.

Alpha particles are emitted from radioactive materials at speeds of 2,000 to 20,000 miles per second. Because of their size and relatively low speeds, they travel only a few centimeters in air and may be stopped by a sheet of paper.

Beta rays consist of particles identical to high speed electrons. They are emitted at very high velocities approaching the speed of light. They have a range of several feet in air and may be stopped by a thin sheet of aluminum.

Gamma radiation consists of very short electromagnetic waves of energy having no mass or weight and travel at the speed of light, 186,000 miles per second. These rays are very penetrating and may be detected after passing through several inches of steel.



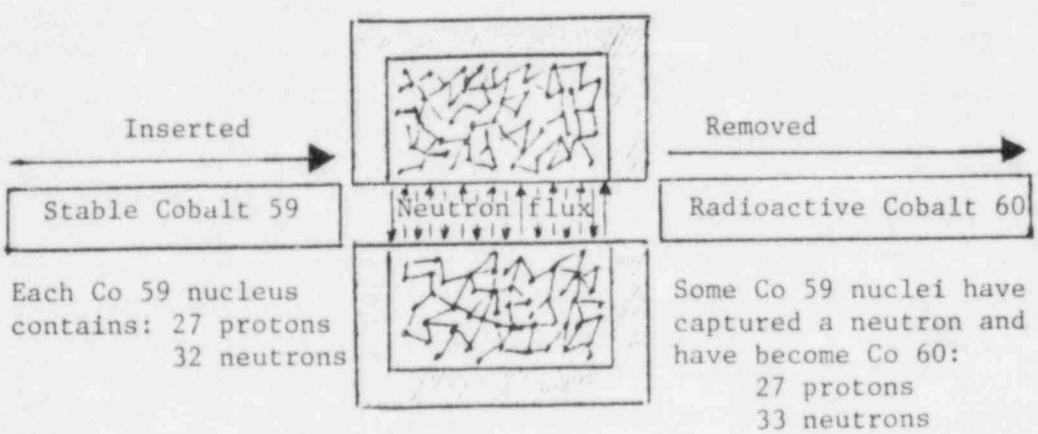
The Penetration Power or Radiation

NUCLEAR REACTORS

Radioactive isotopes of nearly all the elements can be produced by bombardment of normally stable elements with subatomic particles, such as protons, neutrons or electrons. This bombardment causes ordinarily stable atoms to absorb new particles, lose existing ones, or break up into new atomic or subatomic particles. Isotopes can be produced artifically in this manner in either or two ways--by particle accelerators or nuclear reactors.

Most isotopes are produced in nuclear reactors by inserting a small mass of some element into the reactor pile and subjecting it to a bombardment by neutrons. The neutron bombardment rate at the Tuxedo Park reactor is 2.5×10^{13} η/sec./cm.^{2}. For example, the stable cobalt isotope Co-59 may capture a neutron to become radioactive Co-60. Only a relatively few Co-59 atoms become Co-60 depending on the time in the reactor and the rate of bombardment with neutrons.

REACTOR



Note: Only a relatively few Co 59 atoms become Co 60 depending on the time in the reactor and the magnitude of the neutron flux.

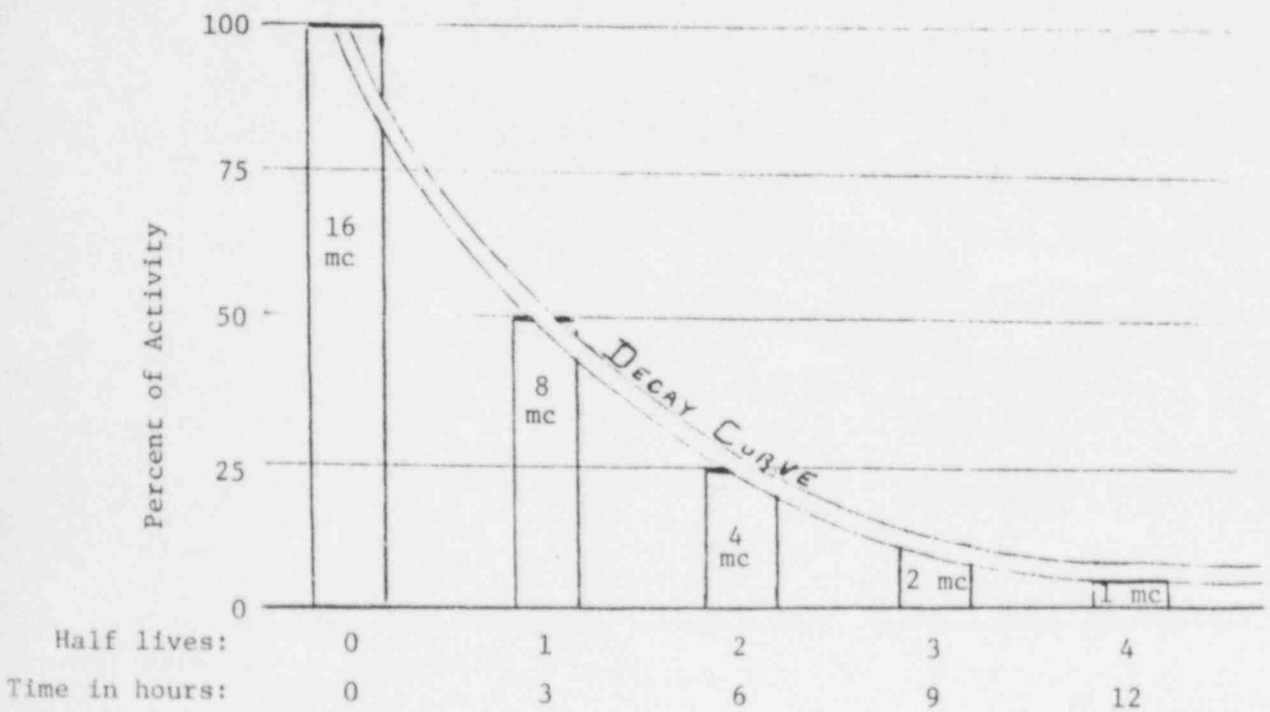
Production of Cobalt-60

A nuclear reactor is also a source of heat as well as neutrons. When a reactor is used as a power plant, it is considered primarily as a source of heat energy. This energy is then used to convert water to steam and the steam is used to drive electrical generators producing electricity.

RADIOACTIVE DECAY

While the particles in stable isotopes cling together in arrangements acceptable to nature, radioisotopes are unstable and tend to disintegrate or decay to more stable forms by emitting neutrons, charged particle or electromagnetic waves. This process of disintegration is called radioactive decay, and the rays and particles released by radioactive materials are called radiation.

The time it takes a radioisotope to achieve stability and therefore ceases being radioactive is measured in terms of "half-life," which is the required time for the radioactivity in a sample of material to be reduced to half of its original amount.



Decay of a Radioactive Isotope with a 3-Hour Half Life

The half lives of radioisotopes can vary from a fraction of a second to millions of years.

0.03 seconds for Boron-13 to 3 million years for Beryllium-10.

RADIATION PROTECTION PROGRAM

Radiation protection programs are based on a philosophy that all ionizing radiation is harmful. However, experience and research have shown that if exposure is kept below a certain level, the individual is unaffected. The problem, then, is to limit exposure to not exceed these recommended levels. To accomplish this, adequate methods and programs for detecting and measuring radiation must be employed.

In a typical radiation installation, two organizations are responsible for establishing and administering the radiation protection program, the Radiation Safety Officer (RSO) and the Medical Department. The RSO, under the direction of the Radiation Committee, assumes responsibility for activities concerned with the radiation safety of employees. These activities include monitoring, hazard evaluation and supervision of operations. The Aluminum Company of America has established a radiation committee which conducts an intracompany radiation safety program. The safety program adopted by this committee is based on rules and regulations set forth by the various States and Federal regulatory agencies.

The Radiation Committee for the Aluminum Company of America consists of Mr. T. B. Bonney, Chairman, Mr. C. N. Cochran and myself as Radiation Safety Officer and will be available for advice and assistance on all radiation safety problems.

Appointed persons, known as Radiation Supervisors at the various plants have the authority to act as liaison between the gauging operations and the Radiation Committee.

This committee feels that it would be beneficial for plant personnel who work with or in the immediate area of radioactive gauging devices, to become familiar with the various conditions involved.

The Medical Department is responsible for medical examinations and treatment of employees and has ultimate jurisdiction in all matters pertaining to radiological health.

RADIATION EXPOSURE

The question involved in the use of radioactive material is not radiation versus no radiation, but rather how much more radiation exposure people can accept consistent with the other hazards of our environment--all balanced against the industrial, medical and research benefits gained. The danger of exposure to radiation is an important health problem and can be divided into two classifications-internal and external exposure.

Radioactive material may accidentally enter into the body by ingestion or inhalation and is very difficult to detect. Once in the body, such materials may come in close contact with the gastrointestinal walls and lung tissues, or they may be carried through the blood stream to various organs. Under such circumstances, even the less penetrating alpha rays, protons or low energy beta rays may produce serious damage. The degree of damage from internal radiation depends upon a number of factors, an important one being the "life of the isotope;"

the shorter the life, the less the danger. For that reason, no isotopes with half-lives greater than two weeks are used for treatment on humans. The degree of selective localization of the isotope within the body must be taken into consideration. Thyroid collects I-131, bone marrow picks up P-32 and bones collect Sr-90. Another important factor is the rate of elimination or biological half-life. Some isotopes like Na-24 are quickly eliminated while others, such as Sr-90, may be localized in the bone and will remain for many years. However, we must, under all circumstances, prevent the entrance of radioactive materials into the body. In the use of sealed sources, ingestion and inhalation of radioactive material is highly impossible due to the construction of the sealed source. Only in the laboratory where we use unsealed radioactive material does this present a problem.

Body tissues vary widely in their sensitivity to radiation when subjected to an external exposure. Gonads, lymphocytes, bone marrow and the gastrointestinal tract are more sensitive than muscles and nerve tissues. The lens of the eyes are the most sensitive. External radiation from an alpha or low energy beta ray is relatively harmless, the higher energy beta and gamma rays are the most harmful. The shorter the time of application of a given dose of radiation, the more severe the biological effect. A dose of 400 rems of X or gamma rays applied within a few minutes over the whole body, or within a fraction of a second in case of an atomic attack, would kill one-half of the population. On the other hand, 400 rems applied over a period of 25 years would amount to about 300 millirems per week and no damage would be expected.

It may be observed that all people are continuously exposed to natural radiation. Cosmic radiation from outer space is ever present. At the same time, the earth's crust contains many radioactive elements which find their way into building materials, food, clothing and many other items for human use. Radiation exposure received by different individuals as a result of natural background are subject to appreciable variations. It is a known fact that due to altitude, the background level is twice as high in Denver as New York.

Many people receive additional radiation for medical reasons. The annual radiation dose averaged over the United States population from diagnostic X-rays is 0.072 rem per year. The dose from one chest X-ray is approximately 1000 mr. Any difference in effects that may result have not been sufficiently great to attempt to control background radiation. It can be seen that humans can and do tolerate considerable radiation during their lifetime.

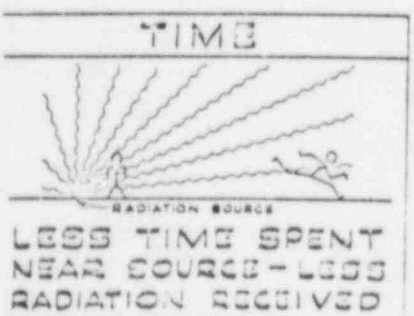
It is believed that the current population exposure resulting from natural or background radiation is a most important point in the establishment of radiation protection guides for the general population. This exposure has been present throughout the history of mankind, and the human race has demonstrated an ability to survive in spite of any ill effects that may result.

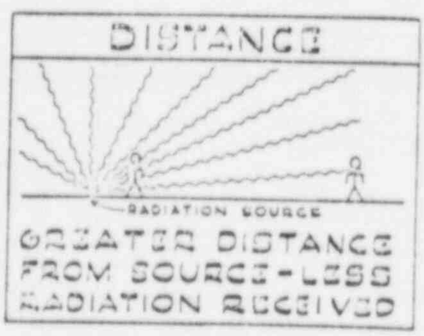
Experience gained from people exposed to background radiation cannot be used easily to predict what should happen to people exposed to industrial radiation but it is possible to estimate the maximum biological damage which could be reasonably expected to result from a given radiation exposure. Using these estimates, a value has been selected at which the radiation risk appears extremely small.

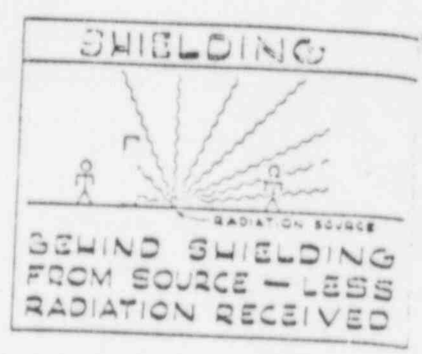
The Nuclear Regulatory Commission and the U.S. Bureau of Standards has stated that a tolerance dose for a human is 100 millirems per week, each week of a lifetime or 2-1/2 mrems per hour. A millirem is a measure of a dose of any ionizing radiation to body tissue in terms of its estimated biological effect. This tolerance figure is not meant to imply that anything will happen to a person if he received more than 100 mrems in one week. The tolerance figure is an assurance that nothing will happen if a person receives less than 100 mrems per week. Since tolerance dose is defined as 100 mrems per week, a person who receives an excess over the hourly rate of 2-1/2 mrems still need not necessarily exceed his weekly tolerance dose. The Federal Radiation Council agrees with the opinion of the NCRP (National Committee on Radiation Protection) that this dose of ionizing radiation is not expected to cause appreciable body damage to a person at any time during his lifetime.

Properly informed persons using gauging devices containing a radioactive sealed source have no more reason to be afraid of radiation hazards than of the hazards involved in working with electrical systems or toxic chemicals. When adequate radiation safety precautions are understood and utilized in everyday practice, no over-exposure of personnel will occur.

Three principles must be applied for controlling body exposure to radioactive sources. They are (1) time, (2) distance, and (3) shielding.

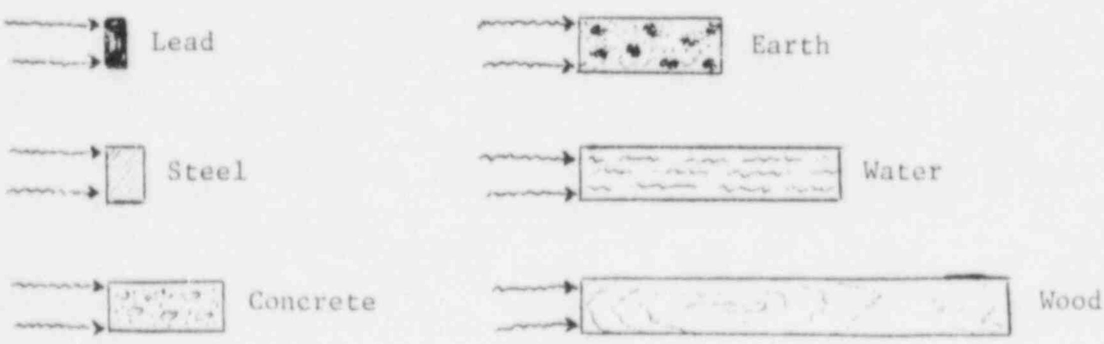






Reducing an individual's working time is the simplest way to limit his exposure. In fields of constant radiation intensity, the dose received by a worker is proportional to the length of time he remains in the area.

The radiation intensity varies as the inverse square of the distance from the source. For example, if a worker doubles his distance from the source, his exposure is reduced to one-fourth; tripling the distance affects a reduction to one-ninth the original exposure. Consider a radioactive source which would be a serious radiation hazard if picked up in bare or gloved hands. By using tongs of suitable length, this source may be handled quite safely for a long period of time. Employees may work closer to radiation sources for longer periods when shielding is interposed between them and the source. Personnel can work next to the face of a radioactive source which, if unshielded, would emit lethal radiation for hundreds of feet. The purpose of shielding is to reduce radiation by means of absorption. Water, concrete, steel and lead are the more common materials used for shielding. Viewing a light bulb through various degrees of dark glasses will illustrate shielding for radiation protection.



Note: These blocks show the relative thickness of several materials required to absorb the same amount of gamma radiation having energy approximately 1 Mev.

<u>Relative Efficiency of Shielding Materials</u>

INDUSTRIAL GAUGING DEVICES

Based on the fact that radiation has the ability to penetrate matter, industry has found a variety of ways of using radioactive isotopes in gauging devices. All of them, however, depend on measuring the change in intensity of a beam of radiation. All that is required is a source of alpha, beta or gamma radiation and a suitable detection device to measure the absorption or reflection of the radiation beam. The radioactive thickness gauge is probably the best example of a routine quality control application using radioisotopes, although other gauging devices act on the same principle - density gauge, etc.

This continuous noncontact gauging method is especially useful when products are moving rapidly, where temperatures are high and where products are soft and may be easily marred. The advantage of radioactive thickness gauges over other devices designed for the same purpose is that no mechanical contact is necessary and hence, they can be used without stopping or cutting the rolling sheet. Such gauges can also guarantee measurements of greater sensitivity and higher precision and are adaptable to automatic control of roller settings. The radioactive material in no way enters into the system or process under investigation, and nothing becomes radioactive by passing through the beam of radiation.

Most models of a radiation gauge consist of four principal parts: a source of radiation, an ionization chamber to detect and convert the radiation to electrical current, an amplifier to boost the current, and a meter or recorder to indicate the fluctuation in change of radiation intensity.

The radioactive source is placed on one side of the sheet material whose thickness is to be measured and a radiation detection device, such as a geiger counter or ionization chamber on the other side. The amount of radiation transmitted through the material is inversely proportional to its thickness.

CONSTRUCTION OF SEALED SOURCE

The manufacturers of gauging devices containing radioactive sealed sources are rigidly controlled by the Nuclear Regulatory Commission. Manufacturers of such devices must submit complete drawings, radiation profiles and prototype testing results to the NRC for approval before manufacturing and distributing gauging devices containing radioactive sealed sources.

The radioactive isotope is double encapsulated in a hermetically sealed housing that prevents the radioactive material from leaking out. The radioactive material is usually bonded into small pellets, then sealed in a leak tested capsule. This unit is then mechanically locked as well as soldered into an outer shell, thus the construction of a sealed source is such that it eliminates the probability of leakage of the radioactive material, both in shipment and use under such abnormal conditions as can be foreseen.

As a special precaution, the NRC requires that all sealed radioactive materials other than gas shall be wipe tested for contamination and/or leakage at intervals not to exceed times specified in license.

Internal exposure resulting from the deposition of radioactive material within the body through inhalation, ingestion, or absorption is eliminated by the safety features built into the construction of the sealed source and the periodic testing of the sealed source.

It is improbable that the amount of radioactive material leaking before discovery in a semi-annual check would be enough to constitute a health hazard. Furthermore, any leaking radioactive material would be retained in the gauge housing by the sealed window covering the opening.

In the construction of gauging devices containing radioactive sealed sources, adequate shielding is provided by the gauge housing to minimize or eliminate any external radiation exposure to personnel working in the immediate area. A failsafe, solenoid operated source shutter, prevents any significant amount of radiation from reaching the outside of the gauge housing with the gauge turned off.

Usually gauging devices are designed so that tolerance dosage is received at or less than a distance of 3 feet from the radioactive source when the source shutter is open. If it is necessary for a person to remain for any length of time at a close distance from the gauge, the shutter should be closed. When the shutter is closed, it is impossible to receive more than a tolerance dose at any point.

To insure complete safety, the following regulations should be followed:

1. Do not remain close to the gauge for extended periods of time unless the shutter is closed.
2. Do not, under any condition, open or tamper with the gauging device.
3. Authorized personnel should be contacted for instructions if it is necessary to remain close to the gauge while it is in the operating condition (shutter open).
4. The shutter should be in the "Off" position when the rolling mill is off (down), or when gauge is not in use.
5. When changing standardization sheets, the gauge should be at the opposite end of the roll or if gauge is located over the standardization block, it should be in the "Off" shutter position.

SURVEY

As stated in the Regulations, personnel monitoring equipment is not required. For some gauging installations, personnel could receive a maximum of 20-30 mrem per week, certainly well below the minimum limits. In past experiences with the numerous nuclear gauges located in the Alcoa plants, the film badges exposure of personnel working near the gauging devices covering a two-month period has repeatedly been reported as "None of these badges show any signs of radiation." Although personnel monitoring is not required, a film badge survey should be made to establish standards for personnel working in the immediate area of radiation producing equipment.

Although the biological effects of radiation can be serious, radiation can be handled in a safe manner and made to perform useful services for mankind.

The potential hazards of automobiles, disease germs and electricity are recognized and proper safety measures are taken in dealing with them. This is precisely the attitude which should be assumed toward radiation hazards. When handled and used correctly, radioisotopes are no more hazardous to work with than a number of other industrial tools that through repeated use have been accepted as commonplace--for example--acids and alkalies, steam and electricity.

MEMORANDUM FOR: William O. Miller, Chief
License Fee Management Branch
Office of Administration

John E. Glenn, Chief
Nuclear Materials Section B
Division of Engineering and
Technical Programs

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7/86

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LICENSE FEE TRANSMITTAL

A. REGION I

1. APPLICATION ATTACHED

Applicant/Licensee: Aluminum Company of America

Application Dated: 5/13/86

Control No.: 105523

License No.: 37-19729-01

2. FEE ATTACHED

Amount: $120.00

Check No.: 13221

3. COMMENTS

Signed Brenda Platchak

Date 5/21/86

B. LICENSE FEE MANAGEMENT BRANCH

1. Fee Category and Amount: 3P $120

2. Correct Fee Paid. Application may be processed for:

Amendment ______

Renewal ✓

License ______

Signed A. Kimberley

Date 5/29/86

ON I FORM 213
(CH 1983)