# Nuclear Gauge Radiation Safety

## TRAINING MANUAL

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# Introduction

Quality control/assurance is necessary to ensure that construction is completed in an efficient, effective manner. Therefore, density and moisture content of soils, and the density, and asphalt content of asphaltic concrete must be measured and recorded. Conventional techniques such as sand cones, cores, and extractions can be used to measure these properties. However, a nuclear density gauge can provide this information more quickly and efficiently. Because the nuclear density gauge contains radioactive material, which can be dangerous if not properly used, transported, or stored, the operator must receive special training.

Completion of this class will satisfy the minimum regulatory requirements that:

1) You are an informed occupation worker. You will not be an expert, but you will have sufficient information to use the gauge in a manner safe for yourself, your fellow workers, and the general public.

2) Allow you to possess and use on your employer's license, portable moisture density gauges containing radioactive material, without immediate supervision.

3) Qualify you to be the Radiation Safety Officer (RSO) of a company.

**Class Schedule**

| | |
|---|---|
| 7:00 AM | Introduction |
| 7:30 AM | Atomic Physics |
| 8:00 AM | Radioactivity |
| 8:30 AM | Break |
| 8:40 AM | Health Safety |
| 9:30 AM | Regulations |
| 10:30 AM | Transportation |
| 11:30 AM | Statistics |
| 12:00 PM | Lunch |
| 1:00 PM | Compaction/Gauge Operation |
| 2:00 PM | Testing Errors |
| 2:30 PM | Break |
| 3:00 PM | Test |
| 4:00 PM | Conclusion |

At the successful completion of the class you will be issued a Certificate of Training. A copy should be retained for review by regulatory agencies.

## SUB-ATOMIC PARTICLES

Matter is made up of three primary particles:

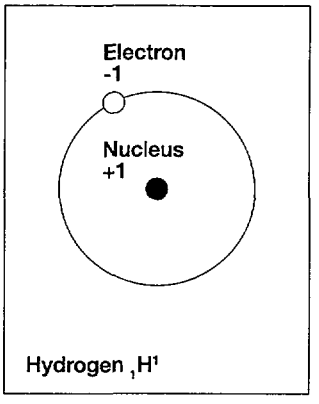
| PARTICLE | SYMBOL | RELATIVE MASS | RELATIVE CHARGE |
|---|---|---|---|
| Proton | p | 1.0073 | +1 |
| Electron | e | 0.0006 | -1 |
| Neutron | n | 1.0087 | 0 |

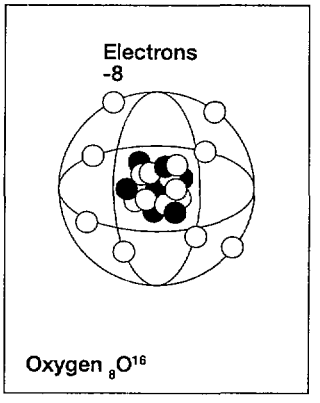
## ELEMENTS/ATOMS

Elements are combinations of the three sub-atomic particles which have unique properties. Typical elements are Silicon, Oxygen, Gold, Copper, and Iron. Currently 103 primary elements have been identified, 90 natural, the rest man-made. A few other elements have been created in the laboratory, but they decay very quickly.

Atom is the Greek word for indivisible, describing the smallest portion that has all the properties of the element. The name was selected before the sub-atomic particles were discovered. We now know that each atom is comprised of a nucleus containing the heavier proton(s) and neutron(s), and the lighter electron(s) orbit around this nucleus.

The simplest element/atom is hydrogen. It has one proton, no neutron and one electron. A more complex element is oxygen that has 8 protons and 8 neutrons in the nucleus, and 8 electrons in orbit.




The atom is not solid. Rather, the atom is largely open space. To illustrate this, consider that if the nucleus of hydrogen was the size of a marble placed on the 50 yard line of a football stadium, the electron would be the size of a pinhead in the stands.

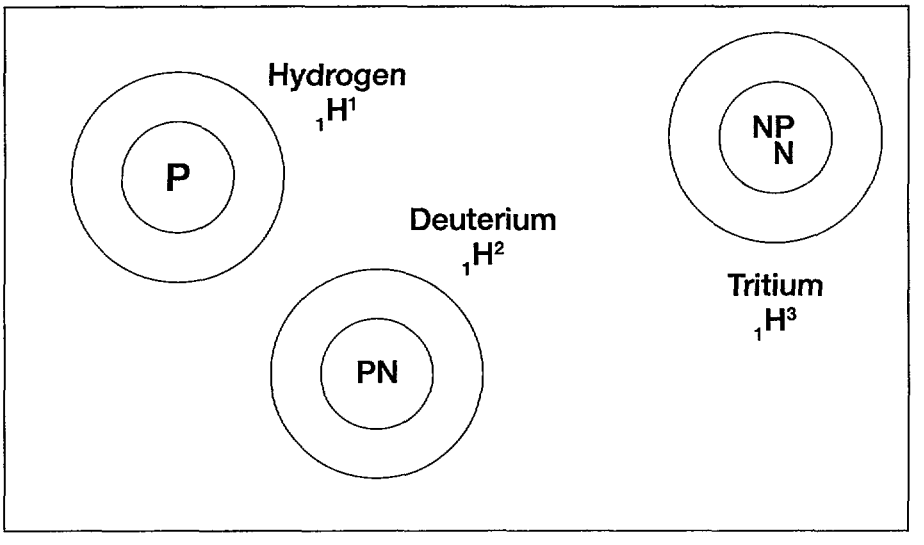
Each element/atom has been assigned a one or two letter symbol that is an abbreviation of its name (generally Latin).

| *Symbol* | *Latin* | *English* |
|---|---|---|
| Au | Aurum | Gold |
| Cu | Cuprum | Copper |
| Fe | Ferrum | Iron |

The **atomic number** (Z) is equal to the number of protons in the nucleus (also the number of electrons in orbit in a neutrally charged atom). The **mass number** (A) equals the sum of the protons and neutrons in the nucleus.

**ISOTOPES**

Elements that have the same number of protons (same atomic number), but different numbers of neutrons (different atomic mass numbers) are called isotopes. Hydrogen has three isotopes. The most abundant (99.985%) hydrogen isotope has one proton and no neutrons. The isotope of hydrogen with two neutrons is called Tritium and is unstable. Tritium is produced in the atmosphere by neutron bombardment of nitrogen.




An atom's ***atomic weight*** is similar to the atomic mass number. However, the atomic weight will not be a round number because it accounts for the distribution of isotopes as they occur naturally. For example, the atomic weight of Hydrogen is 1.008 which accounts for the trace amounts of Deuterium, and Tritium.

EXAMPLE: Silicon has 14 protons and 14 neutrons. It has the Symbol Si, an atomic number of 14, and atomic mass of 28, and its atomic weight is 28.09 AMU.

28←Atomic Mass Number (A)
(p + n)

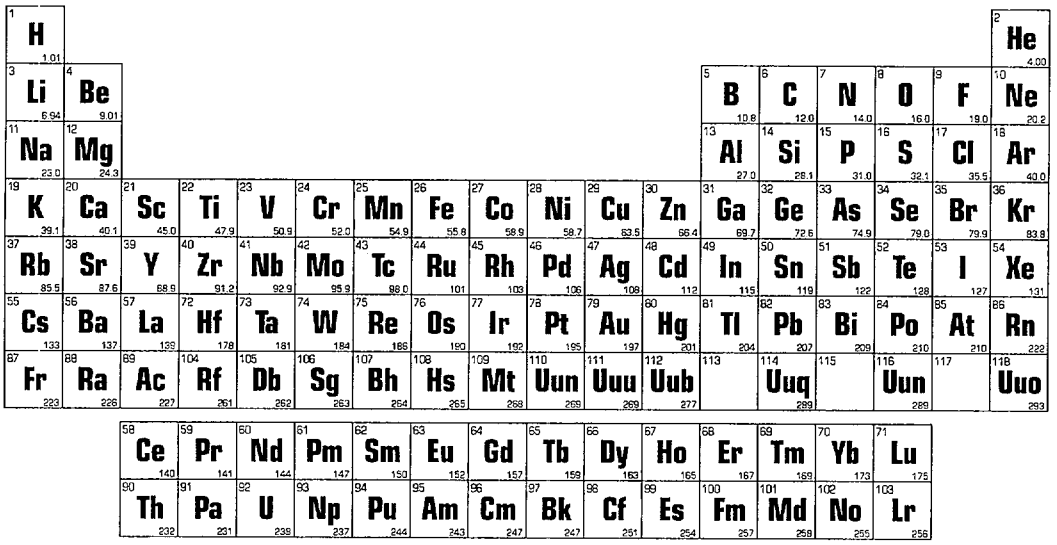
Si

Atomic Number (Z)→14
(p)

## PERIODIC TABLE

The periodic table is an arrangement of the elements in order of increasing atomic number and major changes in chemical properties. The physical properties of an element are mainly a result of the number of electrons in the outer shell (e.g. gases, metals, etc.).

## PERIODIC TABLE OF THE ELEMENTS




## EARTH'S CRUST

While performing construction quality control/assurance, our task is to measure the density of soils. Thus, the elements in the periodic table that we are concerned with are those found in the earth's crust.

| ELEMENT | SYMBOL | ATOMIC NUMBER (Z) | MASS (A) | Z/A | % EARTH'S CRUST |
|---|---|---|---|---|---|
| Oxygen | O | 8 | 16.00 | 0.500 | 49.9 |
| Silicon | Si | 14 | 28.09 | 0.4984 | 26.0 |
| Aluminum | Al | 13 | 26.98 | 0.4818 | 7.3 |
| Iron | Fe | 26 | 55.85 | 0.4655 | 4.1 |
| Calcium | Ca | 20 | 40.08 | 0.4990 | 3.2 |
| Sodium | Na | 11 | 22.99 | 0.4785 | 2.3 |
| Potassium | K | 19 | 39.10 | 0.4895 | 2.3 |
| Magnesium | Mg | 12 | 24.31 | 0.4936 | 2.1 |
| Other | | | | | 2.8 |
| Hydrogen | H | 1 | 1.008 | .9921 | |
| Water | H20 | 10 | 18.016 | .5551 | |

The density of a material is dependent upon its atomic mass (A). But the count rate in the nuclear density gauge is dependent on the number of electrons (atomic number (Z)). For most materials in the earth's crust this presents no problem since the ratio of the atomic number to the atomic mass (Z/A) is approximately 0.5.

## COMPOUNDS AND MIXTURES

Elements in the free state make up only a small fraction of matter. Most matter is found in the form of compounds or mixtures of compounds.

A ***compound*** is two or more elements brought together and united chemically (also called a molecule). The properties of the compound may be different from its elements. For example drinking water, a liquid, is the chemical combination of two gases, hydrogen and oxygen. Table salt is compounded from sodium, a metal, and chlorine, a gas. Individually sodium and chlorine are deadly to man, but when chemically united, salt can be harmlessly ingested.

| | |
|---|---|
| $H_2O$ | Drinking Water (H two O) |
| $C_6H_{14}$ | Gasoline |
| $C_2H_5OH$ | Alcohol |
| $C_{12}H_{22}O_{11}$ | Sugar |

Oxygen, the most abundant element in the earth's crust, can be found in the form of compounds such as:

| | |
|---|---|
| $SiO_2$ | Silica (silicon dioxide) Quartz sand |
| $CaCO_3$ | Limestone (calcium carbonate) Marble |
| $CaO$ | Quicklime (calcium oxide) |
| $H_4A_{12}SiO_9$ | Clay, shale |

A **mixture** is a combination of elements and compounds that are held together by physical means rather than chemical means. Glass is an example of a mixture.

| **Glass** | |
|---|---|
| $SiO_2$ | 70.6% |
| $Na_2O$ | 17.0 |
| $CaO$ | 10.6 |
| $A_{12}O_3$ | 0.8 |
| $MgO$ | 0.1 |
| $Fe_2O_3$ | 0.1 |

Not all isotopes are stable. Isotopes with atomic numbers greater than 92 are unstable because the nuclear binding energy is too weak for the large nucleus. Americium has an atomic number of 95. It is a by-product of neutron bombardment of Plutonium to produce weapons materials. All thirteen isotopes of Americium that have been identified are radioactive.

Additionally, some isotopes with atomic numbers lower than 92 are unstable. For example, Cesium has an atomic number of 55. Of the 22 Cesium isotopes identified, Cesium-133 found in nature is unstable, while Cesium-137, a by-product of making atomic weapons materials, is not. Through controlled nuclear reactions, man has produced a large number of unstable isotopes not found in nature.

Radioactivity is defined as the decay of an unstable isotope to a stable state. Energy is produced during this process. Like other forms of energy, radiation can be useful or harmful depending upon its use.

## ALPHA, BETA, NEUTRON, AND GAMMA RADIATION

There are four types of radiation relevant to the use of a moisture density gauge:

| NAME | SYMBOL | MASS | CHARGE |
|---|---|---|---|
| Alpha | $_2He^4$ | 4 | +2 |
| Beta | e- | 0.0006 | -1 |
| Gamma | energy | 0 | 0 |
| Neutron | $_0n^1$ | 1 | 0 |

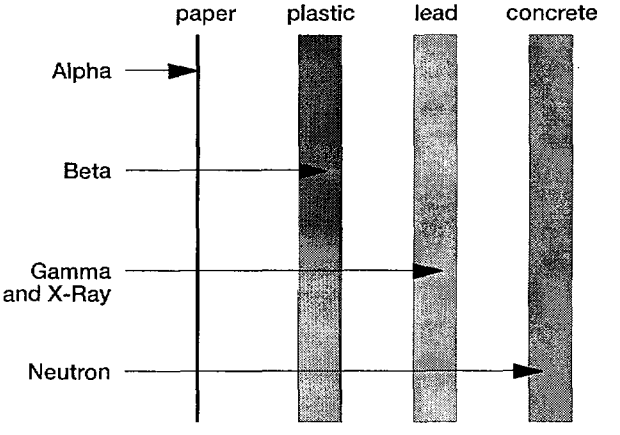
**Alpha** particles travel only about an inch in air and are stopped by a sheet of paper or the skin tissue.

**Beta** particles travel a few feet in air and are stopped by an inch of wood or a thin sheet of aluminum or plastic.

**Gamma** rays travel hundreds of feet in air and are attenuated by thick lead or concrete.

**Neutron** particles travel hundreds of feet in air and are attenuated by water, plastic, or concrete.

Penetrating Distances



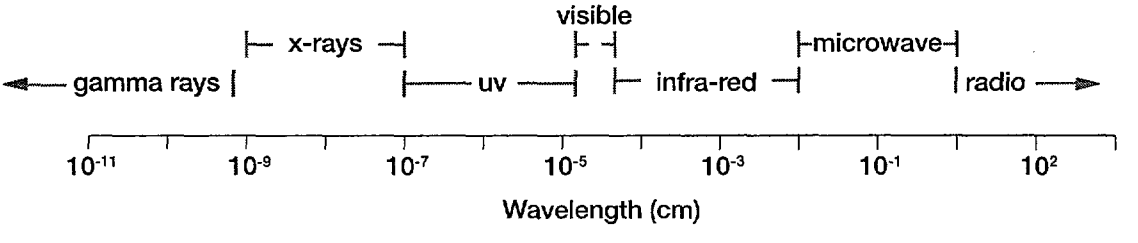
Alpha, Beta and Neutron radiation emits particles that have mass. Neutrons and gamma rays do not have charge.

The **alpha particle** is a large particle composed of two protons and two neutrons and has a charge of +2. It is essentially a Helium atom with two electrons removed. Because of its size and charge the alpha particle has very little penetrating power. The dead layers of your skin will prevent the alpha particle from penetrating the body. This means the alpha particle is not considered to be an external radiation exposure hazard. However, if it enters the body, its large mass can cause considerable damage.

The **beta particle** is the smallest particle. It has the same mass and charge as an electron, but differs in that it comes from the nucleus of an unstable atom. Beta radiation penetrates deeper than alpha radiation because of the small size of a beta particle. Protective clothing will typically stop a beta particle. It can penetrate as deep as the live layers of your skin. Like alpha radiation, the beta particle can cause damage if it gets inside your body.

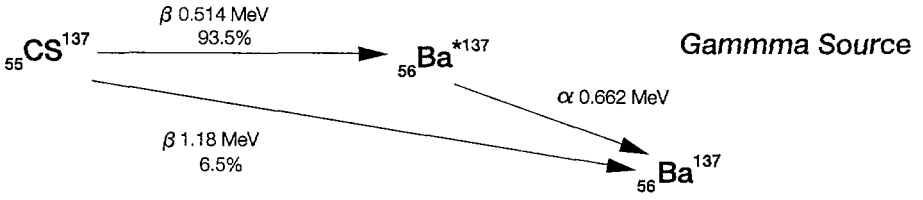
**Neutron particles** that are free from the nucleus can be emitted as radiation. The faster the neutron particle is traveling, the greater the kinetic energy. Higher kinetic energy leads to a potential for greater damage to the body. In addition to the high speeds, the neutron particle has mass, but no charge. As a result, they are able to penetrate deeply. It is possible for a neutron to pass through your body and collide with some atoms, without being completely stopped. Each collision may deposit some of its kinetic energy in your skin and internal organs which may result in damage. Each collision results in a loss of some of its kinetic energy. Eventually, the neutron particle will reach the same energy level as the matter surrounding it. It will then be absorbed by the matter, resulting in a new isotope. When this occurs, a gamma ray is typically released. In space, a free neutron is unstable. When absorbed into a Hydrogen atom, a 2.2 Mev gamma ray is released. It then decays to a proton and an electron with a one-half life of 12 minutes.

**Gamma radiation** is electromagnetic energy that is released from nuclear reactions. It has no mass or charge but is a wave packet of energy (photon) that travels at the speed of light. The electromagnetic spectrum includes radio waves at the low energy end, light in the middle, and X-rays and gamma rays at the high end. X-rays and gamma rays are the same, but differ only in that gamma rays come from changes in the nucleus, while X-rays are released by change in orbital paths of electrons. Neither X-rays nor gamma rays have charge. As a result these rays are very penetrating.

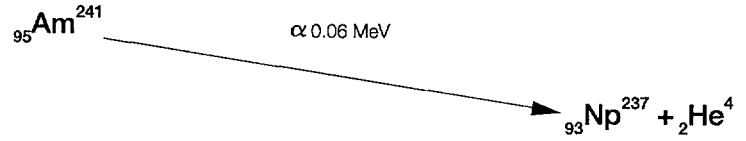


Cesium-137 and Americium-241/Be are both used in portable moisture density gauges. These radioactive materials produce all four types of ionizing radiation. However, the alpha and beta radiation will be stopped by the stainless steel capsule in the source rod. Therefore, when we use a moisture density gauge, we are only concerned with neutron and gamma type radiation.

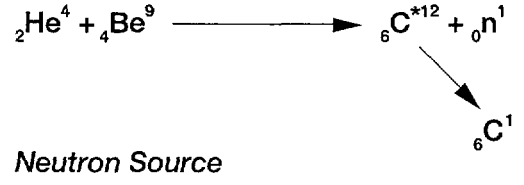
In the process of decaying to Ba-137, the Cs-137 releases beta particles which will be stopped by the capsule wall. Most of the Ba-137 is in an active state. In going to a stable state it releases gamma energy at 0.662 Mev. This gamma energy will be used to determine the density of the measured material.




The Am-241 decays to Np-237 (Neptunium). In the process it releases 0.060 Mev gamma energy and alpha particles. This additional source of low-level gamma energy would confuse our density measurement so it is shielded out by a 1/8" thick cup of carbide or lead.




The alpha particles will not leave the capsule, but by mixing the AM-241 with Be-9 (Beryllium), the alpha particles will combine to produce C-12 (carbon) in an active state. In going to a stable state a free neutron is released. The free neutrons will have an average energy of 4.5 Mev.




**IONIZING VS. NON-IONIZING RADIATION**

Alpha, beta, gamma and neutron radiation are ionizing radiation. They have sufficient energy to change the charge balance of an atom. The radiation may lose part of its energy in ionizing an atom. In the human body, these ionized atoms can affect biological functions.

Sunlight, microwaves, radio waves, lasers, infra-red, and visible light are **non-ionizing radiation**. They don't have enough energy to knock electrons off atoms. They can be damaging by other means, e.g. sunburn. A microwave oven works by causing the water molecules in the food to vibrate at high speed, generating heat. Most microwave ovens operate at 2,450 MHz. This corresponds to a wavelength of 120mm (5 inches), which is long compared to body components.

Also the energy in a microwave is only 1.0 x 10-5 eV. Compare this to a gamma ray from Cs-137 with a wavelength of 3 x 10-7mm, and an energy of 0.662 MeV.

Note: eV (electron volt) is a measure of energy useful at atomic levels. It is the energy to move an electron over a potential of one volt.

$$1 \text{ Mev} = 1.602 \times 10^{-13} \text{ Joule}$$

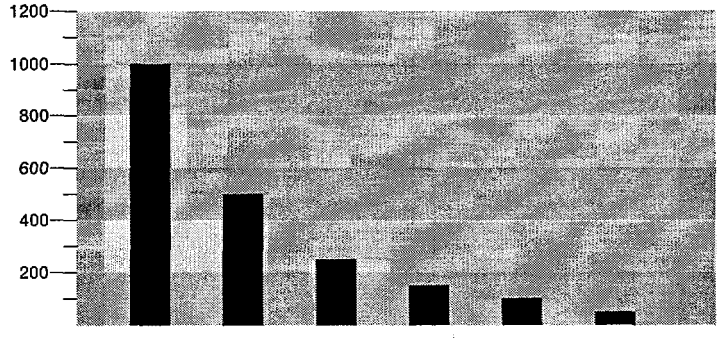
## CURIE

Normally the amount of a material is measured as a quantity or a weight, e.g. a dozen oranges or 10 pounds of potatoes. For a radioactive source it is more important to know its activity. The activity equals the number of disintegrations that are taking place each second. The Curie is the unit of activity, and was established using the decay of one gram of Radium.

One Curie equals $3.7 \times 10^{-10}$ *disintegrations per second*

To measure density, the gauge uses 10 millicuries or less (milli is 1/1,000) of Cesium-137. Ten millicuries of Cesium-137 will produce 370 million disintegrations per second.

**Half-Life** The time required for an amount of radioactive material to decrease by one half.




The two types of radioactive material used in the gauges are Cesium-137, used for density measurements, and Americium-241/Be which is used for moisture measurements. Cs-137 has a half-life of 30 years, while Am-241/Be has a half-life of 458 years.

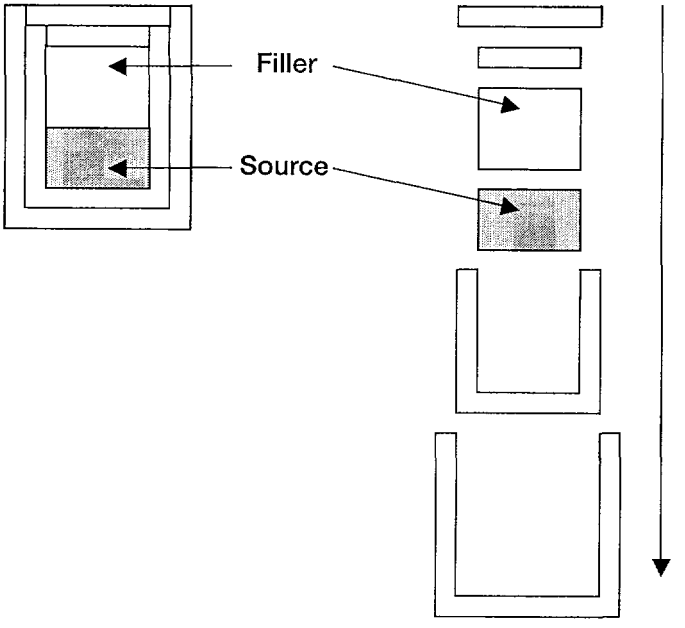
| % Decay | CS-137 30 years | Am-241/Be 458 years |
|---|---|---|
| 0.01 | 1.58 days | 24.0 days |
| 0.1 | 15.8 days | 240.0 days |
| 1.0 | 158 days | 6.64 years |
| 10.0 | 4.56 years | 69.6 years |

To maintain 0.1% data, the density channel must be corrected approximately every two weeks and the moisture channel corrected every eight months. This is normally accounted for by calibrating the gauge using the ratio of the calibration counts to a standard count taken on a known reference standard.

Correspondingly field measurements use the ratio count to current standard count taken on the same reference standard.

## CONTAMINATION

The radioactive material used in the gauge is contained in a dual sealed source capsule. The radioactive material is contained in a welded stainless steel capsule, which is contained inside of a second welded stainless steel capsule. There is little possibility that the radioactive material will escape. When radioactive material is located in an area where it is not wanted, it is referred to as contamination. In older sealed sources the radioactive material was a fine powder. If the source capsule was ruptured, contamination could spread by tracking, smearing, or becoming airborne. Current source construction techniques have eliminated this possibility by depositing the Cesium-137 into a ceramic material and firing it. If a source constructed in this manner is breached, the radioactive material may break or chip, but it would not be in a dust form. The use of a ceramic binder would compromise the intimacy of the Americium/Beryllium mixture so the Am-241/Be is pressed into a pellet. If ruptured it could break into pieces, but would not be released as fine powder.




**Dual Sealed Source**

## UNITS

When only x-ray and gamma radiation were known to man, the units used to express this exposure were known as Roentgens (R). Pronounced *ran-kins*.

***Roentgen*** The ***exposure*** of X-ray or gamma radiation such that the *associated corpuscular emission for 0.001293 grams* of air produces, in air, ions carrying one electrostatic unit of electricity.

***RAD*** The Roentgen has limited use since it does not consider the dose effects of the radiation. Initially, it was replaced by ***Radiation Absorbed Dose***.

***REM*** The RAD only applied to air so it was soon replaced by the REM (***R***oentgen dose ***e***quivalent ***m***an). The REM includes the biological effectiveness of the dose. It is related to the *Roentgen by its relative Biological Effectiveness (RBE), or* Quality Factor (QF) that is defined as one for x-ray and gamma. The RBE/QF is 20 for alpha particles. Therefore, the alpha particle can do considerable damage if the particle gets inside of the body.

| Radiation | RBE/QF |
|---|---|
| X-Ray, gamma | 1 |
| Beta | 1 |
| Neutron, slow | 5 |
| Neutron, fast | 10 |
| Alpha | 20 |

By dealing with REMs, the RBE/QF is built-in. Most low-cost survey meters containing Geiger-Mueller detector tubes, only measure gamma rays and x-rays. Some have a special thin window to allow measuring beta particles. To make this clear their scales are in R/hr indicating Roentgen/hr. With a QF of one, they may be translated directly to REM/hr provided the user understands he is not measuring alpha particles or neutrons. Neutron meters are more complex, requiring a 9-inch diameter plastic ball to simulate the slowing down effect of the hydrogen in the human body. Inside the *sphere is a neutron detector containing a gas such as boron trifloride or* helium-3 which detects the slow neutrons.

## NATURAL RADIATION

The best way for us to appreciate the REM is to know how it relates to our everyday life. Man is exposed each year to approximately 100 to 300 mREM per year. This comes from several natural sources.

| Source | Description | Annual Dose |
|---|---|---|
| Cosmic | From the sun and outer space sources and their reaction with the earth s atmosphere. The effects of Cosmic radiation increases 1 mREM for every 100ft of elevation above sea level. | |
| | San Francisco (sea level) | 44 mREM |
| | Denver (5,280 ft) | 97 mREM |
| Earth | From the natural radioactive materials in the ground | 15 mREM |
| Housing | From the materials we use to build our homes and work places. | |
| | —Stone house | 50 mREM |
| | —Brick or concrete house | 45 mREM |
| | —Wood house | 35 mREM |
| Living | Eating/Drinking/Breathing | 25 mREM |
| | Body | 15-20 mREM |
| | Television (2 hours per day) | 0.3 mREM |
| | Jet plane trip (3,000 mile flight) | 2 mREM |
| Man | Weapons testing fallout | 4 mREM |
| | Medical X-rays (per test) | 9-210 mREM |

Typical yearly totals equal approximately 123 mREM for a person living alone in a wood house in San Francisco, who does not fly, get sick, or watch television. A person living in a stone house in Denver, who flies coast to coast ten times each year, watches four hours of television daily, and receives a dental x-ray (20mRem) would receive 272 mREM annually.

There is no evidence to suggest that people living in regions of higher natural radiation have poorer health. Some of the longest living people in the world live in the high mountain regions of Brazil and India where they receive an average of ten times more radiation than those in other parts of the world.

## DOSE RATE

When unshielded, the two typical types of radiation in the gauge have dose rates as follows:

| Source | Activity | Dose Rate @ 1 meter (exposed sources) |
|---|---|---|
| Ca-137 | 10 mCi | 3.3 mREM/hr |
| Am-241/Be | 40 mCi | 0.088 mREM/hr |
| | | 3.388 mREM/hr (combined) |

Most of the contribution comes from the Cs-137 source. When the source rod is in the SAFE position, the Cs-137 source is shielded by heavy lead and tungsten carbide, attenuating its dose rate.

When the source is shielded, the combined whole body dose rate is reduced to approximately 0.2 mREM/hr at a distance of one meter. Most of the exposure will occur at the user's ankles while the gauge is being carried. The soil shields the gamma rays when the source rod is in the ground.

The exact dose received will vary from different gauges. Consult the gauge manufacturer for specific exposure quantities.

## REGULATORY LIMITS

### *1) Statuary Limits*

As a guideline, world heath safety organizations have set the limits for an occupational worker at 5 REM per year (5000 mREM). Allowing 50 working weeks per year, this breaks down to 100 mREM per week. Note that this allowed weekly occupational dose is in addition to the 100 to 300 mREM per year that the public gets from natural sources.

The lenses of the eyes are allowed 15,000 mREM per year The muscle and tissue of the extremities (hands and feet) can tolerate a larger dose than blood-forming organs and are thus allowed an occupational dose of 50,000 mREM per year.

The public, when near an occupational source, is allowed a dose of 100 mREM per year. Occupational workers less that 18 years of age are allowed 500 mREM per year. A woman must notify her employer in writing that she is pregnant. The women and her employer have several options, but the dose to the embryo/fetus must be limited to 500 mREM.

### *2) Special Projects*

The regulations allow that under special conditions the quarterly limit be 3000 mREM provided the accumulated 5 REM annual limit from the individual's 18th birthday is not exceeded. The dose rate from the gauges is so low this provision will not be of concern.

### ALARA

***A**s **L**ow **A**s is **R**easonably **A**chievable considering social and economical matters.

No matter what the allowable legal limits are, the operator and his company should review their procedures to determine if the exposure could be reduced.

Three ways the operator can reduce the dose:

| | |
|---|---|
| Time | Minimize the time of exposure |
| Distance | Do not get closer than necessary |
| Shielding | Place a shield between the source and the operator. |

ALARA is another way of saying: Use common sense.

## TIME / DOSE

When the operator is using a radioactive source, they are in a radiation field from that source. The strength or dose rate of that field is measured in mREM per hour. For a given dose rate and time in the field the operator will receive a dose.

| TIME |
| --- |
| LESS TIME = LESS DOSE |

Dose= Dose Rate x Time

Example: The whole body dose rates while carrying the gauge is 0.2 mREM/hr. The operator carries the gauge 30 times per day, 5 days per week, 50 weeks per year, approximately 60 seconds each time. How does this dose compare with the allowed annual dose?

Dose = 0.2 mREM/hr x 1 min/time x 30 time/day x 5 day/week x 50 week/per year x 1/60 hr/min

Dose = 25 mREM for one year

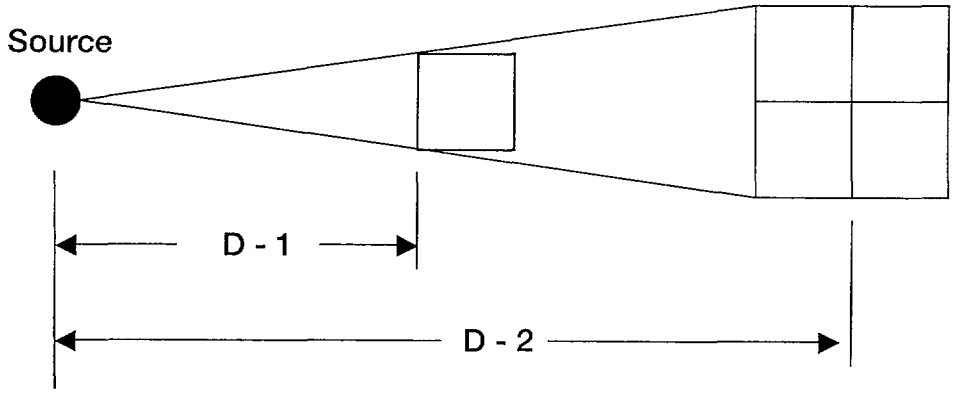
This is 0.5% if the allowed annual dose of 5,000 mREM.

## DISTANCE/SQUARE LAW

Radiation starts from a point source and as the distance increases, the radiation spreads out on a spherical surface. Its intensity at any distance from the source depends upon the square of the distance from the source.

$$I1 \times (D1)2 = I2 \times (D2)2$$

Doubling the distance will reduce the dose rate to one/fourth




Cutting the distance in half will increase the dose rate by four times.

Given the intensity or dose rate at any distance, the dose rate at another distance may be calculated. Example: The dose rate at one meter (39 in) from a 10mCi Cs-137 source is 3.3 mREM/hr. What is it at 100mm (3.9 in), and at 10 meters (33 ft)?

I1 x (1/10)2 = 3.3 x (1)2 I1 x (10)2 = 3.3 x (1)2

I1 = 330 mRem/hr at 100mm I1 = 0.033 mRem/hr at 10m

Cleaning the source rod cavity with a long handle brush will result in a 330 mRem/hr dose rate to the hand.

**SHIELDING (one-half layer)**

Gamma and neutron radiation cannot be completely stopped by shielding, but can only be attenuated. Higher atomic number elements have better shielding characteristics.

**SHIELDING**

**MORE SHIELDING ⇨ LESS DOSE**

$I = I0 * e^{-0.693d/Do}$

Where:

| | |
|---|---|
| I0 | is the dose rate without the shield |
| d | is the thickness of the shield |
| D0 | is the one-half layer thickness |
| I | is the dose rate with the shield |

For a given type of radiation and radiation energy level, the one-half layer thickness is the thickness of a material that reduces the dose rate by one-half.

| Source | One-Half Layer |
|---|---|
| Cs-137<br>(0.662 Mev gamma rays | 0.25" lead or<br>2.21" concrete |
| Am-241/Be<br>(4.5 Mev neutrons) | 2.50" water or plastic |

Reducing the dose rate form a Cs-137 source to one-eighth requires three "half-thicknesses" which equates to three quarters of an inch of lead.

By locating the shield near the source, the total volume of lead that is required can be reduced.

Concrete or cement blocks filled with pea gravel make an excellent storage location shield. Concrete blocks and pea gravel are readily available and relatively inexpensive. Additionally, the hydrogen that they contain helps to shield neutron particles.

## BIOLOGICAL EFFECTS

Radiation harms your body by hitting cells and splitting them into worthless fragments. The human body is capable of repairing damage from physical, chemical, or radiological sources when the injury is received in small quantities. However, a large dose of radiation in a short period can lead to serious injury or death.

The clinically observed effects of radiation can be separated into somatic and genetic effects.

***Somatic*** effects are those that are observed in an individual who has received a large or acute dose of radiation. These effects may include damage to organs or local tissue. The effects may also be delayed as in the case of cancer induced cataracts.

An acute radiation dose is one that might be received from a nuclear explosion. In the case of such a large-scale exposure, a dose of 450,000 mRem is considered to be the LD 50/30. This is the Lethal Dose at which 50 percent of those exposed will die within.

***Genetic*** effects are those that are passed on from one generation to the next. The generation of children born in the Soviet Union following the Chernobyl nuclear disaster demonstrate the genetic effects of radiation.

## MISCELLANEOUS

Radiation is all around us, traveling at the speed of light. We are currently being struck by about 15,000 quanta of radiation every second from natural sources. However, the probability that each particle will cause a cancer or genetic effect is approximately one chance in 50 quadrillion, or one in 50,000,000,000,000,000. Statistically, this equates to one case in 200 people over our lifetime. However, one in five people will die of cancer. Therefore, there is little evidence to suggest that the low level dose from natural radiation is the cause.

The loss of life expectancy (LLE) from a one mRem dose is 1.2 minutes. The people of Harrisburg, PA, received an average dose from Three Mile Island of 1.2 mREM. This is the equivalent to an LLE from four street crossings, driving four miles in an automobile, or an overweight person chewing one stick of gum.

Airplane crashes are very dramatic, yet extremely rare. On a per-mile basis, airplane travel is very safe. The deaths due to an increased exposure to radiation are approximately equal to the deaths caused by airplane accidents.

The water we drink contains radioactive material. Minute amounts of Radium-226 are picked up in the water as it cascades over granite rocks in mountains. Due to the high elevation, a resident of Denver, CO, receives 54 mREM more radiation than someone living at sea level. Statistically, this translate to approximately 200 additional deaths each year in Denver, CO.

Sea creatures have one of the most radiation-free environments. This may explain why they have had a slow evolutionary path.

## RISK

Life is a game in which no player gets out alive. Along the way we accept risks to improve our enjoyment of the game. Our choice of employment is one such acceptance of risk. We may elect to give up the chance for a few additional days at the end of our lives in order to increase our financial gains, or to do work that we enjoy.

Health risks from occupational radiation exposure using a nuclear density moisture gauge are much less than the risk associated with many other events we associate with our normal day to day activities. The risk of being near heavy construction or farm equipment is much greater.

| Daily Activities | Days of Life Lost |
|---|---|
| Smoking | 2,370 |
| Overwieght 20% | 985 |
| Construction worker | 302 |
| Agro worker | 277 |
| Auto accidents | 200 |
| Drinking alcohol | 130 |
| Home accidents | 95 |
| Government employee | 55 |
| Manufacturing worker | 43 |
| Teaching | 30 |
| Natural background radiation | 8 |
| Occupational worker Rem (lifetime) | 1 |

(Life expectancy is 76 years or 27,683 days for someone born in 1980)

Regulations

## NRC VS. AGREEMENT STATE

Since radioactive material can be hazardous to the public if not used properly, its possession and use is controlled by regulatory agencies. In the United States, the federal agency is the Nuclear Regulatory Commission (NRC). They have a central office in Washington, DC, and five branch offices. The branch offices are responsible for licensing and compliance within their district. The regulations the NRC enforces are contained in the Code of Federal Regulation, 10CFR.

The Act that created the NRC also allows the states to regulate themselves provided they agree to follow the regulations set down by the NRC. These states are called Agreement States. Currently 28 states are Agreement States. Agreement State writes its own set of regulations based on 10CFR. In California it is Subsection 4 of Title 17. See Appendix agency listings.

U.S. protectorates such as Puerto Rico and Guam, and federal land within an Agreement State such as a U.S. Forest Service Park or a military installation remain under the control of the NRC.

While the Act of Congress that created the NRC restricted the NRC's control to ***by-product*** materials, the Agreement States have extended their control to naturally occurring radioactive materials such as Radium.

## LICENSE

To possess and use radioactive material, the organization, corporation, partnership, or individual user must obtain a radioactive material license. When the organization applies for a license, it must specify the type, form, amount, and use of the radioactive material.

| Radioactive Material | Form | Amount |
|---|---|---|
| Cesium-137 | Sealed source Humbolt 2200064 | Not to exceed 11 mCi per source |
| Americium-241/Be | Sealed source Humbolt 2200067 | Not to exceed 44 mCi per source |

## USE

For use in Humbolt Scientific Model 5001 Compaction Control Gauge to measure the moisture and density of materials.

The amount allows for a 10% tolerance over the normal activity. You also should state the maximum number of gauges. This allows the NRC to waive the de-commissioning bond for the small quantity of sealed sources involved. In some states, such as California, it is used to determine the fee. Your storage should be adequate for the number of gauges you request.

The requested use should be as general as possible, since the actual use will be limited to the specific applications stated in the license. Unless so stated the gauge cannot be used to do things like helping your child do a science project with radiating seeds.

## STORAGE

The radioactive material must have a permanent place of storage, that must be:

***Secure*** The storage area must be locked in such a manner that unauthorized personnel cannot gain access.

***Posted*** The storage area must be posted with one or more CAUTION RADIOACTIVE MATERIAL signs.
(a storage area for a large quantity of gauges where a user could enter and experience a whole body dose rate exceeding 5 mREM/hr, also must be posted with one or more CAUTION RADIATION AREA signs).

***Safe*** The possible dose that the public could get at the boundaries of the control area must be below regulatory limits of:

2 mRem in any hour, or
100 mRem in a year

The two doses over time allow for occupancy factors.

A boundary dose rate of 2 mRem/hr would be acceptable provided it could be demonstrated that it was a walkway where persons would only occasionally walk by.

For a boundary in an industrial situation where the occupancy is unknown it must be assumed a person may be working full time. The dose rate would have to be 0.05 mRem/hr or less (100 mRem over a normal work time of 2000 hours in a year).

For a few gauges the requirements can easily be met by having the gauge(s) stored in an area that is at least 10 feet from any permanent workstations. At this distance and beyond, the dose rate from the gauge is at background.

***Charging*** Gauges requiring charging should have a power outlet in the storage area.

## LEAK TESTING

Portable moisture density gauges use radioactive material that is doubly encapsulated in stainless steel. The probability of such a sealed source leaking is very remote. To verify that the sealed source in not leaking, the gauge must be tested periodically. NRC requirements are that a leak test be done every 6 months. Sealed sources installed in instruments have been granted a 12 month leak test period by the State of California Other regulatory agencies may honor this period provided it is requested on the license application.

A gauge should be checked upon its receipt to see that its leak test is current and should not be used unless it is current. A new test must be taken within the 6 month period. A leak test kit has a cotton swab or patch which is moistened, wiped around the source area, placed in a plastic bag and then mailed to a lab for analysis. A source is considered as leaking if more than 0.005 microcurie of removable contamination is found. A copy of the leak test certificate should be kept with the gauge and a second copy in the RSO'S files available for inspection by the regulatory agency. If the user has several gauges it is more convenient if they all were tested at the same time, e.g. the first working day of January and July.

**PERSONAL DOSIMETRY**

Dosimetry (measurement of the dose to an individual) is required if the expected dose is 10% or more of the allowed dose of 5,000 mRem in a year. Proper use of a moisture/density gauge will result in a dose less than 1% of the allowed dose, but most regulatory agencies take the position that it may be exceeded if improperly used and thus require dosimetry. Dosimetry is also used for long-term legal protection to the licensee.

Each user must wear a TLD or film badge while using the equipment.

Thermoluminescent Dosimetry (TLD) uses crystals that absorb radiation energy. Plastic and metallic filters are used to distinguish different levels of energy. When the crystals are heated in the laboratory the trapped energy is released as light. TLD badges can be replaced monthly or quarterly.

A film badge is a small piece of film mounted in a plastic carrier. The carrier includes plastic and metallic shields to distinguish different levels of energy. The film is sent to a laboratory each month for development and replaced by fresh film. Film badges record gamma dose with excellent accuracy. A neutron dose is not so accurate and only effective if the film is developed promptly.

Film badge service is available for gamma only or combination gamma and neutron. For users who have gauges with both gamma and neutron sources, some regulatory agencies will allow that since it can be assumed that a gamma exposure will be accompanied by a neutron exposure, a film badge that records gamma only is deemed adequate. Users who have neutron only gauges must subscribe to the expensive combination service.

The TLD or film badge should be clipped to the clothing of the user in the chest/waist area. After analyzing, the laboratory publishes a report showing the readings for the previous month, previous quarter, year to date and lifetime. Readings of less than 10 mRem will not be reported. If a user leaves his employment, he should take a copy of his last report so he can present it to his next employer. Typical TLD and film badge suppliers are:

ICN Dosimetry
800-251-3331

Radiation Detection Company
408-735-8700

When not in use, the film badge should be stored in a secured location at the office/lab away from any sources of heat or radiation. It should not be left in the case with the gauge, the sun on the dash of the vehicle, or on the TV or microwave oven at home. Most readings on a gauge user's film badge are explained by poor storage practices.

**TRAINING**

Persons using devices containing materials must be trained in the safe use of the gauge by completing an approved course offered by an organization licensed to provide training. In some large organizations the Radiation Safety Officer is trained and licensed to conduct the course.

**SAFETY PLAN**

Each organization must have a Radiation Safety Plan that describes procedures to be followed and what to do in case of fire, theft, or an accident.

**RADIATION SAFETY OFFICER**

The licensee must designate some person in the organization as the Radiation Safety Officer (RSO). The RSO is the contact point for the regulatory agency to see that the regulations are followed. The RSO is the person in the organization responsible to see that safe practices are followed and that the proper records are maintained. Designating an RSO does not relieve the owner / officers of the ultimate responsibility.

***When the license is issued the RSO must:***

Post a **Notice to Employer** document issued by the regulatory agency. Normally safety problems would be reported to the organization's Radiation Safety Officer or a manager. This document contains addresses and /or telephone numbers for employees to contact if they are not satisfied with the organization's response.

Post a notice of availability for viewing —the organization's license, safety plan, and a copy of the regulations.

Read the license and see that all conditions are followed.

Maintain record on —license activity, inventory, leak tests, film badge reports, and persons trained and authorized to use the gauges.

Issue to each user a document showing authorization to possess and use radioactive material on the license. This can be a letter or a wallet card. Gauges must be used only by properly trained and authorized individuals.

*When in the field the user should have the following items available for inspection:*

Copy of the Radioactive Material License
Copy of individual's authorization from the RSO
Copy of Gauge Operator's Manual
Copy of Radiation Safety Plan
Copy of the current leak test

Notify the regulatory agency of any incident or condition that might be hazardous to the user or the public. For gauge users this includes:

| | |
|---|---|
| *Immediate* | Accident involving possible dispersement of radioactive material, or theft or loss. |
| *24 Hour* | Exposure of an individual to 5 Rem or more, Accident resulting in the loss of one day or more operation, or Damage to property in excess of $1,000. |
| *30 Day* | Exposure of an individual in excess of the allowable dose of 1.25 Rem per quarter. |

**TRANSFER**

The gauge should not be transferred to another party for service, disposal, sale or use unless the other party is authorized to receive the appropriate radioactive material. The best way to establish authorization is to have a copy of the other's parties' radioactive material license. Look at paragraphs 6,7,8 and 9, for type, form, amount, and use and verify that the license has not expired. The regulations provide that if the user applies for renewal within 30 days of the renewal date, the license is considered in "Timely Renewal" until the regulatory agency issues a new license. If this is the case, along with the copy of the license, get a copy of the Timely Renewal Letter from the regulatory agency or a statement from the other party.

Do not do a friend a favor and loan him the gauge for a few days unless he is properly licensed.

**TEMPORARY STORAGE**

Use of the gauge will involve removing it from its storage location described in the license and bringing it to job sites and other locations to test materials. Normally the gauge will be returned to its permanent storage location listed on the license each evening. Sometimes it will be stored in temporary locations, for example, in a trailer on a job site. This storage location should follow the same rules for security, posting, safety, and charging as the permanent location. If the gauge will be in temporary location for longer than 30 days, the regulatory agency should be notified by letter / FAX. If it will be longer than 180 days the license should be amended. The gauge should not be left in an improper storage location at the job site or in your home.

## RECIPROCITY

Radioactive material may be used in another licensing jurisdiction on a temporary basis. The other licensing jurisdiction must be notified in writing at least 5 days in advance. It can be a letter describing the device, the amount and type of radioactive material it contains, the location the gauge will be used at, and the duration of the intrusion (For the NRC use form 241). Attach a copy of your license.

If it will be for more than 180 days in any calendar year, then it is necessary to get a license in the other jurisdiction.

## SERVICE/MAINTENANCE

Prior to each use, the integrity of the shutter should be checked.

The gauge will require cleaning of the shutter block area, depending on the type of soil and number of tests. To minimize exposure, face the base of the gauge away from you, allowing the body of the gauge to act as a shield when you remove the shutter. Use compressed air or a long handled brush to clean out the shutter area. Although the probability is very low of there being removable contamination, there is no justification to wipe the rod with the bare hand.

Organizations that have a large number of gauges will find it more convenient to remove the source rod for some service activities. To do this requires;

1. Special equipment: a shield container to store the source rod and a survey meter
2. Special training
3. Inclusion of procedures in the radiation safety plan, and permitted on the license

## DISPOSAL

Radioactive material is defined as a hazardous substance. It should not be disposed of without considering others. When the gauge is no longer needed or useful to the organization it is best to transfer the ownership out of the organization. It is possible to avoid disposal fees by transferring ownership to gauge servicing business for parts. If it has no value, a disposal broker such as a manufacturer will take it for a fee. In all cases the recipient must be properly licensed.

## GENERAL

This Radiation Safety Plan covers the procedures for the safe and proper use and possession of radioactive material as contained in portable moisture-density gauges used to measure soil and other engineering materials. When handled in accordance with this plan the radioactive materials present no hazard to the licensee's employees, customers, or the general public.

## RADIATION SAFETY OFFICER

All use and possession is under the direction and supervision of the Radiation Safety Officer (RSO). The RSO is a single point of accountability and responsibility between the Regulatory Agency and the Licensee. The RSO is responsible for all aspects of this Radiation Safety Plan including the following specific duties:

1. To ensure that all terms and conditions of the license are being complied with and that the information contained is up-to-date and accurate.

2. To ensure that the gauges are only used by operators authorized by the RSO, and that they use the gauges in accordance with all regulations. This will include wearing of a suitable personnel monitoring device.

3. To maintain records as required by the license and the regulations.

4. To ensure that all gauges are properly secured against unauthorized removal at all times.

5. To serve as a point of contact and give assistance in case of an emergency such as gauge damage in the field, theft, or fire and to notify the proper authorities.

6. To ensure that all operators have read and understand this Radiation Safety Plan.

7. To arrange appropriate training for all operators.

8. Observe ALARA principals by performing audits of field practices, scheduling safety meetings, and periodically review practices.

In the absence of the RSO, the RSO duties may be assumed by the Alternate Radiation Safety Officer (ARSO).

## OPERATOR

1. The operator will exercise suitable control over the gauge at all times. The operator will follow established operating procedures and keep unauthorized persons away from the gauge. At no time is it to be left unattended or in the possession of an unauthorized person.

2. When not being used for field measurements the gauge will be locked and returned to its storage/transportation case.

3. When testing is complete the gauge will be returned to its permanent place of storage as soon as possible.

4. When using the gauge the operator will wear the personnel monitoring device assigned. When the operator is not using the gauge, the monitoring device will be kept in a radiation-free, low hear area.

5. At all times operators will observe ALARA principles to minimize any dose received:

***A*s *L*ow *A*s *R*easonably *A*chievable**

6. While the equipment is in the operators possession, the operator will have

Copy of the License,
Copy of the letter/card authorization from RSO,
Copy of this Radiation Safety Plan,
Copy of the Gauge Operations Manual, and
Copy of the current Leak Test Certificate.

## TRANSPORTATION

1. Transportation shall be in compliance with 49CFR170-179

2. The gauge will only be transported in an approved DOT shipping container. The shipping case will be checked for integrity and to verify that all labels are present and readable.

3. During transportation the operator will have a Shipping Paper, including an emergency contact telephone number and emergency response information, on the seat adjacent to the driver.

4. During transportation the gauge shall be fully secured in the transporting vehicle and located away from personnel. When transported in a closed vehicle (car or van), the case will be locked and the vehicle will be locked when the operator is not with the vehicle. When transported in an open bed vehicle (pickup truck), the case will be locked and the case securely fastened and locked to the truck bed when the operator is not with the vehicle.

5. Sealed Source and Transit Case Certificates shall be maintained on file by the RSO.

6. Hazmat transportation training shall be refreshed every three years.

**MAINTENANCE**

1. Normal maintenance will include checking of the shutter closure prior to use and cleaning of the shutter chamber as required. The operator will have received proper instruction on how to clean the gauge and will wear the assigned monitoring device.

2. No maintenance will be performed in which the radioactive source is removed from the gauge. The gauge will be returned to the manufacturer or an approved service center for this type of service.

**PERSONNEL MONITORING**

All personnel using the gauges will be assigned a personnel monitoring device of the film badge type or TLD type. The film/TLD will be exchanged during the last week of each month. Badge loss must be supported by a memo to the RSO which includes date of incident, persons involved description of the incident, and measures taken to prevent a reoccurrence.

Any reported exposure greater than 10% of the allowable monthly dose will be investigated by RSO. The RSO will write a memo to the file with information about the possible cause and corrective action taken.

**LEAK TESTING**

A leak test will be performed at the interval specified in the license using an approved leak test kit, and in accordance with the gauge manufacturer's instructions. The gauge will not be used unless the leak test is current. The wipe samples will be collected by the RSO or an approved person who has received proper instructions in collecting the wipe sample and is wearing the assigned monitoring device. Records of leak tests will be maintained for inspection. Any leak test revealing the presence of 0.005 microcurie or greater will be reported to the regulatory agency within 5 working days. The gauge will be removed from service immediately.

**POSTING**

The following documents will be posted near the gauge storage room.

1. Notice to Employees.

2. Notice of who the Radiation Safety Officer is and where a copy of the License Safety Plan, and the Regulations for Control of Radiation may be viewed.

## STORAGE

See Appendix for a sketch showing gauge storage with a minimum of 10 ft to any permanent workstation, security against removal by unauthorized personnel, CAUTION RADIOACTIVE MATERIAL sign posting, and provisions for charging.

While in transit involving overnight storage, the case should be covered so it is not visible from outside the vehicle while the operator is not present. If appropriate, the gauge in its case should be chain locked to the steering wheel in the cab of the truck.

## RECORDS

Records will maintained of:

License records,

Personnel Monitoring,

Leak Tests,

Training User and Hazmat,

Utilization Log (serial number, operator, date out, destination, date returned), and

Physical Inventory (six months).

## TRAINING

All operators will complete an approved Operator's Training Course. Special training will be given as required for special work assignments. HAZMAT training will be refreshed every three years.

## EMERGENCY PROCEDURES

See Appendix for Emergency Response Telephone Numbers

Physical Damage

1. If any moving equipment is involved, stop its movement until the extent of contamination, if any, can be established.

2. Cordon off the area around the incident. An area radius of fifteen (15) feet will be sufficient. Keep unauthorized persons outside the area, and prevent removal of the gauge until authorized by the RSO or regulatory agencies.

3. Visually inspect the gauge to determine the extent of the damage to the source(s), source housing(s), and shielding. If there is any possibility the capsule might be ruptured, dispersement should be minimized.

4. At the earliest possible time, when the situation is under control, contact the RSO. Describe the conditions and follow the instructions of the RSO.

The RSO will contact the appropriate agencies.

## THEFT OR LOSS

1. Immediately notify the RSO. The RSO will immediately notify the appropriate regulatory agency and the police.

## FIRE

1. Call the Fire Department.

2. Take action appropriate with a fire to protect personnel.

3. Notify the RSO.

4. Stand by to advise the firefighters as to the nature, locations and potential hazards of the radioactive materials. Supply them with an information packet consisting of the facility layout and a data sheet of the gauge including a photograph. Be sure to include any other important information, e.g. explosives, chemicals, guard dogs, etc.

**Melting Points:**

| | °F | °C |
|---|---|---|
| Stainless Steel | 2550 | 1400 |
| Carbide | 2000 | 1090 |
| Aluminum | 1005 | 540 |
| Lead | 620 | 327 |
| Poly | 257 | 125 |

Temperatures in an industrial fire will normally range from 500° F at floor level to a high at the ceiling of 1400°F to 1800°F. The poly and lead would melt in more fires, the aluminum only in a severe fire. The stainless steel capsule would not reach its melting point.

## DISPOSAL / DECOMMISSIONING

1. Disposal will only be performed by transfer to a properly licensed organization

2. The regulatory agency will be notified 30 or more days in advance of any relocation of the storage area. Formal decommissioning will not be required provided leak tests are current.

Appendix to the Radiation Safety Plan

**Emergency Response Information**

Telephone Numbers:

***RSO***
Work: _____
Home: _____

***Public Health:***
Days: _____
24 Hour: _____

***Police:***
Business: _____
Emergency: _____

***Fire:***
Business: _____
Emergency: _____

CPN Co: 800-852-7550

Humboldt Scientific Inc: 800-992-4589

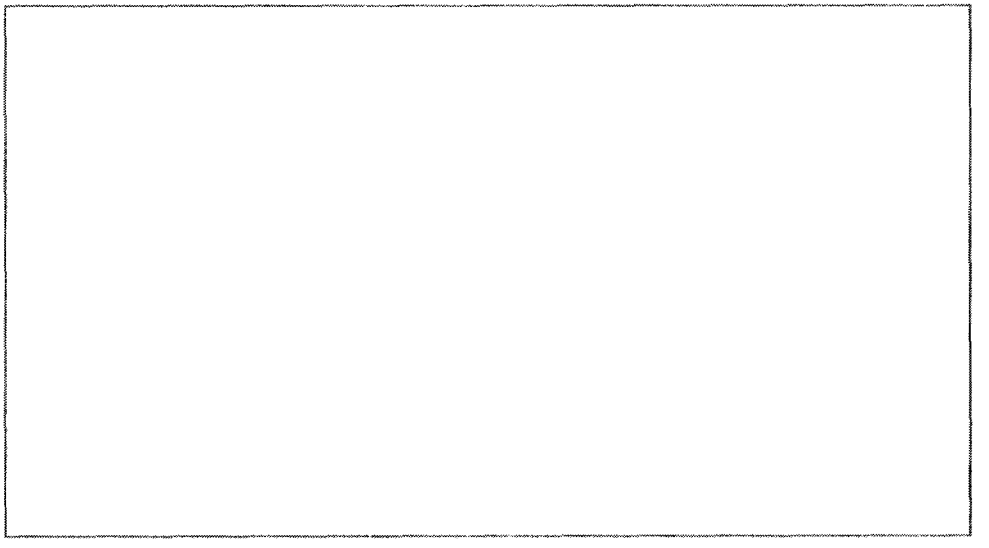
Troxler Electronics Co: 919-839-2676

Seaman Nuclear Corp: 414-762-5100

Storage Location

ABC Company
1234 Main Road
Our Town, ST 12345
(123) 456-7890

Plan View Sketch



Metal Cabinet (72"ht x 36"w x 24"d) locked and posted. Storage cabinet 10 ft from any permanent work stations. Cabinet includes circuit for charging. Maximum storage two gauges.
OR
Separate room locked and posted. Gauges 10 ft from any permanent work stations. Room includes circuit for charging. Maximum storage two gauges.

Transportation

## GENERAL AWARENESS

The transportation of hazardous materials is regulated by the U.S. Department of Transportation. This includes the carrying of the radioactive material as contained in portable moisture/density gauges in private vehicles on public highways. The regulations are published in the Code of Federal Regulations, 49CFR100-177. Copies of this publication are available from the US Government Printing Office. They are updated in October.

The regulations define any employee that is involved with the transportation of hazardous materials, as a HAZMAT employee, and requires that they receive appropriate training by the HAZMAT employer. This training must take place within 90 days of hire or transfer, and must be current within two years. The employer is responsible to maintain records of training and testing.

With high speeds and heavy equipment involved, transportation accidents will occur. The intent of this training is to reduce the occurrences of incidents caused by human error, and to provide guidelines to follow in responding to an accident.

The training will be directed to the primary method of transportation, via private carrier (company truck, personal car), with additional information for transportation via common carriers —truck and air.

## SPECIFIC FUNCTIONS

- ***Shipping Name***

Table 172.101 of 49CFR100-177 contains a list of hazardous materials. The gauge contains radioactive material encapsulated in two each dual sealed stainless steel capsules. The proper shipping name selected from this list is:

Radioactive material, Special Form, NOS, 7, UN3332

Special Form describes a sealed source with minimum possibility to disburse contamination in an accident. This must be certified by a document which is maintained on file for at least one year after the latest shipment (e.g. the last time the gauge was transported in the company vehicle on a public highway). Normally it will be supplied by the gauge manufacturer. If you have gauges from more than one manufacturer you must have a certificate from each. A copy of an IAEA Certificate of Competent Authority as described under International Air Shipments can be used to satisfy this requirement. Class 7 applies to Radioactive Material. UN3332 is an assigned number which allows quick selection in reference manuals.

- ***Reportable Quantity***

49CFR requires that shipments of quantities of hazardous materials above certain levels be reported to the EPA in the event of an accident. For the radioactive materials in the gauge per 172.101 App Table 2, the reportable levels are:

| | |
|---|---|
| Cs-137 | 10000 mCi |
| Am-241 | 10 mCi |

8 to 10 mCi of Cs-137 is not a reportable quantity, but 40 to 50 of Am-241/Be is. For a reportable quantity, RQ must be included either before or after the description. *RQ may also replace the X in the HM column of the shipping name label on the package must include the RQ.*

- ***Packaging***

The package the gauge is shipped in must meet certain requirements. For radioactive material in Special Form, a Type A package is appropriate. The package or a prototype must be tested and a copy of the tests and certification maintained on file for at least one year after the latest shipment. This document will normally be supplied by the gauge manufacturer. The tests include: water spray, free drop, corner drop, compression, and penetration test.

- ***Labeling***

A radioactive label must be selected from the following:

| Radioactive | Dose rate at package surface | Transportation Index |
|---|---|---|
| WHITE-I | = or <0.5 mREM/hr | n/a |
| YELLOW-II | <0.5 mREM/hr to = or <50.0 mREM | = or <1.0 |
| YELLOW-III | <50.0mREM/hr | = or <10.0 |

The gauge instruction manual will include a radiation profile drawing showing dose rate measurements on the surface and at one meter. The portable moisture/ density gauges as manufactured by Humboldt, Troxler, and CPN all fit the RADIOACTIVE YELLOW-II category.

RADIOACTIVE YELLOW-II labels must be placed on two opposite surfaces. The source activity and Transport Index entered should agree with the manufacturer's published data.

The **Transportation Index** is an indicator to the vehicle operator the degree of control required. It is actually the dose rate in mRem/hr at one meter from the package. Since it is intended to be used by non-technical personnel it is expressed as a dimensionless number rounded up to the nearest 1/10th. For multiple package shipments the driver limits the vehicle total TI to 50. Package(s) with a TI of 1.0 or less should not be closer to passengers than one foot.

• ***Marking***

The package must be marked with the following:

Shipping Name

| |
|---|
| RQ, Radioactive material, special form n.o.s., UN3332 |

Package Type

| |
|---|
| **7 A TYPE A** (in ½ characters) |

Country of Origin (for international shipments)

| |
|---|
| **USA** |

CPN and TEL combine them into a single label. HSU combines them with the YELLOW-II label.

• ***Shipping Paper***

The shipment must be accompanied by shipping papers which include:

Name of Shipper
Description, RQ
Contents and activity (in parentheses)
Label Category
Transport Index
Package Type
Certification/Signature:

This is not required for a private carrier if the shipment is not to be transferred to another party. It is easiest to include it, just in case.

Emergency Contact:

A telephone number which must be monitored at all times. The shipment is in transit and answerable by a person knowledgeable of the hazardous material being shipped and has comprehensive emergency response information, or has immediate access to a person with such knowledge. For normal daytime work this can be the organization's phone number with instructions to notify the RSO. When shipping the gauge for service, the service centers will normally supply a 24 hour number.

*A sample shipping paper for private carriage is shown in the Appendix.*

## EMERGENCY ACTION

*Emergency Response*

Emergency response is covered by the Emergency Response Information document in the Appendix.

*Notification*

In addition to emergency response notification to the local Public Health Agency for an accident involving radioactive material, the National Response Number must be notified within 24 hours in the event of a transportation accident involving the release of radioactive material, the death or hospitalization of personnel, or property damage in excess of $50,000.

National 800-424-8802

## DRIVER RESPONSIBILITY

*Inspection*

The gauge and package should be checked prior to each shipment. This should include the integrity of the package (case, hinge, hasps) and that all required labels and marketing are installed, readable, and not faded, and the gauge and package are locked.

*Bracing*

The package should be braced in the vehicle to prevent movement during transportation or a reasonable accident. This can be accomplished by brackets, chain, wire rope, or cord.

*Safety*

The package should not be in the passenger compartment. The preferred locations are the rear of a pickup, rear of a van, or trunk of a sedan.

*Secured*

The package should be chained or wire-roped and locked to the bed of a pickup or locked in the freight area of a van, or locked in the trunk of a sedan to prevent theft.

*Driving*

Drive in a friendly, low-profile manner, e.g. minimum lane changes. And park in the outer area of a public parking lot.

*Shipping Papers*

The driver should have within view and within reach (normally on the seat adjacent to the driver) the shipping paper, and the emergency response information sheet. To satisfy HAZMAT and other regulatory requirements it is recommended that each gauge have a documentation package as follows:

Shipping paper
Emergency Response Sheet
Owner's License
Leak Test Certificate
Certificate of Sealed Source
Certificate of Package

## MISCELLANEOUS

RADIOACTIVE YELLOW-III shipments require place carding of the vehicle on all four sides and the driver must have a commercial driver's license (CDL). WHITE-I and YELLOW-II do not require place carding or a CDL.

## COMMERCIAL SHIPMENTS

The previously defined requirements for private carriage transportation apply with the following changes/additions:

***Label:*** Cosigner/Cosignee. An address label must be on the package.

***Seal:*** The package must incorporate a seal that if broken will show improper entry.

Additional requirements depend upon the mode of commercial transportation; truck, air-domestic, and air-international.

## TRUCK FREIGHT

***Shipping Paper:***
The shipping paper will be a Bill of Lading supplied by the carrier and properly filled out by the shipper. If more than the gauge will be shipped, the hazardous material must be listed first. The pre-printed Bill of Lading includes the certification. A sample Bill of Lading is in the Appendix.

***Driver:***
The driver may keep the shipping papers in a pocket on the driver's door.

## AIR TRANSPORT, DOMESTIC

In the USA, shipment of the radioactive material in the gauge is not allowed on passenger carrying aircraft. This is not a problem since Federal Express, a cargo only airline, can transport the gauge anywhere in the USA overnight. While it is a domestic shipment, Federal Express has opted to follow the requirements of the International Air Transport Association (IATA) rather than 49CFR. This requires some changes and additional information.

***Shipping Paper:***
Federal Express has a special combination document that is both an Air Bill and a Declaration of Dangerous Goods Document. The DG document has specific places for the shipping information. It includes certification. A sample Federal Express DG Air Bill is in the Appendix.

The words "Cargo Aircraft Only" must appear on the Air Bill.

The source activity must be stated in units of Bq, instead of, or in addition to the units of mCi on the DG document.

| | |
|---|---|
| 8 mCi | 296 MBq |
| 10 mCi | 370 MBq |
| 40 mCi | 1.48 GBq |
| 50 mCi | 1.85 GBq |
| 100 mCi | 3.7 GBq |

The size of the package in mm or meters must be stated on the DG document.

***Label:***
The source activity must be stated in units of BQ, instead of or in addition to the units of mCi on the RADIOACTIVE YELLOW-II labels.

A CARGO AIRCRAFT ONLY Label must be installed within 6" of each of the two RADIOACTIVE YELLOW-II labels.


Pay careful attention to details of completing the form. Any minor error, like leaving the title off of the signer will be cause for rejection of the shipment. The carrier is not allowed to make corrections. You will be required to go to the terminal.

**AIR TRANSPORT, INTERNATIONAL**
International air shipment of radioactive material is under IATA requirements. Most countries outside the USA will allow portable moisture/density gauges to be carried on passenger planes. However any international air shipments into or out of the USA must enter or exit the USA on a cargo only aircraft.*

***Shipping Paper:***
The shipping paper will be an Air Bill supplied by the carrier and properly filled out by the shipper. The pre-printed Air Bill includes the certification. A normal practice is for the shipper to supply a Letter of Instruction, which includes the required export declaration, to a Forwarder, who in turn completes the Air Bill.

The words "Cargo Aircraft Only" must appear on the Air Bill.

****There is an exception. If the gauge is intended for use in, or incident to, research, medical diagnosis or treatment, then the gauge is allowed on a passenger carrying plane. The DG document must be completed by "X"ing out the CARGO AIRCRAFT ONLY section, and a statement must be included on the Air Bill "This shipment is intended for use in research, medical diagnosis or treatment."***

Besides the Air Bill, a Shipper's Declaration of Dangerous Goods must accompany the shipment. This form is obtainable from the Air Carrier. It has a red "candy stripe border." Two copies are required. It is best to supply additional copies if more than one carrier is involved in the routing. A sample is in the Appendix.

The source activity must be stated in units of Bq on the DG document.

The size of the package in mm or meters must be stated on the DG document.

The DG document must cite the number of a Certificate of Competent Authority that was obtained from the appropriate government agency prior to the first export shipment of the type of sources in the gauge. In the USA it is obtained from the DOT This document will generally be supplied by the gauge manufacturer, which obtained them from the source manufacturer. These documents expire. Current copies should be obtained as appropriate. Some carriers require that copies of the cited Certificate be attached to the DG document. Certificates of Competent Authority on file may be used to satisfy the Special Form certification required to be on file for at least one year after the latest shipment.

***Label:***
The source activity must be stated in units of Bq on the RADIOACTIVE YELLOW-II labels.

A CARGO AIRCRAFT ONLY Label must be installed within 6" of each of the two RADIOACTIVE YELLOW-II labels.

***Marking:***
A label showing country of origin.

| |
|---|
| **USA** |

## COUNTING STATISTICS

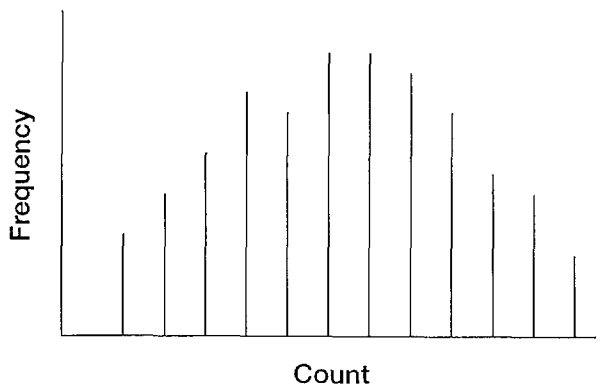
If you take more than one reading at the same location with the gauge, you will find that each count is slightly different. This is due to the random nature of the radioactive decay. We are interested in how this variation effects three applications:

1) How many seconds are required for the measurement to be statistically acceptable?

2) Is the new standard count acceptable?

3) Performance check.

A collection of data, such as the heights of students in a class, or a series of one minute counts on a nuclear gauge will have a distribution.




Two key pieces of information about the distribution are the average value, and the standard deviation, which demonstrates how tightly the data is grouped around this average.

The ***average*** value, $\overline{X}$

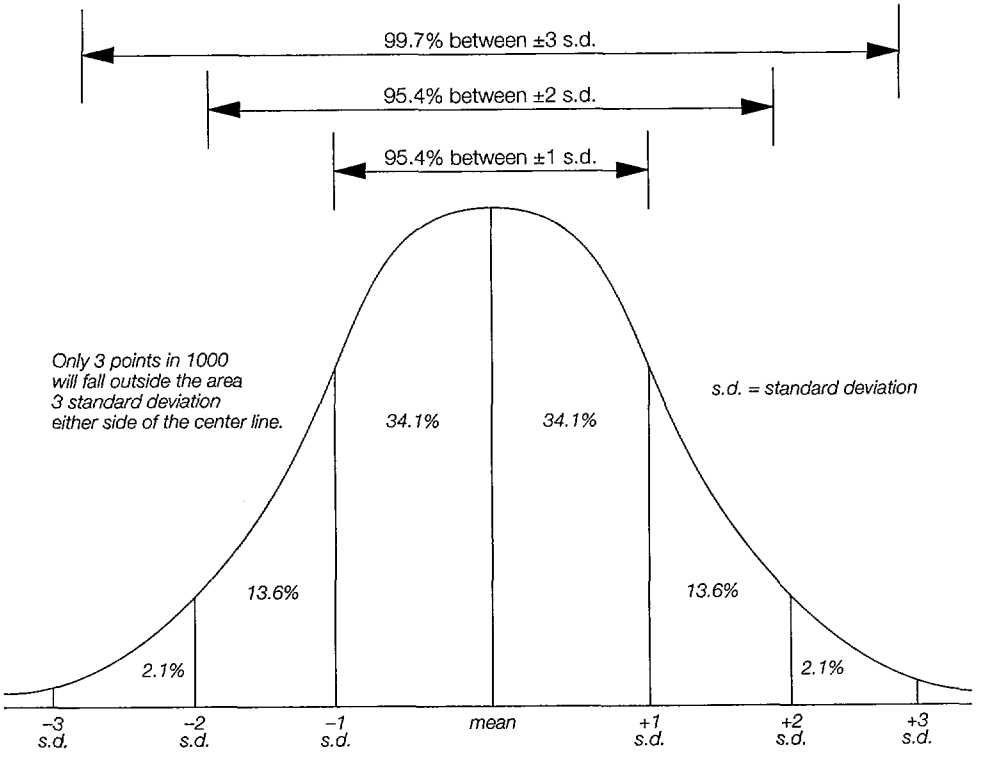
$$\overline{X} = \frac{\sum X}{n}$$

And the ***standard deviation***, s

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

There are a number of shapes that fit physical data. The most common one has four names: Normal, Gaussian, Standard, and Bell Shaped.

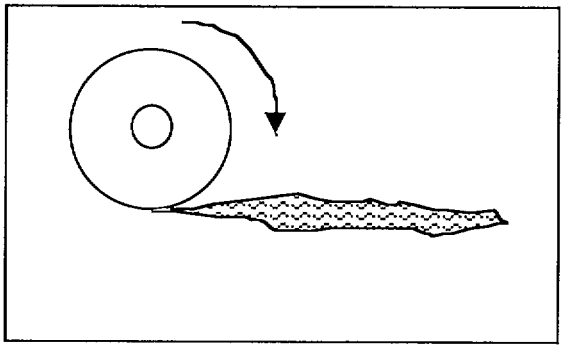
The value of the standard deviation normally depends upon the process. For example, a new lathe produces one inch diameter parts with a one standard deviation of 0.005" while an old lathe with worn bearings produces them with a 0.015" standard deviation.




The expected distribution shape and spread are important. For a series of measurements taken without moving the gauge, the gauge user can predict that 68% will be within one standard deviation of the average.

## SOILS

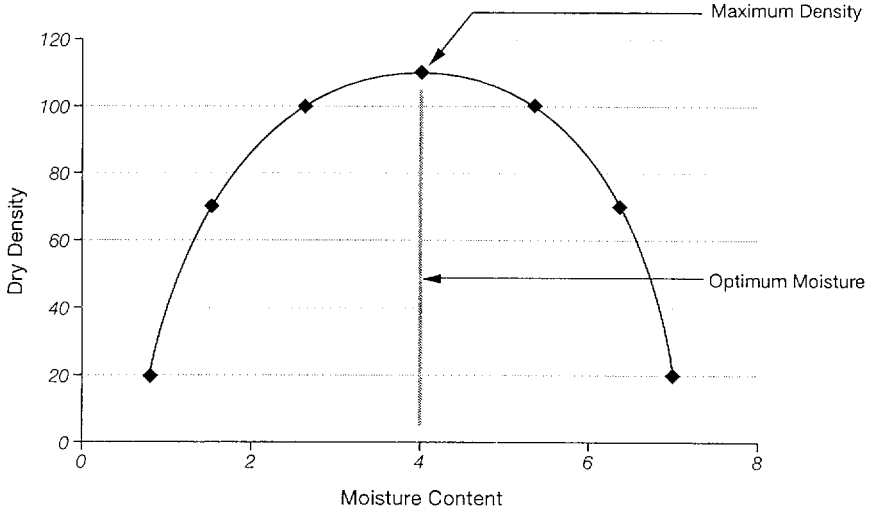
Man-made structures such as buildings, roads, and parking lots typically require level building pads. To achieve a smooth, flat subgrade, material may be removed from borrow locations and placed in fill locations. When placing fill, the loose borrow material is compacted by rolling heavy equipment over it to increase its density. As density increases, the load that the soil can support increases. It is generally necessary to compact the material in lifts of four to twelve inches thick in order to achieve sufficient compaction.



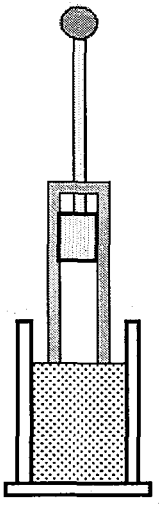
Field density measurements can be taken quickly and easily using a moisture density gauge. The in-place field density results have been shown to correlate well with other physical properties of soil including the strength, consolidation, and bearing capacities. As a result, high field densities generally indicate high bearing capacities and soil strength, and a decrease in consolidation.

**Density** is defined as the mass per unit volume. Wet density, also known as the bulk density, includes both the soil solids and moisture within a given volume. Dry density includes only the soil solids in a given volume. Most compaction requirements are based on the dry density, though some agencies specify wet density for compaction control.

The theoretical maximum density for a borrow material depends on the type of soil, the compaction effort applied, and the amount of moisture present. Moisture acts as a lubricant between the soil particles. Friction will prevent maximum compaction if there is not enough moisture in the soil. However, high moisture contents will displace the more dense soil particles, preventing maximum compaction. For every soil type and compaction effort, there is a ***maximum density*** that occurs at an ***optimum moisture content.***



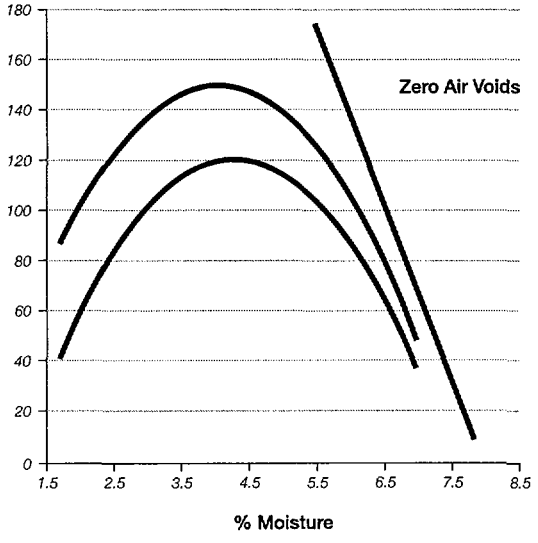
The Standard Proctor method, ASTM D698, was written by the American Society for Testing and Materials to provide laboratory testing guidelines for the determination of maximum density and optimum moisture contents of soil. When performing ASTM D698, three equal layers of soil with known moisture contents are compacted in a four inch diameter mold with a known volume. Compaction is achieved by dropping a 5.5 pound hammer from a height of 12 inches on each layer of soil 25 times. The compacted sample is then trimmed to the exact height of the mold and weighed to determine the mass of the compacted material. Density can then be calculated using the known volume and mass. The entire process is repeated at continuously higher moisture contents. Eventually, the moisture will increase to the point where it begins to displace the denser soil particles. The relationship between mass and moisture can be plotted, revealing the maximum obtainable density, and the optimum moisture content. This test must be done on a sample from each borrow source used during the construction project.



When more than 20% of the soil sample is retained on a 3/8 inch sieve and less than 30% is retained on 3/4 inch sieve, a six inch diameter mold must be used to determine the maximum obtainable density and optimum moisture content.

Additionally, the project specifications may require a Modified Proctor, ASTM D1557. The basic methods used for ASTM D1557 are the same as those used in ASTM D698, with the exception of soil layering (5 layers) and changes in the equipment. These changes include the use of a ten pound hammer that is dropped from a height of 18 inches. When a four inch mold is used, the ten pound hammer is dropped 25 times for each layer. When a six inch mold is used, a ten pound hammer is dropped 56 times for each layer.

The process is generally referred to as "pounding a Proctor" after the inventor.




ASTM D698 was written for fills and embankments using compaction equipment available in the 1930's (Standard Proctor, 12,375 ft-lbf/ft$^3$). As traffic loads increased, D1557 (Modified Proctor, 56,250ft-lb/ft$^3$) was written. ASTM D1557 helps to promote higher soil compaction that can support heavy structural loads.

AASHTO and Government agencies have written similar procedures for Proctors

| | D698 (12,375) | | D1557 (56,250) | |
|---|---|---|---|---|
| DIAM | 4" | 6" | 4" | 6" |
| WEIGHT | 5.5# | 5.5# | 10# | 10# |
| DROP | 12" | 12" | 18" | 18" |
| BLOW/LAYER | 25 | 56 | 25 | 56 |
| LAYER | 3 | 3 | 5 | 5 |

A fill area may involve materials from several borrow locations, each with their own maximum densities and optimum moisture contents. Therefore, it is the responsibility of the gauge operator to identify the borrow source material and corresponding maximum density and optimum moisture.

Compacting soil to 100% of the maximum density takes more control and effort than compacting to 90%. The increased compaction also costs more. To minimize costs, the percent compaction is typically specified as low as possible, while still achieving the necessary strength for its intended use. For critical applications such as an airfield, 100% compaction is worth the added effort. For fills that will support structures, 95% compaction is typical. For less critical applications which do not support structures, 90% may be acceptable. In a trench backfill, 90% compaction may be specified for the fill around the pipe, with 95% compaction for the top foot.

The project specifications may also include an acceptable moisture range. For example, ± 2% of optimum may be required. This requirement helps to assure that the results achieved in the field will be similar to those in the laboratory.

**ASPHALT**

Asphalt is similar to soil with the addition of liquid bitumen. When the asphalt is hot, it can be compacted easily, but once cool, the asphalt is nearly impossible to compact. The required compaction effort will depend on the aggregate mix in use. Unlike soil, the maximum wet density is used to determine the percent compaction of asphalt. Laboratory tests are used to determine the maximum wet density of the asphalt. The asphalt is placed while hot and cools during compaction. Therefore, over-compaction can fracture the asphalt mat and reduce the density.

*Note: More and more agencies are now using gyratory compactors and Superpave design procedures for design and application of asphalt mixtures.*

## QUALITY CONTROL

Having determined the target maximum density and optimum moisture content for soils, it is necessary to measure the compaction to verify that the targets are being met. Several testing methods are available. Each method has its own set of advantages and disadvantages

| SOILS | ASPHALT |
|---|---|
| Sand cone | Core |
| Balloon test | |
| Drive cylinder | |
| Nuclear guage | Nuclear Gauge |

The ***sand cone*** can be sufficiently accurate in the hands of a good operator, but is time consuming (four to six test per day typically). It involves digging a hole, weighing the removed material to determine its mass, and then filling the hole with sand of a known specific gravity to determine the volume of the hole. The removed material is placed in a sealed container to retain the field moisture conditions. It is oven dried, generally in a laboratory overnight, or tested in some other manner to determine the moisture content. All heavy moving equipment must be halted to prevent densification of the free falling sand. The volume of measurement is approximately 0.15 $ft^3$.

The ***balloon test*** is a similar volume displacement test, except that water or oil is used to fill the hole. The hole is lined with a thin membrane (balloon) to prevent seepage.

The ***drive tube*** works well in mid range soils. In clay soil it tends to compress the samples as it is driven. Clean sandy soils tend to fall from the chamber as it is being extracted.

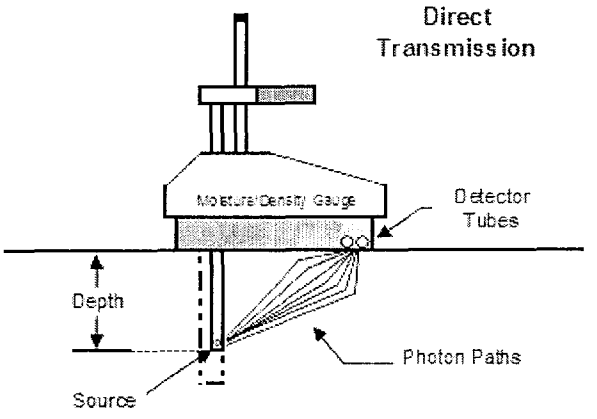
A core taken of an asphalt surface after it has cooled can be weighed to determine its mass and a water displacement test performed to determine its volume. For open graded and absorption mixes a sealing method such as CoreLok ASTM P131-01 should be used for determination of density.

## NUCLEAR GAUGE DIRECT TRANSMISSION METHOD

On an earth fill application, borrow material is generally placed and compacted in six to twelve inch lifts. The appropriate lift thickness is determined by the type of soil and the compaction equipment. For example, a heavy sheepsfoot roller can compact a thicker lift than a lightweight smooth-drum roller.

In the direct transmission method a hole is punched or drilled two inches deeper than the compacted lift. A 0.662 Mev gamma-ray source is placed at the bottom of the lift using a source rod. Gamma rays are released in all directions. The rays react with the soil in two ways, known as Compton ***scattering***, and photoelectric ***absorption***. A typical 0.662 Mev gamma ray in soil will be scattered two to three times over an average path length of 70 mm before being absorbed. Two gamma-ray detectors in the base of the gauge count the number of gamma rays that arrive at the base of the gauge on the soil surface. When the soil is highly compacted,

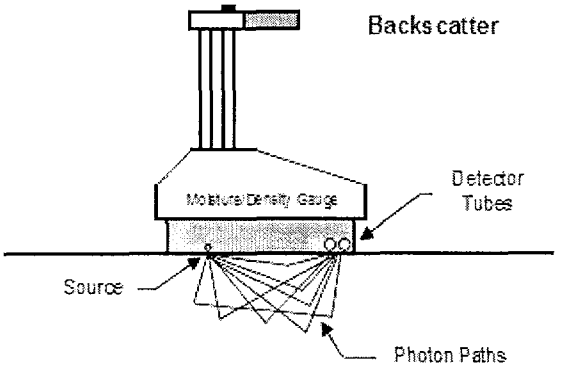
few gamma rays will pass through the soil. Loosely compacted material will allow a greater number of gamma rays to pass. The gamma-ray detectors are connected to electronic counting and timing circuits that can display the gamma ray count over a fixed time, or the density of the material. The volume of soil represented by each measurement is approximately 0.22 $ft^3$.




The transmission method is largely unaffected by surface roughness. Therefore, it is the preferred method for measuring soil density.

## NUCLEAR GAUGE BACKSCATTER DENSITY METHOD

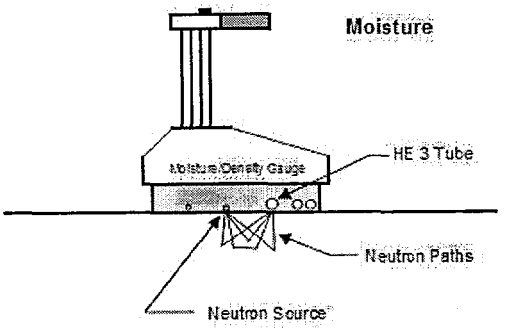
In the backscatter method the source and detector are on the surface. No hole in the material is required. The backscatter method is only capable of measuring the top 3.5" of material. This method is more sensitive to surface irregularities than the direct transmission mode. Therefore, test site preparation is important. To improve the measurement, the manufacturer has placed shielding between the source and detectors to prevent the detectors from being inundated with gamma rays that have not passed through the material being tested. The volume of material represented by each measurement is approximately one-half that of the transmission method.




Because no hole is required in the material being tested, the backscatter method is the preferred method of measuring asphalt compaction. If possible, the backscatter method should be avoided for soil density testing due to the potential for large surface roughness error.

## NUCLEAR GAUGE MOISTURE MEASUREMENT

To facilitate the measurement of moisture in the material being tested, 40 mCi of Am-241/Be are installed in the base of the gauge. The decay of Am-241/Be results in the release of high-energy neutrons, which collide with the atoms in the soil. With each collision, the neutron loses energy. The amount of energy lost will depend upon the size of the nucleus of the atom. Collision with a large Oxygen nucleus (8 protons and 8 neutrons) will change the neutron's path direction with little loss in energy (velocity). Collision with a same size Hydrogen nucleus (1 proton) will result in a loss of velocity and a change in direction. The amount of energy lost will be greater if the collision is a direct hit than a glancing blow. When the velocity of the neutron has slowed to the point where it no longer loses energy with each collision, it is defined as a thermal neutron. At this point it drifts through the soil until it is either absorbed by one of the soil atoms or decays (one-half life 12 minutes) into a proton and an electron. The following table shows various elements found in the soil and their affects on the neutron.




| ELEMENT | SYMBOL | ATOMIC NO. | ATOMIC WT. | COLLISIONS TO THERMALIZE | BARNS (absorption) |
|---|---|---|---|---|---|
| Hydrogen | H | 1 | 1.0008 | 18 | 0.332 |
| Boron | B | 5 | 10.0081 | 105 | 985 |
| Oxygen | O | 8 | 16.000 | 152 | 0.0002 |
| Aluminum | Al | 13 | 26.98 | 251 | .023 |
| Silicon | Si | 14 | 28.09 | 262 | 0.16 |
| Calcium | Ca | 20 | 40.08 | 371 | 0.44 |
| Iron | Fe | 26 | 55.85 | 514 | 2.53 |
| Cadmium | Cd | 48 | 112.41 | 1028 | 2450 |

The gauge also contains a $He^3$ detector in its base. $He^3$ is a gas through which fast neutrons will pass without any reaction, while slow or thermal neutrons will be captured, generating a pulse. The pulse count rate indicates the moisture of the soil. The higher the moisture content, the less the neutrons penetrate the soil before being thermalized.

If the dominate elements in the soil are Silicon, Calcium, and Oxygen the thermal neutron count rate will be a good indication of Hydrogen in the free water form of $H_2O$. Trace amounts of Iron, Boron, and Cadmium will shift the calibration curve.

## GAUGE VERIFICATION

It is important that the accuracy of a gauge is verified periodically. Standard counts are taken daily to account for source decay correction. However, the performance of the gauge can change with time due to many mechanical and electronic factors. A block of known density should be periodically used to verify the accuracy of the gauge. Commercially available blocks can be used for this purpose. Consult your gauge manufacturer for more information in this area.

## QUICK LIMITS

Low density — The density of water is 62.4 lb/ft$^3$. The density of uncompacted soil falling from a dump truck is approximately 70 lb/ft$^3$.

High density — The specific gravity of granite is approximately 2.65. This corresponds to a calculated density of 165.4 lb/ft$^3$.

$$2.65 \times 62.4 \text{ lb/ft}^3 = 165.4 \text{ lb/ft}^3$$

*Soil density readings below 70 lb/ft$^3$ or above 165.4 lb/ft$^3$ should be questioned.*

## STANDARDS

ASTM has written three test methods applicable to the use of nuclear portable moisture / density gauges.

ASTM D2922 - Density of Soil and Soil-Aggregate by Nuclear Methods
ASTM D3017 - Water Content of Soil and Rock in Place by Nuclear Methods
ASTM D2950 - Density of Bituminous Concrete in Place by Nuclear Methods

AASHTO and other agencies have written similar standards.

## MACHINE ERRORS

### *Calibration*

Calibration is normally performed by the manufacturer, service centers, or large users. Normally it will be valid unless the geometry of the gauge is changed. Most government agencies require that a verification test must have been performed within the previous year, or after a major repair has been performed. ASTM D2922, ASTM D2950, and ASTM D3017 require a calibration each 24 months and a verification test every 12 months. The calibration block must meet international standards for length and mass. However, the density of the block is not specified. Establishing the density of a calibration block generally involves determining its mass by a balance and its volume either by a water displacement test or using calipers.

### *Worn Rod Indexing*

Although the index latch and the index wedge are either made up of stainless steel or hardened for long wear, they will show gradual wear with time. They should be checked periodically and replaced before they affect the measurement. Wear of 0.005" will cause a density error of +0.025 lb/ft$^3$ at 6." Gauges with a single wear surface should be checked more often.

### *Circuitry*

This can be a malfunction of the detector, or electronic components, or a low battery condition. It generally is catastrophic, but may be gradual.

## OPERATOR ERRORS

### *Wrong Calibration*

For a keyboard depth select gauge or table look up gauge, the operator should always check that the correct depth or chart has been selected. Generally the operator will observe this error due to its large difference from the expected density.

### *Not in the notch*

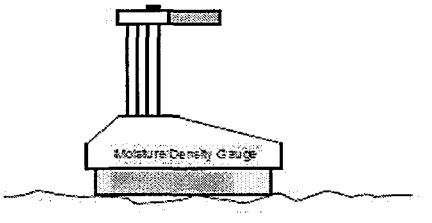
While the notch indexing is normally positioned properly, it is possible to have it slightly off position. A shift of 0.005" downward will cause a density error of +0.025 lb/ft$^3$ at 6".

### *Not against the side of the hole*

After the source rod is set to the selected depth, the entire gauge should be pulled so that the source rod is against the hole side. Failure to do so may reduce the density by 0.5lb/ft$^3$.

### *Improper seating*

Proper seating is important, especially in the backscatter position. The scraper plate should be used to prepare a smooth surface. Prior to testing, the gauge may be slid back and forth to improve seating.



*Not current or improper standard count*
The Standard count is used to correct for long-term aging of the source material and the electronic circuits. The source material will gradually decay approximately 2.3% per year.

## APPLICATION CONSIDERATIONS

*Time of Measurement*
Radioactive decay is a random process. Thus the count used to determine the density will vary from measurement to measurement with the gauge in the same location. This variation in the count becomes smaller as the length of time for a test increases.

The operator can reduce the variation by counting for four minutes (SLOW key selection). However, this may not be appropriate on a hot asphalt mat or where a large number of tests are being taken.

Variation in ±lb/ft$^3$, one standard deviation (68.8% of measurements)

| | ¼m | 1m | 4m |
|---|---|---|---|
| | FAST | NORMAL | SLOW |
| Transmission 6" | 0.5 | 0.25 | 0.125 (at 125 lb/ft$^3$) |
| Backscattter | 1.0 | 0.5 | 0.25 (at 125 lb/ft$^3$) |
| Moisture | 0.5 | 0.25 | 0.125 (at 10 lb/ft$^3$) |

*Wet surface*
Material that has been recently watered will measure a higher wet density than the true wet density, due to the water retained in the pores. The dry density will remain the same.

*Rough Surface*
The gauge measures the density of the material between the source and the detector(s). The surface of a material such as asphalt will have air voids between the protruding rocks. The apparent density of this air interface will be less than the density of the material below the surface. The effect of this error will depend upon the roughness of the surface and the gauge geometry. To account for surface roughness of the surface on asphalt it is generally necessary to take gauge readings, as well as cores at the same location in order to correlate the gauge with the in-place asphalt. The cores are typically not available until the next day when the mat has cooled.

The surface roughness error can be reduced by filling the surface voids with sand or a similar filler. Typically it will reduce the surface roughness error 1.0 to 2.0 lb/ft$^3$. Too much sand will elevate the gauge causing the gauge to read low in density.

*Too close to objects*
If the gauge is calibrated in a flat, open area, above surface structures such as trench wall will cause reflections and increased counts. This can be avoided by calibrating the gauge in the area where the test will be performed.

### *Pin compaction*

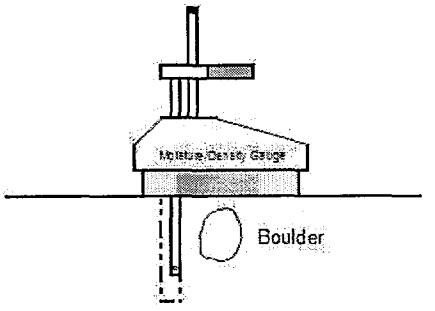
When the drill pin is driven into the soil it will compact the soil slightly. The volume of compacted material in the path of the gamma rays is so small that this error is negligible.

### *Hole Surface Damage*

If the drill pin is not removed carefully it may cause soil around the hole to break away. For most measurements at depths 6 inches and below, the path of the gamma rays is such that this error will be negligible.

### *Non-soil material in the measurement path*

A large piece of debris or a boulder in the measurement path will cause the density to be higher than the actual average density. A large air void or organic material in the path will cause the displayed density to be lower. Rotating the gauge 90 degrees or 180 degrees may eliminate this problem.




### *Bound Hydrogen*

The nuclear method is the fastest method of measuring moisture. Generally the nuclear method results are the same as the oven dried results. However, the moisture reading may be high when sources of hydrogen are present.

Periodically, soil samples should be taken from beneath the gauge, and oven dried to verify the moisture content.

### *Other Methods*

#### *Oven Dry*

The best method and the one by which all other methods are measured. Its primary disadvantage is that it is an overnight laboratory process requiring the sample to be dried at 105 degrees C for 24 hours as specified in ASTM D2216.

#### *Microwave*

This method is becoming more popular due to its quick results. However, it does not work for all soils, particularly those with an iron ore component.

## GENERAL SITE SAFETY

Construction sites can be extremely dangerous and even deadly if precautions are not taken. Hazards are almost everywhere. However, with a little care and preparation, the gauge operator can reduce the chances that an accident will occur.

To reduce the likelihood of a collision, vehicles should be parked in an area that is out of the way of heavy equipment. Some sites may have a designated area for this purpose.

When performing a test, the gauge operator should inform the contractor and all equipment operators in the area that testing is in progress. Further, a safety vest should be worn to make the operator more visible. The operator should never attempt to perform testing behind or near a piece of equipment, even if the equipment is not running. Someone may enter the equipment and begin moving without knowing you are there. When working at night, it is particularly important to inform the contractor when and where you will be testing so that injuries can be avoided.

Whenever possible, the operator should park their vehicle between the test site and the contractor's equipment. This will provide a barrier between you and the equipment. Additionally, a safety light may be added to the vehicle, making it more visible.

## TRENCH SAFETY

Never enter a trench that is deeper than four feet deep unless proper shoring or a trench box has been installed. Trench wall collapses can be deadly even when a person is only partially buried. In addition to a trench box or shoring, a ladder must also be in place before entering the trench.

## ASPHALT PAVING AND HIGHWAY CONSTRUCTION

When working near traffic, it is extremely important to keep your eyes on approaching vehicles. This is especially true when work is done behind cones or barrels instead of concrete barriers. Remember to wear your safety vest to increase your visibility.

Care must be taken when exiting the construction site because you may be merging into traffic that is traveling at a high rate of speed. In addition, visibility may be impaired by warning signs or barriers.

# Appendix

# Agreement State Agency Contacts

**ALABAMA**
CONTACT: David Walter
Phone: (334) 206-5391
Fax: (334) 288-7207
ADDRESS:
Office of Radiation Control
Department of Public Health
201 Monroe Street
Montgomery, AL 36130-171
Website: N/A

**ARIZONA**
CONTACT: John Wilson
Phone: (602) 225-4845
Fax: (602) 437-0705
ADDRESS:
Arizona Radiation Regulatory Agency
4814 South 40th Street
Phoenix, AZ 85040
www.state.az.us

**ARKANSAS**
CONTACT: Jared Thompson
Phone: (501) 616-2301
Fax: (501) 661-2468
ADDRESS:
Division of Radiation Control and
Emergency Management
Department of Health
4815 West Markham Street, Slot 30
Little Rock, AK 72205-3867
Website: N/A

**CALIFORNIA**
CONTACT: Gerard Wong
Phone: (916) 323-275
Fax: (916) 324-3610
ADDRESS:
Radiologic Health Branch
Food, Drugs, & Radiation Safety Division
P.O. Box 942732
Sacramento, CA 94234-7320
www.dhs.cahwnet.gov/RHB/index.htm

**COLORADO**
CONTACT: Jake Jacobi or Tom Pentecost
Phone: (303) 692-3036
Fax: (303) 692-3692
ADDRESS:
Laboratory and Radiation Services Division
CO Dept. of Public Health & Environment
8100 Lowry Blvd.
Denver, CO 80230-6928
www.cdphe.state.co.us/lr/li home.asp

**FLORIDA**
CONTACT: Mike Stephens
Phone: (850) 245-4545
Fax: (850) 921-6364
ADDRESS:
Bureau of Radiation Control
Department of Health
4052 Bald Cypress Way, Bin # C21
Tallahassee, FL 32399-1741
www.doh.state.fl.us/environment/radiation

**GEORGIA**
CONTACT: Neil Maryland of Thomas Hill
Phone: (404) 362-2675
Fax: (404) 362-2653
ADDRESS:
Radioactive Materials Program
Department of Natural Resouces
4244 International Pkwy, Suite 114
Atlanta, GA 30354
www.ganet.org/dnr/environ/

**ILLINOIS**
CONTACT: Gibb Vinson or Ted Henry
Phone: (217) 785-0600
Fax: (217) 785-9868
ADDRESS:
Department of Nuclear Safety
1035 Outer Park Drive
Springfield, IL 62704
www.state.il.us/idns

**IOWA**
CONTACT: George Johns
Phone: (515) 242-6280
Fax: (515) 725-0318
ADDRESS:
Bureau of Radiological Health
Iowa Department of Public Health
Lucas State Office Building
407 SW 7th Street, Suite D
Des Moines, IA 50319
www.idph.state.ia.usipa/rh.htm

**KANSAS**
CONTACT: Pam Watson
Phone: (785) 296-1565
Fax: (785) 296-0984
ADDRESS:
Department of Health and Environment
Bureau of Air and Radiation
Forbes Field, Building 283
Topeka, KS 66620
www.kdhe.state.ks.us/radiation

# Agreement State Agency Contacts

**KENTUCKY**
CONTACT: Vicki Jeffs
Phone: (502) 564-3700
Fax: (502) 564-1233
ADDRESS:
Radiation Health and Toxic Agents Branch
Cabinet for Health Services
275 East Main Street, Mail Stop HS 2E-D
Frankfort, KY 40621-0001
Website: N/A

**LOUISIANA**
CONTACT: James Sanford
Phone: (225) 765-0143
Fax: (225) 765-0220
ADDRESS:
Radiation Protection Division
Protection Office of Air Quality & Radiation
7220 Bluebonnet Road (7081 0)
P.O. Box 82135
Baton Rouge, LA 70884-2135
www.deg.state.la.us

**MAINE**
CONTACT: Shawn Seely
Phone: (207) 287-5696
Fax: (207) 287-4172
ADDRESS:
Division of Health Engineering
10 State House Station
Augusta, ME 04333
www.lanus.state.me.us/dhs/eng/rad/.htm

**MARYLAND**
CONTACT: Carl Trump
Phone: (410) 631-3301
Fax: (410) 631-3198
ADDRESS:
Maryland Department of the Environment
Air and Radiation Management Agency
2500 Broening Highway
Baltimore, MD 21224
www.mde.state.md.us/arrba/Programs/
Radiolog/radi2log.html

**MASSACHUSETTS**
CONTACT: Salifu Dakubu
Phone: (617) 727-6214
Fax: (617) 727-2098
ADDRESS:
Radiation Control Program
Department of Public Health
174 Portland Street, 5th Floor
Boston, MA 02114
www.state.ma.us/dph/rep/radia.htm

**MISSISSIPPI**
CONTACT: B.J. Smith or Robert Nelson
Phone: (601) 987-6893
Fax: (601) 987-6887
ADDRESS:
3150 Lawson Street
P.O. Box 1700
Division of Radiological Health
State Department of Health
Jackson, MS 39215-1700
www.msdh.state.ms.us/radiological/indes.htm

**NEBRASKA**
CONTACT: Jim BeFrain
Phone: (402) 471-8566
Fax: (402) 471-0169
ADDRESS:
Department of Health and Human Services
Regulation and Licensure
301 Centennial Mall South
P.O. Box 95007
Lincoln, NE 68509-5007
www.hhs.state.ne.us

**NEVADA**
CONTACT: Stanley Marshall
Phone: (775) 687-5394
Fax: (775) 687-5751
ADDRESS:
Radiological Health Section
Nevada State Health Division
1179 Fairview Drive, Suite 102
Carson City, NV 89701-5405
www.state.nv.us/health/bhps

**NEW HAMPSHIRE**
CONTACT: Dennis O'Dowd
Phone: (603) 271-4585
Fax: (603) 225-2325
ADDRESS:
Radiological Health Bureau
Health and Welfare Building
6 Hazen Drive
Concord, NH 03301-6527
Website: N/A

**NEW MEXICO**
CONTACT: Bill Floyd
Phone: (505) 827-1862
Fax: (505) 827-1544
ADDRESS:
Bureau of Hazardous and Radioactive Materials
Department of Environment
2044 Galisteo Road, P.O. Box 261 10
Santa Fe, NM 87502
www.nmenv.state.nm.us

**NEW YORK**
CONTACT: Clayton Bradt or Charles Bums
Phone: (518) 457-1202
Fax: (518) 458-7406
ADDRESS:
Radiological Health Unit
Division of Safety and Health
NYS Department of Labor
NYS Office Campus, Building 12, Room 169
Albany, NY 12240
Website: N/A

**NORTH CAROLINA**
CONTACT: Marion Eaddy
Phone: (919) 571-4141
Fax: (919) 571-4148
ADDRESS:
Division of Radiation Protection
3825 Barreft Drive
Raleigh, NC 27609-7221
www.dri.enr.state.nc.us/

**NORTH DAKOTA**
CONTACT: Justin M. Gdffin
Phone: (701) 328-5188
Fax: (701) 328-5200
ADDRESS:
North Dakota Department of Health
Division of Environmental Engineers
1200 Missouri Ave, Box 5520
Bismark, MD 58506-5520
www.health.state.nd.us/ndhd/environ/ee/RAD/materials.htm

**OHIO**
CONTACT: Mark Light
Phone: (614) 644-2727
Fax: (614) 466-0381
ADDRESS:
Bureau of Radiation Protection
Ohio Department of Health
P.O. Box 118
Columbus, OH 43266-0118
Website: N/A

**OKLAHOMA**
CONTACT: H.A. Cave
Phone: (405) 702-5100
Fax: (405) 702-5101
ADDRESS:
Department of Environmental Quality
Radiation Management Section
Oklahoma City, OK 73101-1677
Website: N/A

**OREGON**
CONTACT: Sylania Matin
Phone: (503) 731-4014
Fax: (503) 731-4081
ADDRESS:
Radiation Protection Services
Oregon State Health Division
P.O. Box 14450
Portland, OR 97214-0460
Website: N/A

**RHODE ISLAND**
CONTACT: Al Cabral
Phone: (401) 222-2438
Fax: (401) 222-2456
ADDRESS:
Division of Radiation Control
3 Capitol Hill, Room 206
Providence, RI 02908-5097
www.health.state.ri.us

**SOUTH CAROLINA**
CONTACT: James Peterson
Phone: (803) 737-7407
Fax: (803) 737-7412
ADDRESS:
Radiological Health Branch
Department of Health and Environmental Control
2600 Bull Road
Columbia, SC 29201
www.scdhec.nethealth.reg./hrrh.htm

**TENNESSEE**
CONTACT: Johnny Graves
Phone: (615) 532-0383
Fax: (615) 532-7938
ADDRESS:
Division of Radiological Health
Land C Annex, Third Floor
401 Church Street
Nashville, TN 37243-1532
www.state.tn.us/environmentstateenv/access.htm

# Agreement State Agency Contacts

**TEXAS**
CONTACT: Pete Myers
Phone: (512) 834-6688
Fax: (512) 834-6690
ADDRESS:
Bureau of Radiation Control
Texas Department of Health
1 100 West 49th Street
Austin, TX 78756-3189
www.tdh.state.tx.us/ech/rad/pages/brc.htm

**UTAH**
CONTACT: Craig Jones
Phone: (801) 536-4264
Fax: (801) 533-4097
ADDRESS:
Division of Occupational
and Radiological Health
168 North 1950 West
P.O. Box 144850
Salt Lake City, UT 84114-4850
www.deg.state.ut.us/egrad/drc hmpq.htm

**WASHINGTON**
CONTACT: Terry Frazee
Phone: (360) 236-3221
Fax: (360) 239-2255
ADDRESS:
Division of Radiation Protection
Airdustrial # Center Building 5
P.O. Box 47827
Olympia, WA 98504-7827
www.doh.wa.gov/ehp/rp

# NRC States and Regional Offices

**HEADQUARTERS**
U.S. Nuclear Regulatory Commission
Wasington, DC 50555-0001
www.nrc.gov/nrc.html

**REGION I**
475 Allendale Road
King of Prussia, PA 19406-1415
610-337-5000

Connecticut
Delaware
New Jersey
Pennsylvania
Vermont

**REGION II**
61 Forsyth Street, SW, Suite 23T85
Atlanta, GA 30303
404-562-4400

Puerto Rico
Virginia
Virgin Islands
West Virginia

**REGION III**
801 Warrendale Road
Lisle, IL 60532-4351
630-829-9500

Indiana
Michigan
Minnesota
Missouri
Wisconsin

**REGION IV**
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-8064
817-860-8100

Alaska
Hawaii
Idaho
South Dakota
Wyoming

# Conversion Factors

| UNITS | ENGLISH | SI | CONVERSION |
|---|---|---|---|
| Energy | Electron Volt | Joule | 1 ev = 1.602 x 10–19J |
| Activity | Curie | Becquerel | 1 Ci = 3.7 x 1010 Bq |
| Exposure | Roentgen | Coulombs per kg of air | 1 R = 2.58 x 10–4 C/Kg |
| Dose | Rad | Gray | 1 rad = 10–2 Gy |
| Equiv Dose | Rem | Sievert | 1 rem = 10–2 Sv |

# SPECIAL FORM CERTIFICATE EXAMPLE

Reference GB/353/S-85

Certificate Issue 5

# Certificate of Approval
# of
# Design for Special Form Radioactive Material

| Title |
|---|
| Capsule X.1218 |
| Drawing Nos and Specification References |
| Assembly: A 62269 Issue C<br>Details: A 62268 Issue C<br>Special Form Drawing List: SFDL/353 Issue 3 dated 18 October 1999<br>SM/GB/353/S-85 dated 21 February 1991: QA/MS/353/1199 Issue 1 dated 22 November 1999 |
| Q.A. Programme Ref: Nycomed -Amersham's & AEA(T)'s IPD QAM |

| Radioactive Material | Maximum Activity |
|---|---|
| Caesium 137 | 555MBq |

**THIS IS TO CERTIFY that the Secretary of State for the Environment Transport and the Regions being, for the purposes of the Regulations of the International Atomic Energy Agency, the Competent Authority of Great Britain in respect of inland surface transport and of the United Kingdom of Great Britain and Northern Ireland in respect of sea and air transport and the Department of the Environment for Northern Ireland being the Competent Authority of Northern Ireland in respect of inland surface transport, have approved the above mentioned Special Form Design. Radioactive material manufactured to the above-mentioned design qualifies as special form radioactive material and as such will meet the requirements of the regulations overleaf.**

**This Certificate of Approval applies only to the design as set out in the above named drawings and specifications submitted by AEA Technology plc**

**In the event of any alteration in the composition of the package, the package design or in any of the facts stated in the application for approval, this certificate will cease to have effect unless the Competent Authority is notified of the alteration and the Competent Authority confirms the certificate notwithstanding the alteration.**

**This Certificate Cancels all Previous Issues and is valid until 31 January 2003**
**COMPETENT AUTHORITY IDENTIFICATION MARK: GB/353/S-85**

UNITED KINGDOM COMPETENT AUTHORITY FOR THE TRANSPORT
28 JAN 2000
OF RADIOACTIVE MATERIALS

Transport Radiological Adviser
Department of the Environment
Transport and the Regions
Great Minster House
76 Marsham Street
London SW1P 4DR

*On behalf of the Secretary of State for the Environment Transport and the Regions and the Department of the Environment for Northern Ireland*

TROXLER

# TESTING RESULTS FOR TYPE A PACKAGES FOR TROXLER GAUGES/CASES

## INSTRUCTIONS FOR FINDING YOUR 7A TYPE A TESTING RESULTS:

1. Determine your shipping case type by using the drawing below.
2. Find your gauge model number in the first column of the table on the next page.
3. Find the corresponding case in the second column of this row.
4. Gauges that are no longer in production may not be listed. Please contact your Troxler representative or the Troxler corporate headquarters if you need assistance.

## TESTING PERFORMED & RESULTS (unless otherwise indicated in footnotes):

**Water Spray:** Subjected the package to a water spray simulating rainfall of approximately two inches per hour for one continuous hour.

Results: No physical damage to the package was observed, unless otherwise noted in footnotes.

**Vibration:** The package was vibrated with a displacement of 0.1" at approximately 12 Hz for a period of 24 continuous hours.

Results: No physical damage to the package was observed, unless otherwise noted in footnotes.

**Free Drop:** The package was dropped from a height of four feet onto a non-yielding surface from a position to cause maximum damage to the package.

Results: The case was scratched due to the abrasiveness of the concrete, but no other physical damage to the package was observed, unless otherwise noted in footnotes.

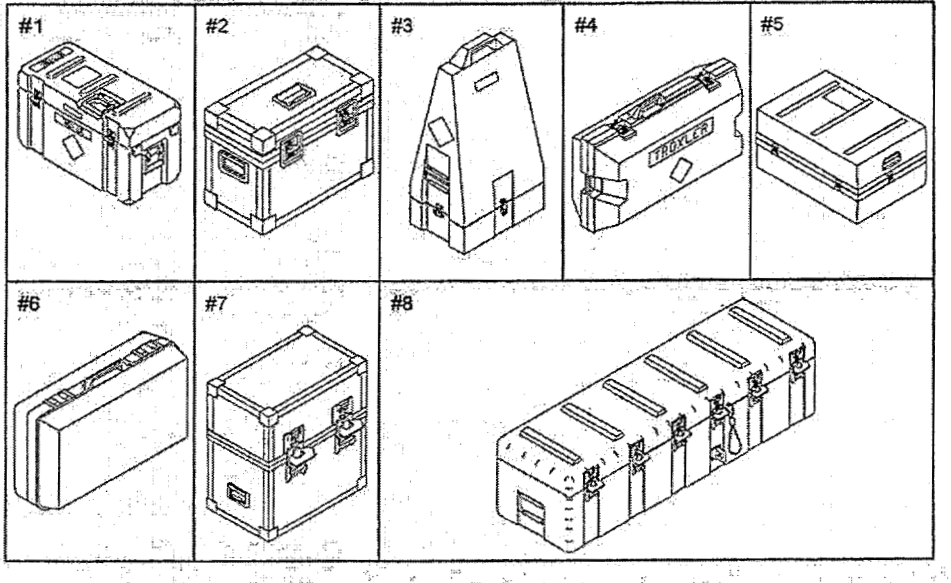
**Penetration:** The package was placed on a non-yielding surface. A 1-1/4" diameter, 13-pound steel cylinder with a hemispherical end was dropped in the vertical position from a height of 40" onto the package to a point to cause maximum damage to the package.

Results: No physical damage to the package was observed, unless otherwise noted in footnotes.

**Compression:** Package was placed on a non-yielding surface and subjected to a compressive load of at least 13 kilopascals multiplied by the vertically projected area of the package, in square feet, for 24 continuous hours.

Results: No physical damage to the package was observed, unless otherwise noted in footnotes.

## PACKAGE DRAWINGS:



# PRIVATE CARRIER BILL OF LADING FOR A 3400 SERIES GAUGE

This example shows a bill of lading for a 3400 Series gauge transported by private carrier. This document is NOT required to be dated.

NOTE

**Your source type, source activity, and TI may differ from this example. The "RQ" requirement applies only to sources containing americium-241.**

Your Company's Letterhead

BILL OF LADING

**Shipper:** ABC Paving Company
0000 Road Drive
Anywhere, U.S.A.

RQ, Radioactive material, Type A package,
Special Form, 7, UN3332

Cs-137 0.30 GBq (8.0 mCi)
Am-241:Be 1.48 GBq (40.0 mCi)

Radioactive Yellow II Label, TI = 0.3

**** EMERGENCY CONTACT: (919) 839-2676 ****

(SIGNATURE)
SHIPPER

# COMMON CARRIER BILL OF LADING EXAMPLE FOR A 3400 SERIES GAUGE

This is an example of a bill of lading for a 3400 Series nuclear gauge being shipped by a common carrier.

**NOTE**

**Your source type, source activity, TI, and certificate of competent authority numbers may differ from this example. The "RQ" requirement applies only to sources containing americium-241.**

## *SB Freightways*
## BILL OF LADING

| DATE | P.O. NO. | SHIPPER NO. |
|---|---|---|
| SHIP DATE | | |

| CONSIGNEE (TO) | SHIPPER/CONSIGNOR (FROM) |
|---|---|
| RED E. WAITING | ABC PAVING COMPANY |
| DEF PAVING INTERNATIONAL | 456 MAIN STREET |
| 123 DIRT ROAD | ANY OTHER TOWN, U.S.A. 67890 |
| ANYTOWN, U.S.A. 12345 | |

| PHONE NO. | EMERGENCY RESPONSE NUMBER* (REQUIRED IF HM COLUMN MARKED) | ROUTE |
|---|---|---|
| | 919-839-2676 | |

(SUBJECT TO CORRECTION)

| Number of Packages | HM * | Kind of Packaging, Description of Articles, Special Marks and Exceptions | Weight (lb) | Class or Rate Ref. | Cube (Optional) |
|---|---|---|---|---|---|
| 1 | x | RQ, Radioactive Material, Type A package, | | | |
| | | Special Form, 7, UN3332 | | | |
| | | Cs-137 0.30 GBq (8.0 mCi) | | | |
| | | Am-241:Be 1.48 GBq (40 mCi) | | | |
| | | Radioactive Yellow II label, TI = 0.3 | | | |
| | | | | | |
| | | Dim 35 x 45 x 78 cm | | | |
| | | | | | |
| | | Emergency Contact: (919) 839-2676 | | | |

THIS IS TO CERTIFY THAT THE ABOVE-NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED, AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

| SHIPPER/CONSIGNOR | CARRIER |
|---|---|
| WANDA SHIPPITT | SB FREIGHTWAYS |
| AUTHORIZED SIGNATURE DATE | AUTHORIZED SIGNATURE |

TROXLER

# SHIPPER'S DECLARATION FOR DANGEROUS GOODS EXAMPLE FOR A 3400 SERIES GAUGE

This is an example of a Shipper's Declaration for Dangerous Goods for shipping a 3400 Series nuclear gauge by air.

## NOTE

**Your source type, source activity, TI, and certificate of competent authority numbers may differ from this example. The "RQ" requirement applies only to sources containing americium-241.**

SHIPPER'S DECLARATION FOR DANGEROUS GOODS

Shipper

ABC PAVING COMPANY
123 DIRT ROAD
ANYTOWN, U.S.A. 12345

Air Waybill No.

Page of Pages

Shipper's Reference Number *(optional)*

Consignee

DEF PAVING INTERNATIONAL
456 MAIN STREET
ANY OTHER TOWN, U.S.A. 67890

*Two completed and signed copies of this Declaration must be handed to the operator.*

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: *(delete non-applicable)*

XXXXXXXX XXXXXXXX XXXXXXXX | CARGO AIRCRAFT ONLY

Airport of Departure:

Airport of Destination:

Shipment type: *(delete non-applicable)*

XXXXXXXXXXXXXXX | RADIOACTIVE

NATURE AND QUANTITY OF DANGEROUS GOODS

| Dangerous Good Identification | | | | Quantity and type of packing | Packing Inst. | Authorization |
|---|---|---|---|---|---|---|
| Proper Shipping Name | Class or Division | UN or ID No. | Subsidiary Risk | | | |
| RQ, Radioactive Material Type A package, Special Form | 7 | UN3332 | | Cesium-137, 0.30 GBq (8 mCi) Americium-241:Beryllium 1.48 GBq (40 mCi)<br><br>All packed in one Type A package<br><br>Dim 35 x 45 x 78 cm | Yellow II<br><br>TI=0.3<br><br>DIM 35x45x 78 cm | SPECIAL FORM CERT GB/353/S85 GB/7/S-85 |

Additional Handling Information

**This shipment may be carried on passenger aircraft outside U.S. jurisdiction.**
**Special Form Approval certification is attached to dangerous goods declaration.**
**EMERGENCY CONTACT: (01) 1-919-839-2676**

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations

Name/Title of Signatory

**Wanda Shippitt, Shipping Coordinator**

Place and Date

ANYTOWN, U.S.A. Ship Date

Signature *(see warning above)*

# FEDERAL EXPRESS® FORM EXAMPLE FOR A 3400 SERIES GAUGE

This is an example of the Federal Express version of a Shipper's Declaration for Dangerous Goods.

**NOTE**

**Your source type, source activity, TI, and certificate of competent authority numbers may differ from this example. The "RQ" requirement applies only to sources containing americium-241.**

FedEx. Dangerous Goods Airbill — Sender's Copy — RETAIN FOR 1 YEAR — RETAIN THIS COPY FOR YOUR RECORDS

The World On Time.

1 From — Sender's FedEx Account Number —
Sender's Name: WANDA SHIPPITT — Phone: ( 444 ) 444-4444
Company: ABC PAVING COMPANY
Address: 123 DIRT ROAD
City: ANYTOWN — State: U.S.A. — ZIP: 12345

2 Your Internal Billing Reference

3 To
Recipient's Name: RED E. WAITING — Phone: ( 555 ) 555-5555
Company: DEF PAVING INTERNATIONAL
Address: 456 MAIN STREET
City: ANY OTHER TOWN — State: U.S.A. — ZIP: 67890
For HOLD at FedEx Location check here: Hold Weekday; Hold Saturday
For WEEKEND Delivery check here: Saturday Delivery; Sunday Delivery

4a Express Package Service — Packages up to 150 lbs.: FedEx Priority Overnight; FedEx Standard Overnight; FedEx 2Day; FedEx Express Saver

4b Express Freight Service — Packages over 150 lbs.: FedEx 1Day Freight; FedEx 2Day Freight; FedEx 3Day Freight

5 Packaging: Other Packaging — Dangerous Goods cannot be shipped in FedEx packaging

6 Special Handling: Dangerous Goods as per attached Shipper's Declaration; Extra Attendant Only

7 Payment: Bill to: Sender; Recipient; Third Party; Credit Card; Cash/Check
FedEx Account No.
Credit Card No. — Exp. Date
Total Packages — Total Weight — Total Declared Value: $ .00 — FedEx Use Only

Signature Release Unavailable

374

FedEx Tracking Number: 811508706847 — Form ID No. 0204

Page 1 of 1 Pages

TRANSPORT DETAILS
This shipment is within the limitations prescribed for: XXX PASSENGER AIRCRAFT XXX CARGO AIRCRAFT ONLY
Airport of Departure:
Airport of Destination:

*Two completed and signed copies of this Declaration must be handed to the operator.*

WARNING
Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

Shipment type: (delete non-applicable) XXX NON-RADIOACTIVE / RADIOACTIVE

NATURE AND QUANTITY OF DANGEROUS GOODS

| Dangerous Goods Identification: Proper Shipping Name | Class or Division | UN or I.D. No. | Packing Group | Subsidiary Risk | Quantity and Type of Packaging | Packing Instr. | Authorization |
|---|---|---|---|---|---|---|---|
| RQ, Radioactive Material, Type A package, Special Form, | 7 | UN3332 | | | Cesium-137 0.30 GBq (8.0 mCi) Americium-241;Beryllium 1.48 GBq (40.0 mCi) All Packed In One Type A Package Dim 35 x 45 x 78 cm | Yellow II TI = 0.3 DIM 35x45x 78 cm | SPECIAL FORM CERT. GB/353/S85 GB/7/S-85 |

Additional Handling Information

Prepared for AIR TRANSPORT according to: (Customer MUST check one) ☐ 49 CFR ☒ ICAO / IATA

NOTE

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name and are classified, packaged, marked, and labeled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations.

Name/Title of Signatory: Wanda Shippitt, Shipping Coordinator
Place and Date: ANYTOWN, U.S.A. — Ship Date
Signature (Not required when sending via fax)

Emergency Telephone Number (Required for U.S. Origin or Destination Shipments): 919-839-2676

ACCEPTABLE FOR PASSENGER AIRCRAFT. THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

TROXLER

# EMERGENCY RESPONSE INFORMATION EXAMPLE

TROXLER NUCLEAR GAUGE EMERGENCY RESPONSE INFORMATION
REQUIRED FOR TRANSPORTATION
(Reference DOT P5800.5 ERG93 and 49CFR)

Call Troxler Electronic Laboratories, Inc. at (919) 839-2676 for Emergency Assistance.

1. PROPER SHIPPING NAME:

- Radioactive material, Type A package, Special Form, UN3332

POTENTIAL HAZARDS

2. HEALTH HAZARDS

- Radiation presents minimal risk to lives of persons during transportation accidents.
- Undamaged packages are safe; damaged packages or materials released from packages can cause external radiation hazards. Contamination is not suspected.
- Packages (cartons, boxes, drums, articles, etc.) identified as "Type A" by marking on packages or by shipping papers contain non-life endangering amounts. Radioactive sources may be released if packages are damaged in moderately severe accidents.
- Packages (large and small, usually metal) identified as "Type B" by marking on packages or by shipping papers contain potentially life-endangering amounts. Because of design, evaluation, and testing of packages, life-endangering releases are not expected in accidents except those of utmost severity.
- Commonly available instruments can detect most of these materials.
- Water from cargo fire control is not expected to cause pollution.

3. FIRE OR EXPLOSION

- Packagings can be consumed without content loss from sealed source capsule.
- Radioactive source capsules and Type B packages are designed to withstand temperatures of 1475 °F (800 °C).

EMERGENCY ACTION

4. IMMEDIATE PRECAUTIONS

- Priority response actions may be performed before taking radiation measurements.
- Priorities are life saving, control of fire and other hazards, and first aid.
- Isolate hazard area and deny entry. Notify Radiation Authority of accident conditions.
- Delay final cleanup until instruction or advice of Radiation Authority.
- Positive pressure self-contained breathing apparatus (SCBA) and structural firefighter's protective clothing will provide adequate protection against internal radiation exposure, but not external radiation exposure.

5. FIRE

- Do not move damaged packages; move undamaged packages out of fire zone.
- **Small Fires:** Dry chemical, $CO_2$ water spray or regular foam.
- **Large Fires:** Water spray, fog (flooding amounts)

6. SPILL OR LEAK

- **Do not touch damaged packages or spilled material.**
- Slightly damaged or damp outer surfaces seldom indicate failure of inner container.
- If source is identified as being out of package, stay away and await advice from Radiation Authority.

7. FIRST AID

- Use first aid treatment according to the nature of the injury.
- Persons exposed to special form sources are not likely to be contaminated with radioactive material.