Section 58.0
IONIZING RADIATION

A. Purpose

The purpose of this procedure is to provide guidance to **JAGUAR ENERGY SERVICES, LLC** personnel who work around or near radioactive equipment such as X-ray equipment and gauges on radiographic equipment or other sources of radiation.

1. The implementation of this procedure will enable **JAGUAR ENERGY SERVICES, LLC** to comply with OSHA 29 CFR 1926.53.

2. This procedure addresses the equipment used for detecting radiation as well as controlling it by the use the of the three basic controls:
   (a) Time
   (b) Distance
   (c) Shielding.

B. Scope

This procedure applies to **JAGUAR ENERGY SERVICES, LLC** personnel who work near radioactive sources or radiographic equipment.

1. This procedure also applies to employees who may be exposed to radioactive materials generated by someone working nearby.

2. This procedure **does not** cover non-ionizing radiation such as is associated with electric and magnetic fields, sub-radio fields, radio frequency, microwave, optical radiation, and lasers.

3. **JAGUAR ENERGY SERVICES, LLC** personnel should refer to the NORM procedure for specific precautions and work practices for working on equipment or piping that may be contaminated with Naturally Occurring Radioactive Materials (NORM).

C. Responsibilities

1. The Safety Coordinator or his/her designee responsible for ensuring that employees have completed the training required by this procedure.
   (a) Additional responsibilities include:
      (i) The implementation of this Policy.
      (ii) Documentation of completion by each employee.
      (iii) Take corrective actions on all violations or suspected violations of this procedure.
      (iv) Ensuring that this procedure is followed in work done at a client's or **JAGUAR ENERGY SERVICES, LLC** location.
      (v) Ensuring that proper records are maintained on all work performed where radioactive equipment such as X-ray equipment and gauges on radiographic equipment or other sources of radiation are present.
      (vi) For reviewing and revising the procedure as required.

2. The Safety Director is responsible for aiding in the implementation of this Procedure.
   (a) Additional responsibilities include:
      (i) Keeping the Safety Coordinator informed of any concerns or potential exposure to **JAGUAR ENERGY SERVICES, LLC** personnel involving ionizing radiation.
      (ii) Providing appropriate safety equipment to **JAGUAR ENERGY SERVICES, LLC** personnel.
      (iii) Investigating all employee concerns regarding radioactive equipment such as X-ray equipment and gauges on radiographic equipment or other sources of radiation on **JAGUAR ENERGY SERVICES, LLC** or client's premises.
      (iv) Reviewing current technical information available on radioactive equipment such as X-ray equipment and gauges on radiographic equipment or other sources of radiation.
      (v) Maintaining medical surveillance records on personnel working on or near radioactive equipment such as X-ray equipment and gauges on radiographic equipment or other sources of radiation.

(i) The Assistant Secretary of Labor, affected employees and designated employees' representatives shall have access to this program.

(vi) Investigating all employee concerns regarding radioactive equipment such as X-ray equipment and gauges on radiographic equipment or other sources of radiation.

(vii) On **JAGUAR ENERGY SERVICES, LLC** or client premises.

(viii) Informing the Safety Coordinator of any suspected or newly identified sources of radioactive equipment, such as X-ray equipment and gauges on radiographic equipment or other sources of radiation at **JAGUAR ENERGY SERVICES, LLC** or client's premises.

3. The Supervisor is responsible for providing assistance in the implementation of this policy.
   (a) Additional responsibilities include:
      (i) Informing the Safety Director of any incidents involving radioactive equipment, such as X-ray equipment and gauges on radiographic equipment or other sources of radiation.
      (ii) Informing the Safety Director of any suspected or newly identified sources of radioactive equipment, such as X-ray equipment and gauges on radiographic equipment or other sources of radiation at **JAGUAR ENERGY SERVICES, LLC** or client's premises.
      (iii) Ensuring that all employees are informed of any suspected or newly identified sources of radioactive equipment, such as X-ray equipment and gauges on radiographic equipment or other sources of radiation on **JAGUAR ENERGY SERVICES, LLC** or client's premises.

4. **JAGUAR ENERGY SERVICES, LLC** personnel are responsible for adhering to the rules, guidelines and work practices in this procedure.
   (a) Additional responsibilities include:
      (i) Completing the training required by this procedure.

(ii) Recognizing and anticipating all job hazards including situations that can involve exposure to ionizing radiation.

(iii) Observing and following warning signs and ensuring that they do not open equipment containing radioactive sources or handle radioactive materials.

(iv) Reporting to their supervisor any suspected or newly identified sources of ionizing radiation on **JAGUAR ENERGY SERVICES, LLC** or customer premises.

D. Procedure

1. Ionizing radiation is radiation that has sufficient energy to remove electrons from atoms.

2. Some materials are naturally radioactive; others can be made radioactive in a nuclear reactor or accelerator.

3. **JAGUAR ENERGY SERVICES, LLC** personnel must be able to recognize work situations with exposure potential and take appropriate precautionary measures.

4. All individuals are exposed to ionizing radiation from various natural sources.
   (a) These sources include cosmic radiation, and other naturally occurring radioactive materials (NORM) within the environment and human body.
      (i) For more information on NORM refer to the NORM procedure.
   (b) **JAGUAR ENERGY SERVICES, LLC** personnel are most likely to encounter man-made sources of ionizing radiation when working on or near radiographic equipment used in metallurgical studies of pipes and equipment.
   (c) Additional sources of ionizing radiation include:
      (i) X-ray equipment
      (ii) Gauging devices
      (iii) Meters.

5. The most common types of ionizing radiation are
   (a) Alpha
   (b) Beta
   (c) Neutron particles
   (d) X-or gamma radiation.

6. Alpha particles are energetic, positively charged particles that quickly lose energy when passing through matter.
   (a) They are commonly emitted in the radioactive decay of the heaviest radioactive elements, such as uranium and radium.

7. Alpha particles lose their energy rapidly and do not penetrate very far, however they can cause damage over their short path through tissue.
   (a) These particles are usually completely absorbed by the outer dead layer of skin and are therefore not a hazard outside of the body.
   (b) However, they can be very harmful when ingested or inhaled. Alpha particles can be stopped completely by a sheet of paper.

8. Beta particles are fast moving, positively or negatively charged electrons, emitted from the nucleus during radioactive decay.
   (a) Humans are exposed to beta particles from manmade and natural sources such as tritium, carbon-14, and strontium-90.
   (b) Beta particles are more penetrating than alpha particles but are less damaging over equally traveled distances.
   (c) Some beta particles are capable of penetrating the skin and causing radiation damage; however, as with alpha emitters, beta emitters are generally more hazardous when they are inhaled or ingested.
   (d) Beta particles travel appreciable distances in air, but can be reduced or stopped by a layer of cloth or by a few millimeters of a substance such as aluminum.

9. X-rays are high energy photons produced by the interaction of charged particles with matter.
   (a) X-rays and gamma rays have essentially the same properties, but differ in origin.
   (b) X-rays are emitted by processes outside of the nucleus, while gamma rays originate inside the nucleus.

(c) X-rays are generally lower in energy and therefore less penetrating than gamma rays.

(d) Literally thousands of X-ray machines are used in industry for examination, inspection and process controls.

10. Dose and Health Effects

(a) Ionizing radiation is measured in terms of the:
- (i) Strength or radioactivity of the radiation source (becuqerel, Bq or Curie, Ci)
- (ii) Energy of the radiation (electron volts, eV)
- (iii) Level of radiation in the environment (roentgen, R)
- (iv) Radiation dose or amount of radiation absorbed by the body (rad)

(b) Equal doses of different types of radiation are not equally harmful.
- (i) Alpha particles produce greater harm than do beta particles, gamma or X-rays for a given absorbed dose.

(c) To account for this difference, radiation dose is expressed as equivalent dose in units of sievert (Sv)
- (i) Previously this was measured in rem.

(d) The dose in Sv is equal to the absorbed dose times a "radiation weighting factor." Prior to 1990 this was called Quality Factor (QF).

(e) One Sv is equivalent to 100 rem.

(f) One Sv is a large dose.

(g) A regulatory body recommends:
- (i) Effective Dose:
  - (i) 50 mSv - Threshold Limit Value (TLV) for annual dose for radiation workers in any one year.
  - (ii) 10 mSv - TLV for annual average dose, averaged over five years.
- (ii) Equivalent Dose
  - (i) Lens of the eye - 150 mSV
  - (ii) Skin - 500 mSv
  - (iii) Hands and Feet - 500 mSV
- (iii) Embryo-Fetus exposures
  - (i) Monthly equivalent dose - 0.5 mSv
  - (ii) Dose to the surface of women's abdomen - 2 mSv for the remainder of the pregnancy
  - (iii) Intake of radionuclide - 1/20 Annual Limit on Intake

(iv) Sum of internal and external exposure but excluding doses from natural sources

(i) The International Commission on Radiological Protection (ICRP) recommends 1 mSv for the annual dose limit for the general public.

(h) The effects of being exposed to large doses of radiation at one time (acute exposure) vary with the dose.

(i) Following are some examples:

Health Effects of Radiation Exposure

Dose	Health Effects
10 Sv	Risk of death within days or weeks.
1 Sv	Risk of cancer later in life (5 in 100).
100 mSv	Risk of cancer later in life (5 in 1000).

(a) Certain health effects of radiation clearly have thresholds below which the health effect does not appear depending on whether there is an acute or chronic type of exposure.

(b) Acute exposures, called radiation syndrome, can be subdivided as listed in the following chart

Health Effects of Acute Radiation Exposure

Whole Body Dose (rads)	Health Effects
200	Blood systemic effects including depression or destruction of bone marrow causing anemia and susceptibility to infection.
1000	Gastrointestinal effects include destruction of the intestinal epithelium with nausea, vomiting and diarrhea.
2000	Central nervous system effects include direct damage to the nervous system and loss of consciousness within minutes.
450 (LD50)	Causes death in half of those exposed.

(a) Committed dose refers to the radiation dose that is constantly accumulated in an organ or tissue when a radioactive material gets into the body by inhalation or ingestion.

(b) Committed dose is the total dose accumulated during 50 years following the intake.
- (i) In general, radionuclide taken up by the body do not distribute equally throughout the body.
- (ii) Often the radionuclide concentrates on a certain organ.
- (iii) For example, radium and plutonium tend to concentrate in bone.

(c) The effective dose is the sum of the equivalent doses in all the organs and tissues of the body.

(d) The primary means for controlling radiation exposure include:
- (i) Detection of exposure
- (ii) Use of the three basic controls:
  - (i) Time
  - (ii) Distances
  - (iii) Shielding.

2. Detectors

There are a variety of detectors and readout devices used for monitoring and measuring radiation.

(a) Examples of detectors are listed in the following chart.

Examples of Radiation Detectors

Detector	Radiation Type
Film badges	Gamma, X-ray and high energy beta radiation
Thermoluminescence detectors	Gamma, X- ray and beta radiation
Pocket dosimeters	X- ray and gamma radiation
Ionization chambers	Gamma, X- ray, beta and sometime, if window is thin enough, alpha
Geiger- Mueller counters	Beta, gamma and X-ray
Scintillators	Alpha, beta and gamma

(a) Film badges consist of a small piece of photographic film wrapped in an opaque cover and supported with a metal backing.
- (i) The badge is removed and the film is developed at certain intervals.

(ii) The amount of darkening of a film is then compared to a control film that was not exposed to radiation during the same time period.

(b) Thermoluminescence detectors generally contain a small chip of lithium fluoride.

(i) Ionizing radiation causes the chip to emit light which is read by the dosimeter.

(c) Pocket dosimeters provide an immediate radiation dose and their function is based on electrostatic charging and movement of a quartz fiber.

(i) Ionization chambers can measure ionization in a small volume of air.

(i) Since ionized air is conductive, this instrument is able to measure the current between to electrodes in an ionization chamber.

(d) A Geiger-Mueller counter uses an ionization chamber filled with a gas and has a greater voltage supplied between its electrodes.

(i) This makes the instrument capable of detecting very small amounts of radiation.

(e) Scintillators are designed to measure the light flashes created by the interaction of ionizing radiation and scintillator materials.

2. **Controlling Exposure**

There are three basic methods for controlling exposure to radiation: time, distance and shielding.

(a) Time

There is a direct relationship between the exposure dose and the duration of the exposure.

(i) The longer the exposure, the greater the radiation injury.

(i) Therefore, if the exposure period is cut in half, then the dose received is reduced by one-half.

(ii) For example, if the exposure rate is 2.5 rem/hr (0.25 mSv/hr), 40 hours results in 100 mrem (1 mSv) exposure.

(iii) If the exposure rate is 10 time higher, then the time must be reduced to one-tenth (to 4 hours) for the same dose.

(b) Distance

The inverse square law can be applied to determine the change in external penetrating radiation exposure with the change in distance from a radiation source.

(i) If you double the distance from the source of radiation, you will essentially decrease the exposure by $(½)^2$ or one-fourth the original exposure.

(ii) It is important to understand that the inverse square law applies to a point source in free space where there is no scattering of radiation.

(iii) This means that in real life, while this is a practical applicable approach, we must consider the surrounding surfaces that may reflect radiation and change the exposure.

(b) Sometimes areas may be barricaded or roped off to restrict entrance into an area.

(i) These types of areas should have a sign bearing the standard radiation symbol (**insert graphic of symbol**).

(ii) Do not enter these areas unless you have been trained, authorized and have the appropriate equipment.

(c) Shielding

Shielding is commonly used to protect against radiation sources.

(i) High density materials, like lead, used as shields, require less thickness than low density materials like concrete.

(ii) Half value layers are used to calculate the type and thickness of a shielding material required to contain a radiation source.

(iii) Half value layer is the thickness of a substance necessary to reduce the intensity of a beam of gamma or x rays to half its original value.

2. Safe Work Practices

(a) **JAGUAR ENERGY SERVICES, LLC** personnel should adhere to the following work practices, rules and guidelines:

(i) Read and comply with all radiation barriers, signs, labels, and postings.

(ii) Do not climb over barrier fences, or defeat any radiological protection systems.

(iii) Use time, distance, and shielding to maintain your radiation dose as low as possible.
(iv) Know the radiological conditions of the area you are entering.
(v) If possible, move the item being worked on away from the source of radiation, or move the source of radiation away from the work area.
(vi) Position yourself so that shielding is between you and the source.
(vii) Wear safety glasses/ goggles to protect the eyes from beta radiation, when applicable.
(viii) Do not eat, drink, or smoke around radiation sources.

3. Personal Protective Equipment

(a) If work requires any action that might produce dust or if loose contamination is suspected, Field Service Personnel should take the following additional precautions:
  (i) Utilize a respirator approved for radioactive particulates.
  (ii) Wear suitable PPE such as:
    (i) Coveralls
    (ii) Disposable tyvek
    (iii) Gloves
  (iii) Conduct activities in well-ventilated areas to which access has been restricted.
  (iv) Plastic ground covers should be utilized, to the extent possible, to contain contaminants and facilitate cleanup.
  (v) Gloves, respirators, coveralls and rags should be decontaminated or placed in double bags and sealed for proper disposal.

B. Training Requirements

1. **JAGUAR ENERGY SERVICES, LLC** personnel will be trained on the following topics:
  (a) Hazards of ionizing radiation.
  (b) Dose and health effects.
  (c) Procedures, precautions, and equipment to prevent exposure.
  (d) The contents of this procedure.

C. Training Frequency

(a) Initially upon hire.
(b) If the employee is observed not properly implementing this procedure.
(c) If the procedure changes.
(d) Yearly if exposed to radiation over excepted levels.

D. Definitions

1. **Alpha Particle** is a small, positively charged particle made up of two neutrons and two protons. It has a very high velocity and is produced by radioactive materials, including uranium and radium.

2. **Background Radiation** is radiation from cosmic sources; naturally occurring radioactive materials, including radon and global fallout as it exists in the environment from the testing of nuclear explosive devices.

3. **Becquerel (Bq)** is the International System (SI) unit for activity of radioactive material.
   (a) One Becquerel is the quantity of radioactive material that undergoes one nuclear transition per second.

4. **Beta Particle** is a small electrically charged particle thrown off by many radioactive materials; identical to an electron.
   (a) Beta particles emerge from radioactive materials at high speeds.

5. **Committed Dose Equivalent** is the calculated dose equivalent projected to be received by tissues or organs over a 50-year period after an intake of radionuclides into the body.

6. **Containment device** is a barrier, such as a glove bag or tent for inhibiting the release of radioactive material from a specific location.

7. **Daughter** (As used in radioactivity) refers to the product nucleus or atom resulting from the decay of the precursor or parent.

8. **Decay** is when a radioactive atom disintegrates.
   (a) What remains is a different element.

(b) An atom of polonium decays to form lead, ejecting an alpha particle.

9. **Dose Equivalent** is the product of absorbed dose in rads (or grays) in tissue and a quality factor for the specific type of radiation.
   (a) Dose equivalent is expressed in rem.

10. **Electron volt (eV)** is a unit of radiation energy.
    (a) One eV is equivalent to the energy needed to accelerate an electron across a 1 volt potential.

11. **Half-life** (For a single radioactive decay process) represents the time required for the activity to decrease to half its value by that process.

12. **High Efficiency Particulate Air (HEPA) Filter** is a throwaway extended pleated medium dry-type filter with a minimum particle removal efficiency of 99.97% particles with a diameter of 0.3 micrometers.

13. **Gamma-rays (gamma radiation)** is the most penetrating of all radiation.
    (a) Gamma-rays are very high-energy X-rays.

14. **Isotope** is an element with the same atomic number but different atomic weight.

15. **Natural radioactivity** is the radioactive background; or more properly, the radioactivity that is associated with the heavy naturally occurring elements.

16. **Nuclide** is a type of atom characterized by its mass number, atomic number and energy state of the nucleus, provided that the mean life in that state is long enough to be observable.

17. **Personal Dosimetry** is devices, such as thermoluminescent dosimeters (TLDs), and pocket ionization chambers (pencils), designed to be worn by a single person for the assessment of dose equivalent.

18. **Rad** is a measure of the dose of any ionizing radiation to body tissue in terms of energy absorbed per unit of mass of the tissue.

19. **Radioactive** is the property of an isotope or element that is characterized by spontaneous decay to emit radiation.

20. **Radioactivity** is the emission of energy in the form of alpha, beta or gamma radiation from the nucleus of an atom.
    (a) Always involves change of one kind of atom into a different kind.
    (b) A few elements, such as radium, are naturally radioactive.

21. **Radionuclide** is a radioactive nuclide; one that has the capability to spontaneously emit radiation.

22. **Rem** is a measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of one roentgen of X-rays.
    (a) Current terminology refers to this equivalent dose as sievert (Sv).
    (b) One Sv equals 100 rem.
    (c) **Sievert (Sv)** is the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv = 100 rem).