U.S.NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

HRTD Human Resources Training & Development

Industrial Radioactive Material (Nuclear Gauges)

Gauge Presentation Outline

- Overview
- Portable Gauges
- Fixed Gauges
- Other Industrial Devices
- Regulatory Issues
- Accidents

Comment

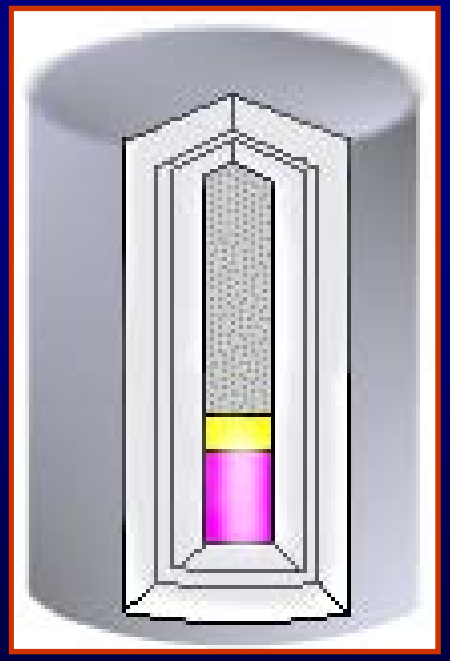
- For Irradiators, Industrial Radiography, and Well Logging, there are specific NRC technology courses which cover the equipment and radioactive sources used and the operations performed; however, there is no NRC sponsored technology course covering other industrial uses of RAM
- As a result, this overview will provide somewhat more detail than that which is provided for the other areas covered in this inspection course
- These slides were obtained from various sources and modified to correspond to current rules

Overview

- The 1950's & 1960's were an era of research for commercial uses of radionuclides resulting in the development of numerous industrial RAM applications [Atoms for Peace]
- Ionizing radiation is now an integral tool for a wide variety of industries; in many cases, there are no economical substitutes capable of the tasks performed by radiation sources

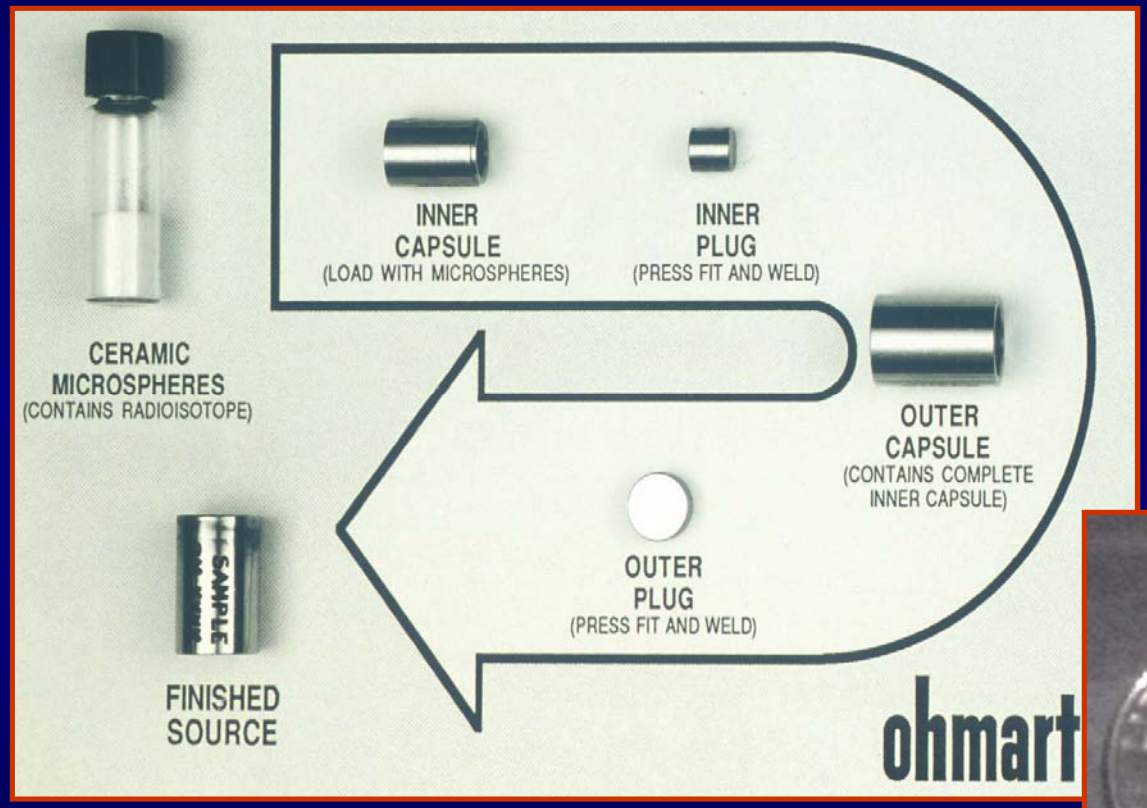
Overview Sealed Source

- The majority of industrial RAM applications use sealed sources, though unsealed RAM is also utilized
- Most applications are based on very simple principles to accomplish the required task
- Typically a source & detector combination employing basic nuclear interactions is used



Sealed Source

Overview Sealed Source



Double Encapsulation Sealed Source Assembly

Overview

- Most devices in this overview are recent models; however, older/obsolete models may be encountered during inspections & incident responses
- Resources for identifying unknown RAM devices include:
  - NRC's Sealed Source & Device Registry (SSDR)
  - State & Federal radiation control agencies
  - Manufacturers
  - ORAU

Overview

- This presentation will concentrate on Portable and Fixed Gauges which might be possessed under either a General or Specific license (GL or SL) - these devices have numerous applications in a wide variety of industries
- Also discussed will be ionizers, calibrators, self luminous devices and other industrial applications involving radioactive material

Focus Elements

(condensed version)

We will be looking at the FEs as they apply to the devices:

FE-1: Control of RAM (security & accountability)

FE-2: Adequate RAM shielding

FE-3: Limit hazards to RAM

FE-4: Appropriate dosimetry (if required)

FE-5: Proper radiation instrumentation

FE-6: Training of workers

FE-7: Appropriate management oversight & program/personnel audits

Gauging Devices

Fixed Gauge

Portable Gauge

PORTABLE GAUGES

Portable Gauges

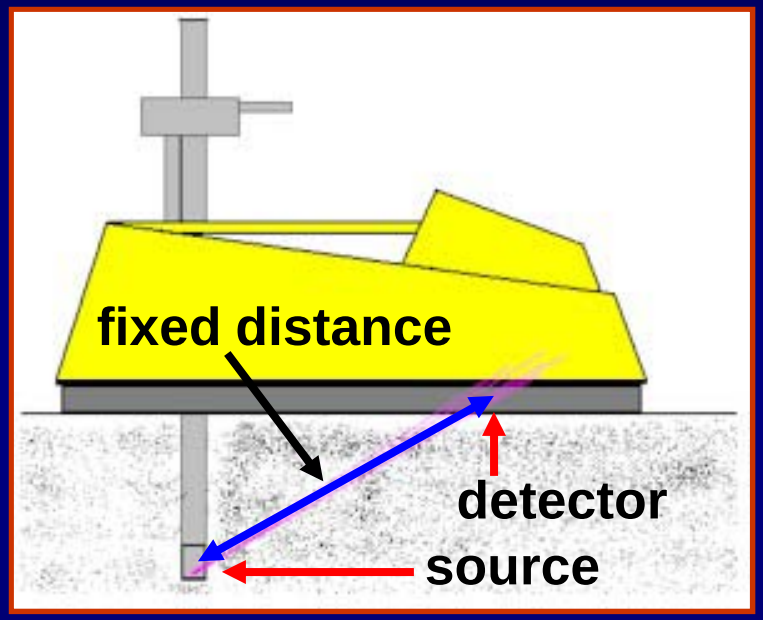
- Used in industries such as construction, civil engineering & agriculture to perform on-site measurements such as soil moisture or asphalt density in paving
- Moisture/density gauging is a form of non-destructive testing; eliminates need to take core samples
- Two basic methods used:
  - Backscatter
  - Direct Transmission

Portable Gauges

Measures soil density by transmission and soil moisture by backscatter

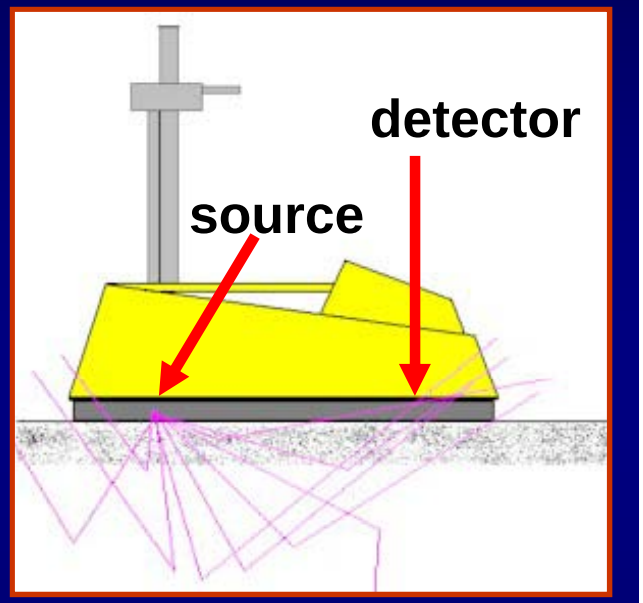
Direct Transmission

- most precise method
- to measure soil density, the source is placed beneath the surface through a punched hole - radiation travels a fixed distance to the detector on the base of the gauge
- density of the soil measured by amount of radiation transmitted



Backscatter

- eliminates punched access hole - both source and detector is on the surface
- radiation reflected (scattered) back to the gauge by the material being measured
- insensitive beyond a depth of a few inches



Portable Gauges

- Typical Sources : 8-10 millicuries of ^{137}Cesium (gamma) & 40-50 millicuries of ^{241}Americium/Beryllium (neutron)
- In ~9 minutes, an unshielded 10 mCi ^{137}Cs source can deliver 5 rem to a worker's extremities at a 1 cm distance (some gauges contain sources with even higher activities)

Common Portable Gauges

Troxler Electronic Labs

Humboldt Scientific Corporation

CPN (now Instrotek)

Portable Gauges

Troxler Gauge Transport Case
(DOT Type A 7A container)

Portable Gauges

Troxler "Roof Reader"

- Nuclear hydrotectors provide moisture measurements of water content in the thermal insulation of pipes and vessels (moisture build-up in piping insulation is an indicator of corrosion under the insulation)
- Also used to detect moisture in other locations such as under roofing material

FE-1: RAM Security & Accountability

What actions can inspectors take?

- Become familiar with lost/stolen/orphaned source incidents (NRC INs, event reports, NMED database)
- Recognize program weaknesses - study licensees' facilities & interview workers
- Portable gauge security at permanent facilities is not a significant problem
- Portable gauge security at temporary job sites is more of a problem
- Portable gauge security during transportation (particularly overnight stays) is a MAJOR problem

FE-1: RAM Security & Accountability

- Recent increased security measures for portable gauges include NRC's 10 CFR 30.34(i) and compatible Agreement State requirements for two independent physical controls to prevent unauthorized access to gauges when not under constant surveillance.
- When opportunities present themselves (e.g., spot a gauge operator at a field site), perform partial inspection with particular focus on security issues
- Emphasize importance of security & accountability during inspections; appeal to licensee by emphasizing costly civil penalties & homeland security

FE-2: Adequate RAM Shielding

Potential for compromises to portable gauge shielding:

- **Shielding can be damaged if gauge is run over by a truck or heavy construction equipment**
- **Shielding can be compromised by damage to the gauge during routine operations**
- **Improper use and maintenance can damage shielding**

Inspector actions:

- **Learn from past incidents, study program weaknesses, and look for trends… trends?**

FE-3: Limit Other Hazards to RAM

Moderate potential for other hazards

- Portable gauges are not typically at risk from fire, explosion and corrosive chemicals like fixed gauges are.

Inspector actions:

- Discuss with the licensee the hazards identified during the inspection (portable gauge stored near a water heater, etc…)

FE-4: Proper Dosimetry

- Portable gauge operators are typically monitored with whole body dosimetry, although it is not always required
- Personnel monitoring is not a key performance indicator, but can reveal trends

Inspector actions:

- If personnel monitoring is required, evaluate use & records; look for any exposures that indicate poor work practices

FE-5: Proper Radiation Instrumentation

- Survey meters not typically possessed:

  Note: licensees must have access to a meter

- If meter(s) possessed, review typical inspection items such as calibration dates

FE-6: Training Of Workers

- Training for gauge operators is sometimes insufficient, either because initial training was poorly performed or not performed at all
- Most portable gauge users attend a training course provided by a specific gauge manufacturer
- Refresher training not typically required for safety, but is required every three years for transportation
- (49 CFR 172 Subpart H)

FE-7: Appropriate Management Oversight & Program/Personnel Audits

- Management oversight & participation in radiation protection program (RPP) can vary widely among licensees, as can scope of program
- Program audits are often inadequate; field audits are not typically required for gauge users
- It is incumbent upon management to ensure proper training, since gauge users have little to no oversight in the field

Key Performance Indicators

Training

- Usually the root cause of all other problems
  - Are operators aware of security requirements & procedures, such as the portable gauge security requirement of 2 independent physical barriers to prevent unauthorized removal of gauge when not under constant surveillance?
  - If problems are identified with transportation in the field, ask about refresher HAZMAT training, required every 3 years

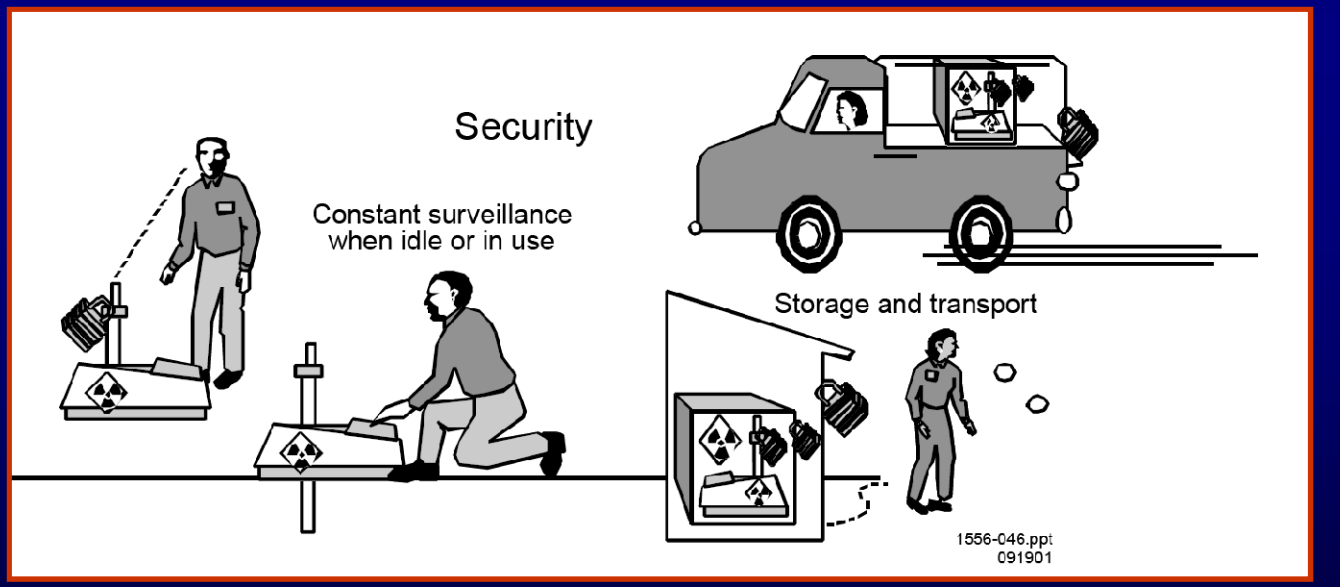
Key Performance Indicators

Security & accountability

- **Stolen/lost gauges are common occurrences; lots of reasons they occur, but few easy solutions**

Are gauges left unattended?

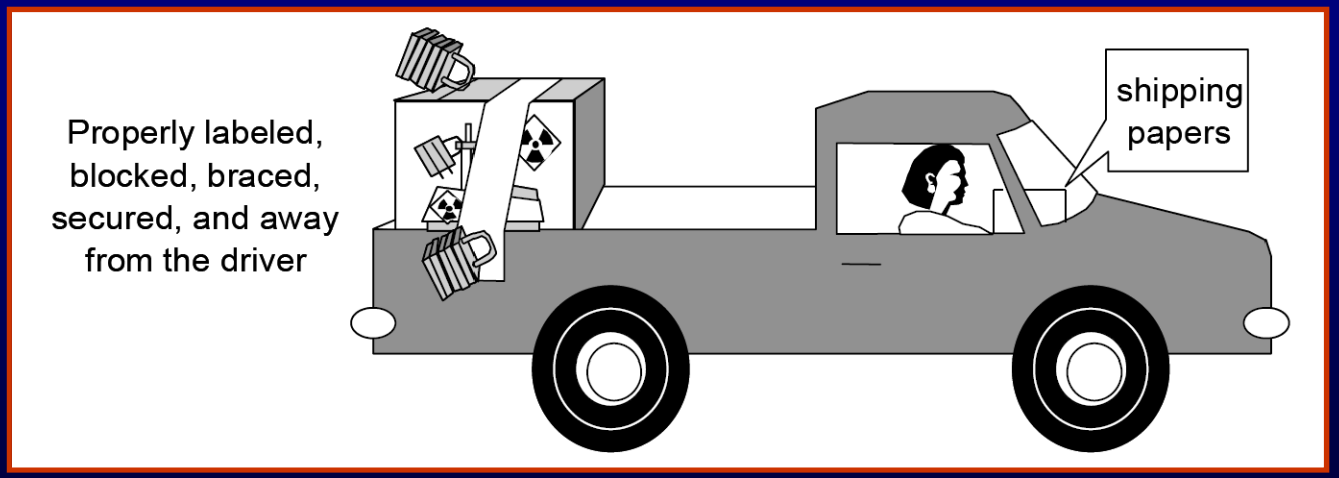
Are security measures adequate?



Key Performance Indicators

Transportation

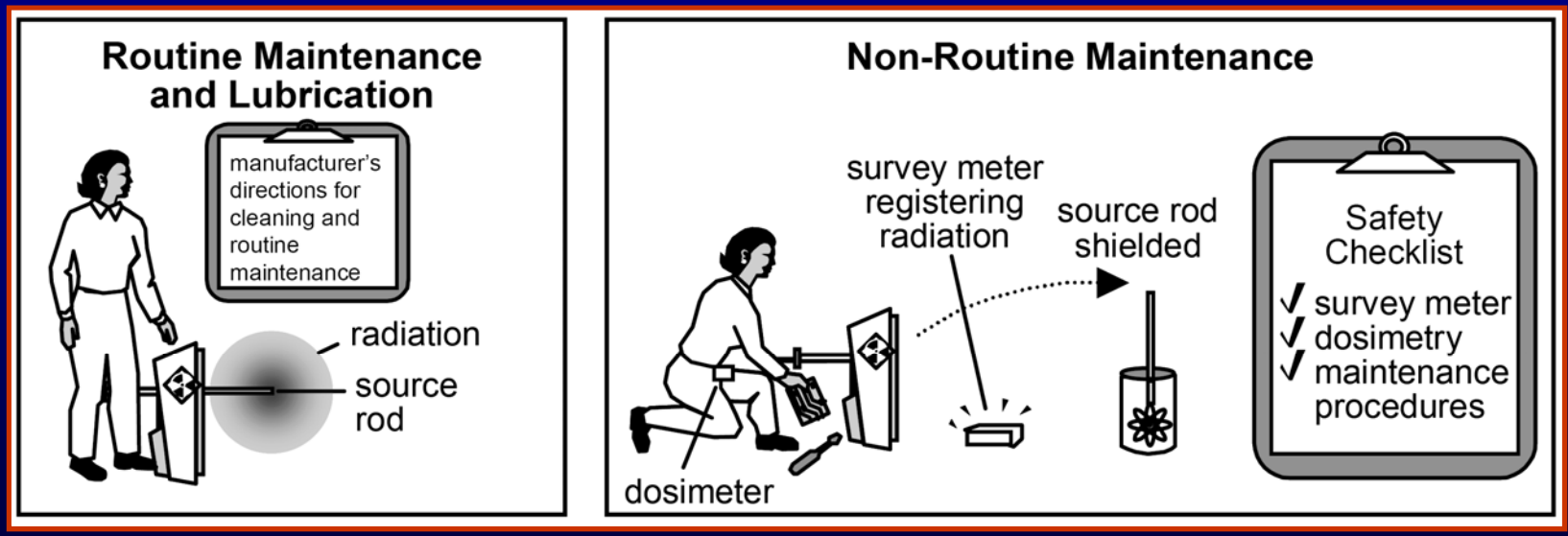
- **Noncompliance is common; can lead to bigger problems**
  - **Are gauges transported in the back of the truck, out side of case, without blocking & bracing?**



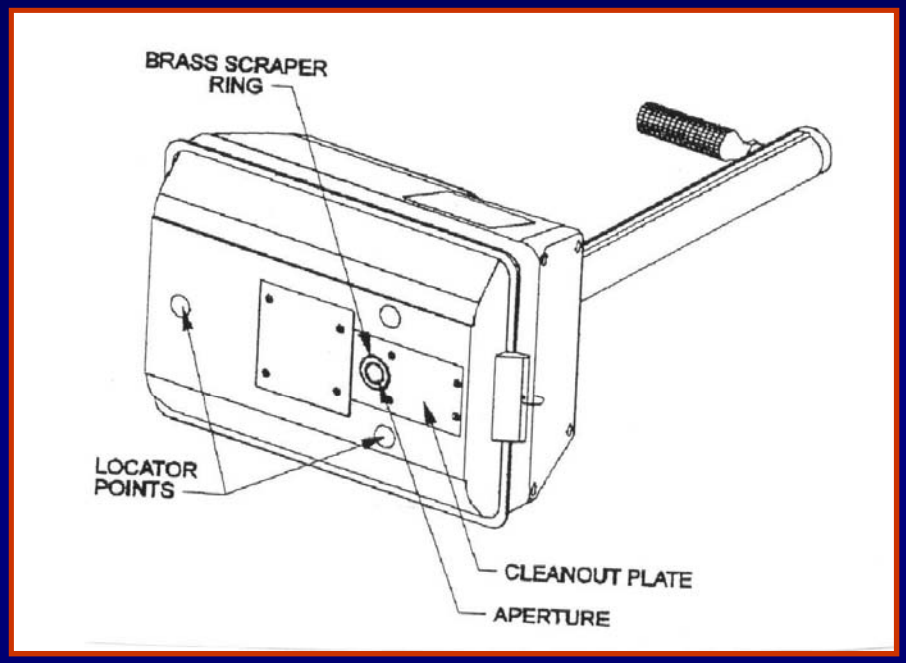
Key Performance Indicators

Maintenance

- **Greatest potential for exposure**
  - **Does worker know how to perform maintenance without unnecessary exposures?**



Gauge Maintenance



Become familiar with the proper techniques for routine gauge maintenance so you know if it's being done properly

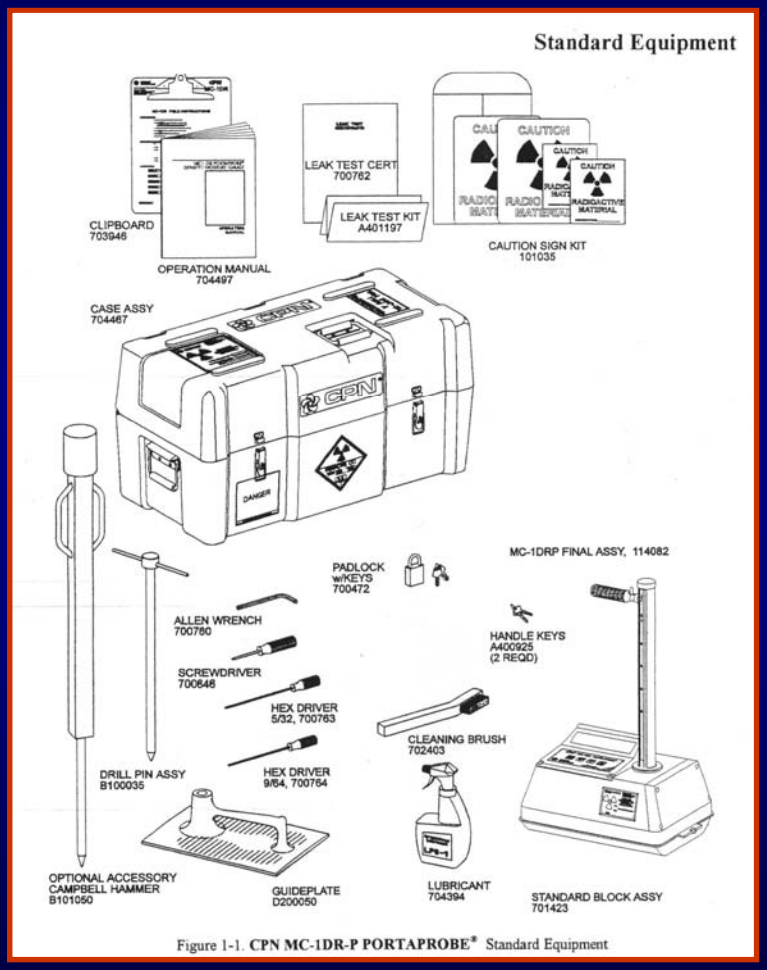


Figure 1-1. **CPN MC-1DR-P PORTAPROBE®** Standard Equipment

Inspection of Field Operations

Direct observation of licensed activities provides the best evaluation of a licensee's performance

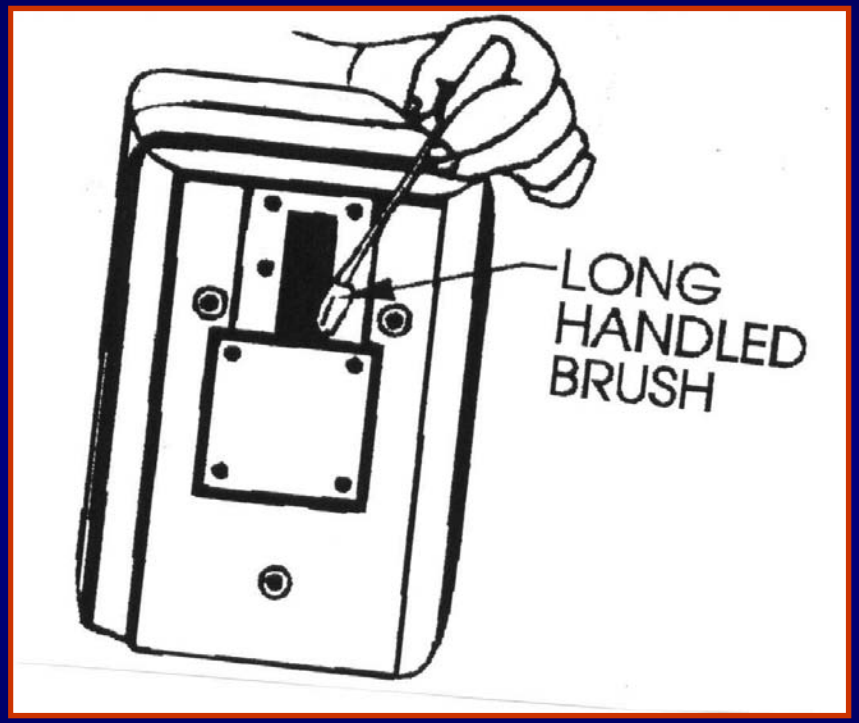
Inspection of Field Operations

Question:
What's wrong with this set up?

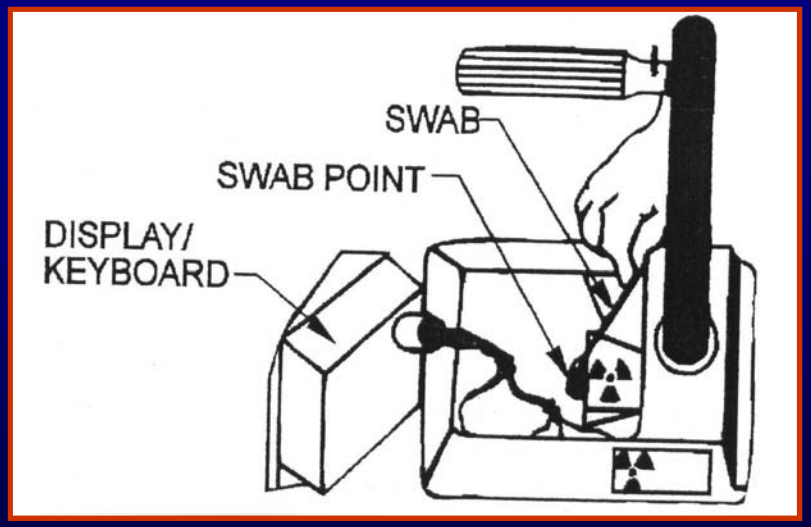
Answer:
Transport case lacks DOT labels

Leak Testing

RSO and/or designee(s) should be able to demonstrate the proper technique for taking a leak test sample



^{137}Cs



^{241}Am

Factors Contributing to Accidents

Use of the Survey Meter

Lack of Regulatory Control

Equipment Failure

ACCIDENT

Poor or No Training

Not Following Safety Procedures

Inadequate or Missing Safety Program

"Understand why accidents can occur when using nuclear gauges"

Accidents Involving a Portable Nuclear Gauge

Moisture/Density Road Gauge

- Source: ^{137}Cs & $^{241}Am/Be$
- Description: Gauge crushed by heavy equipment

FIXED GAUGES

What is a Fixed Nuclear Gauge?

- Device used throughout industry, mostly in process control and quality control
- Basically a source + detector: the amount of radiation that passes through or reflects off of the material supplies real-time data
- Gauges used when rapid non-destructive measuring technique is needed

Types of Fixed Nuclear Gauges

- Nuclear gauges can be divided in two types:
  - Transmission
  - Backscattering
- There are also gauges that use x-rays instead of radioactive isotopes

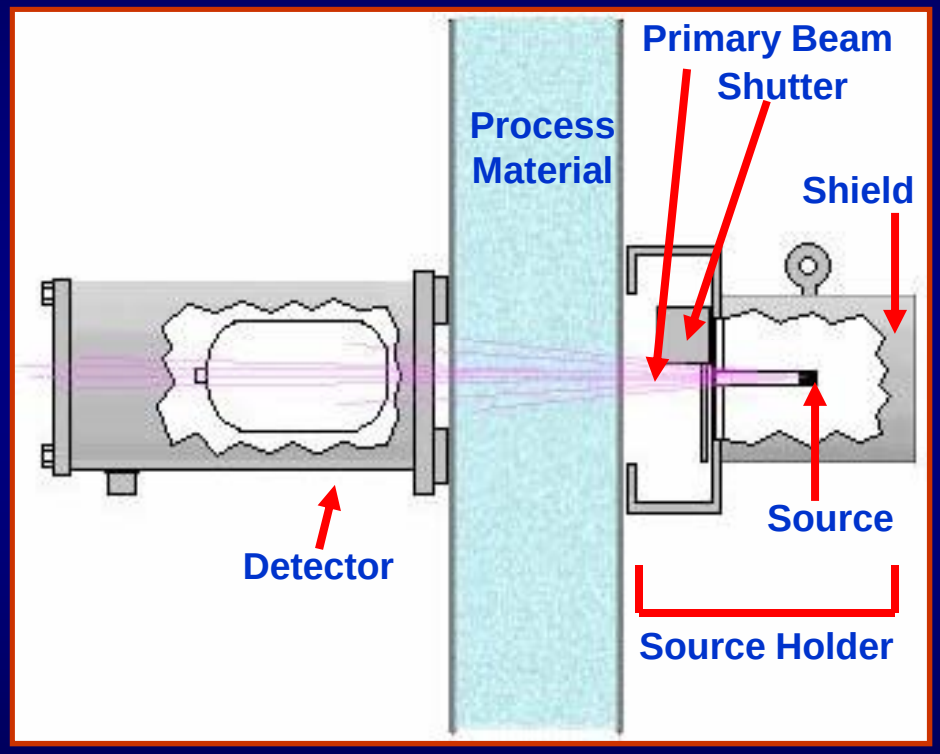
Fixed Gauge Components

Source &
Source Holder

Microprocessor

Detector

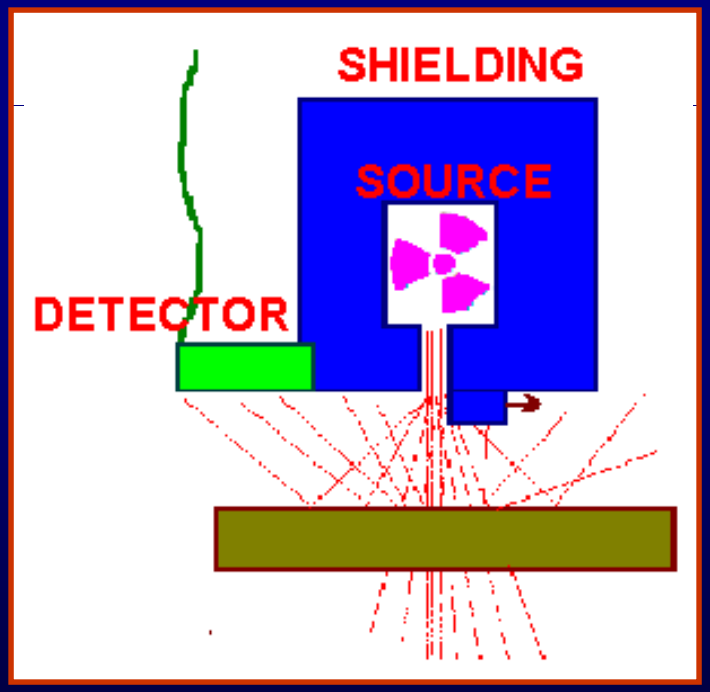
Transmission Gauges



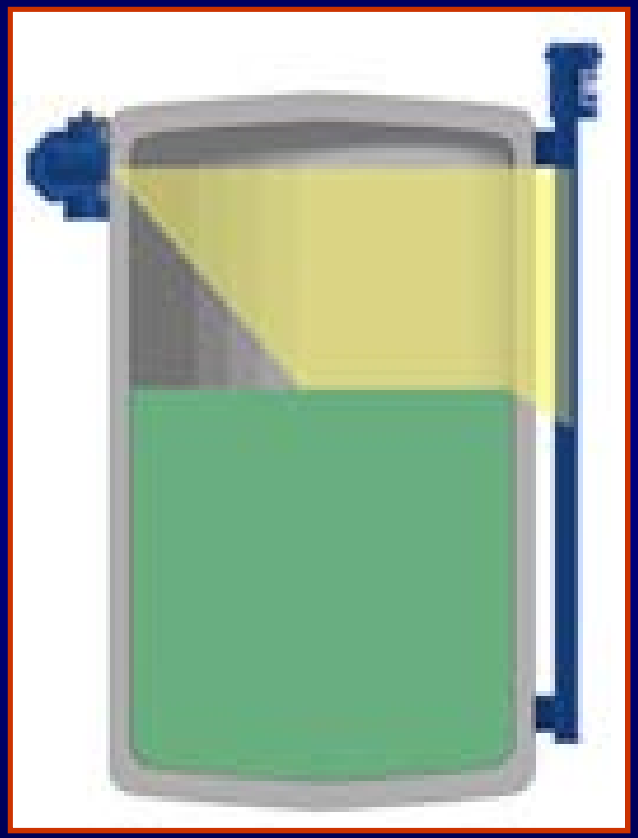
The source is placed on one side of the material to be examined and the detector is placed on the other side so that when the shutter is open, the detector measures how much of the emitted radiation is actually transmitted through the material

Backscatter Gauges

The detector is placed on the same side as the source, measuring the amount of radiation scattered back from the material to the detector



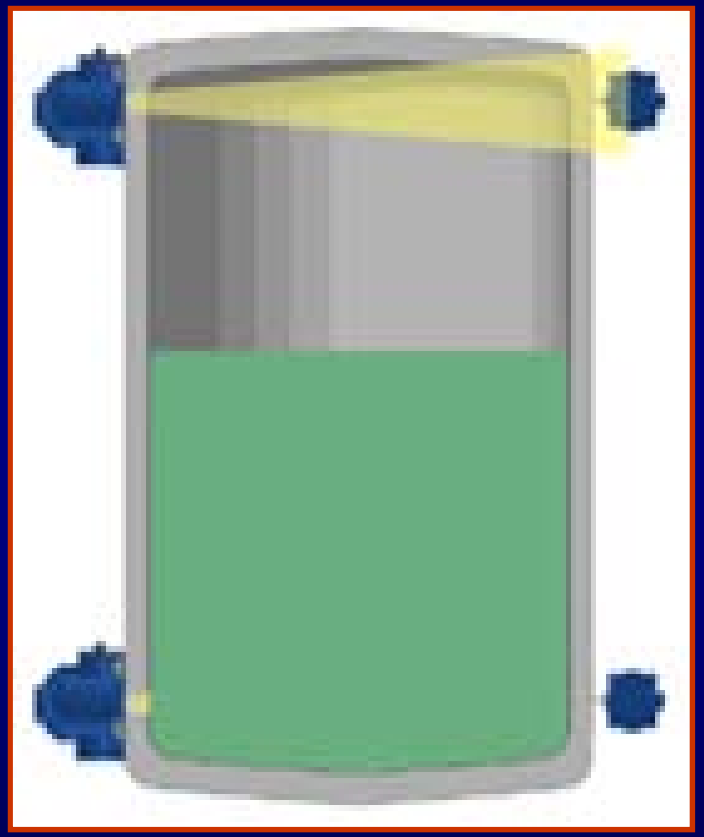
Continuous Level Applications



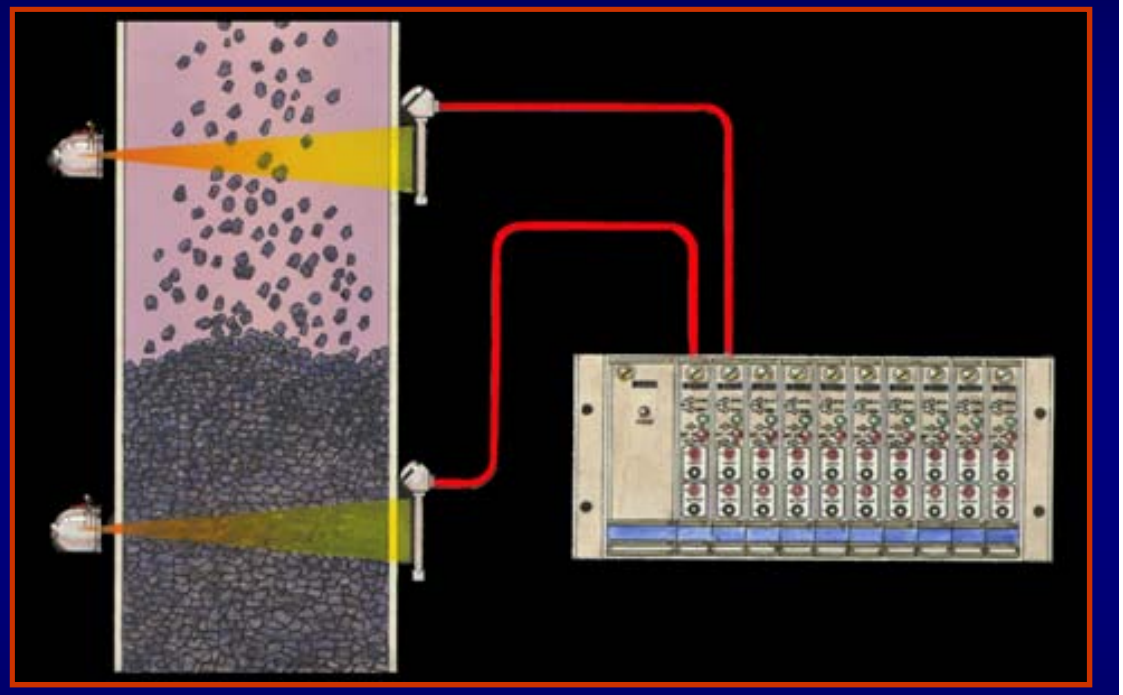
Single source, strip detector

Potato Bin

Point Level Applications

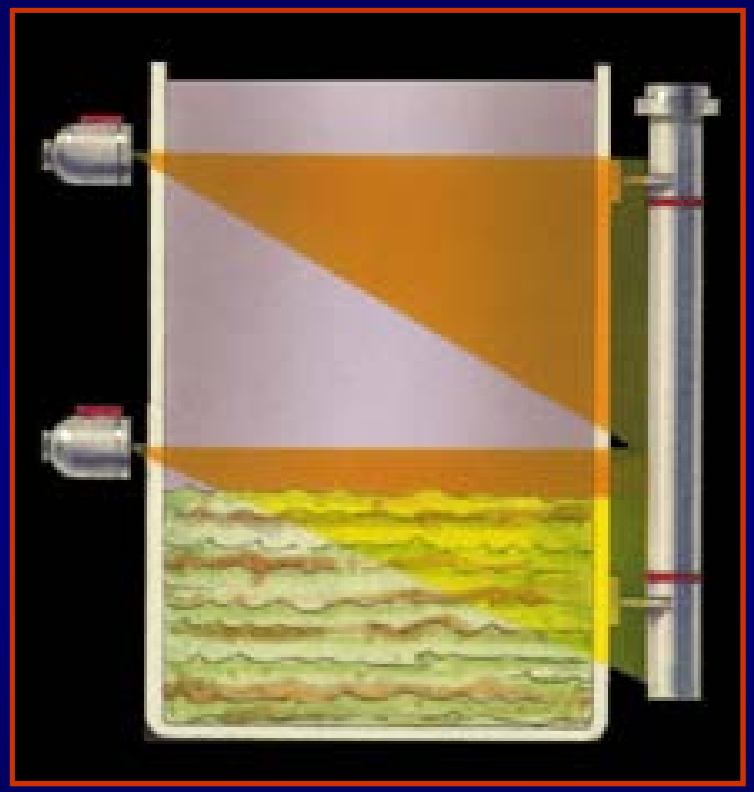


Dual sources & detectors

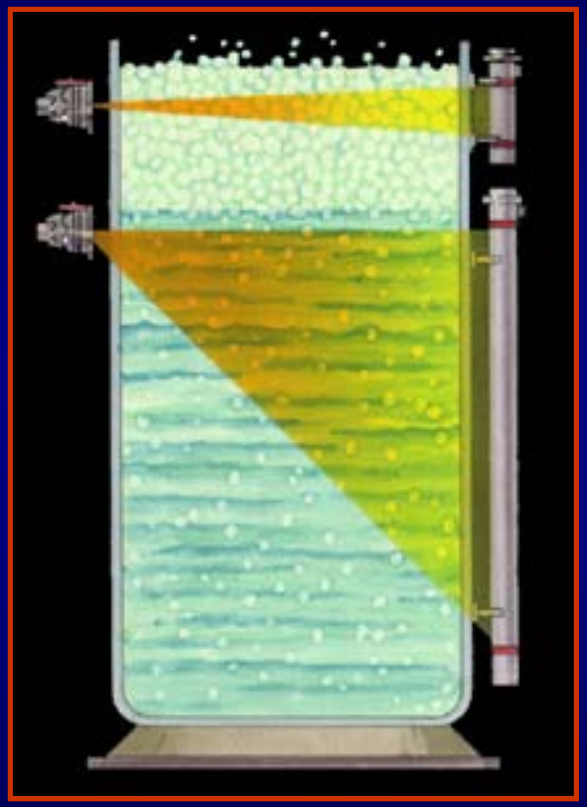


Coal Chute

Other Fixed Gauge Applications



Multi-source, strip detector



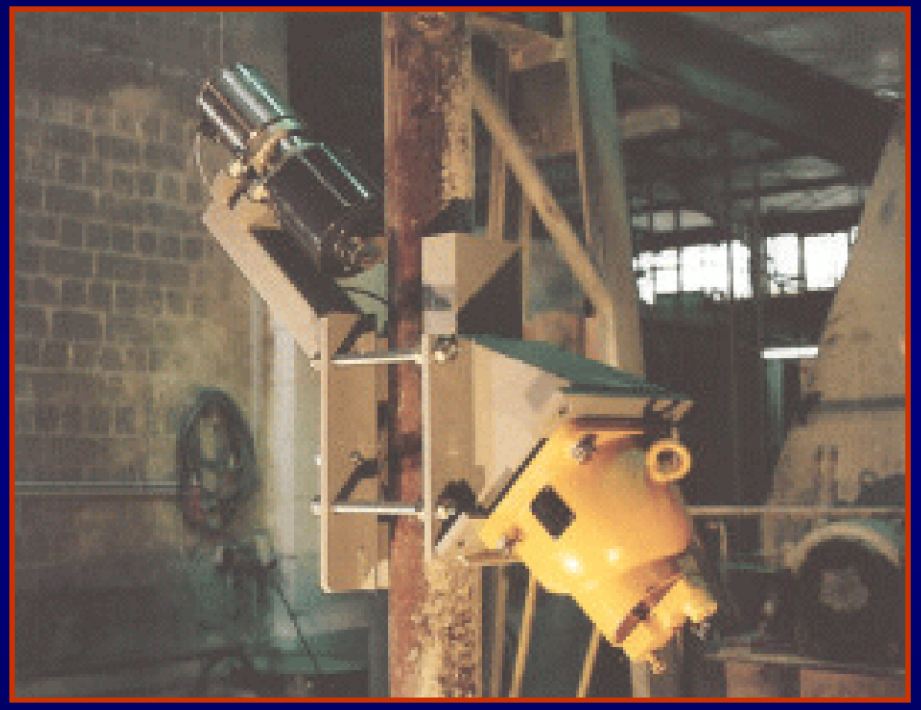
Vapor density configuration

Sample Fixed Gauges

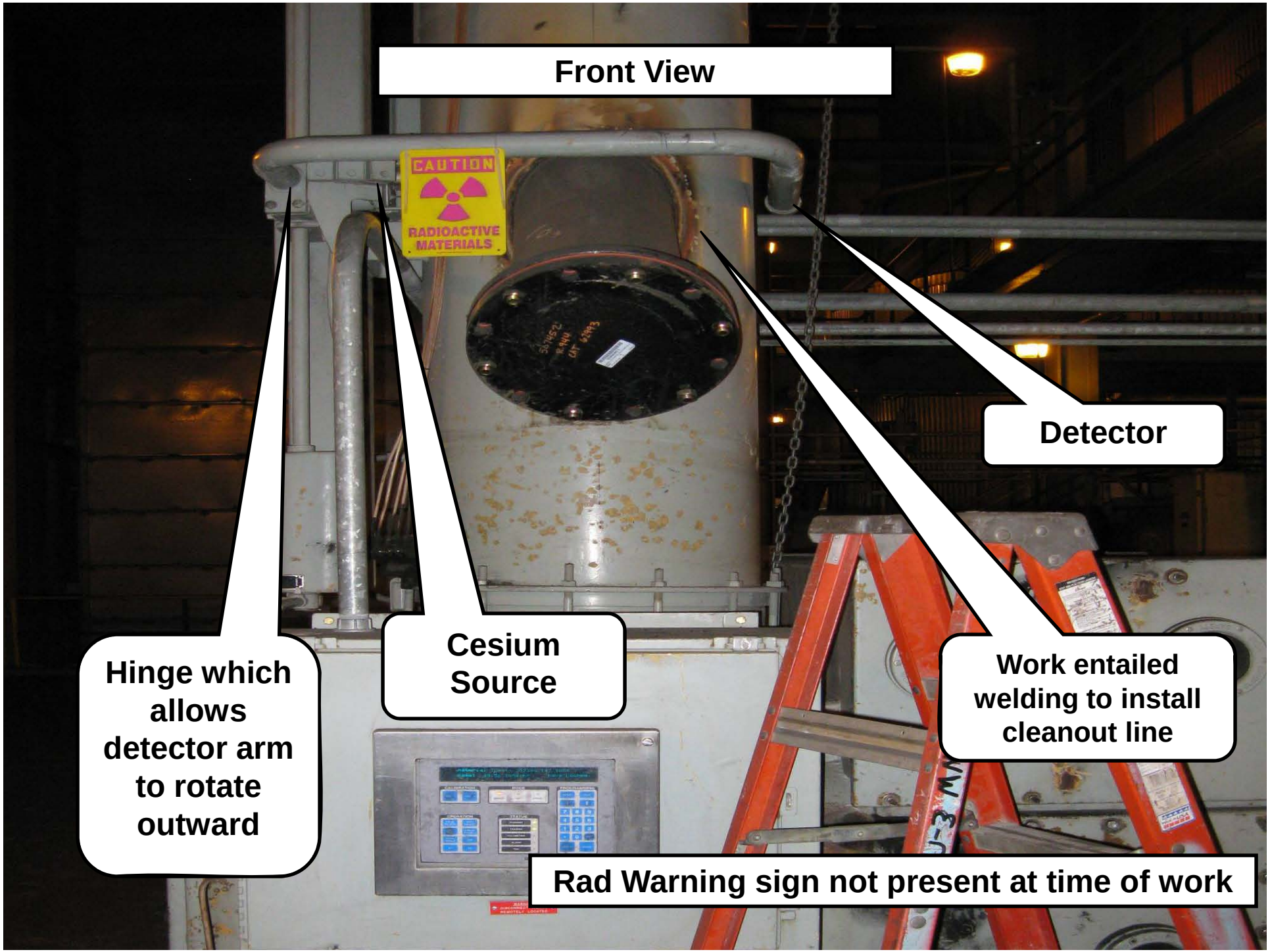
In-line density gauge

Sample Fixed Gauges

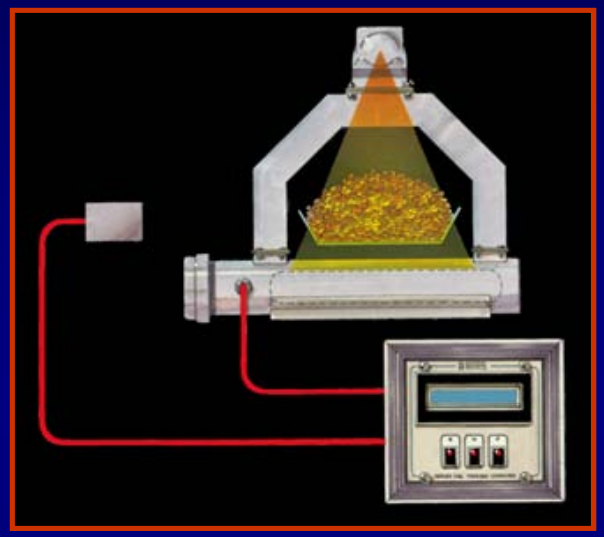
Level gauge mounted on a process tank at a paper mill

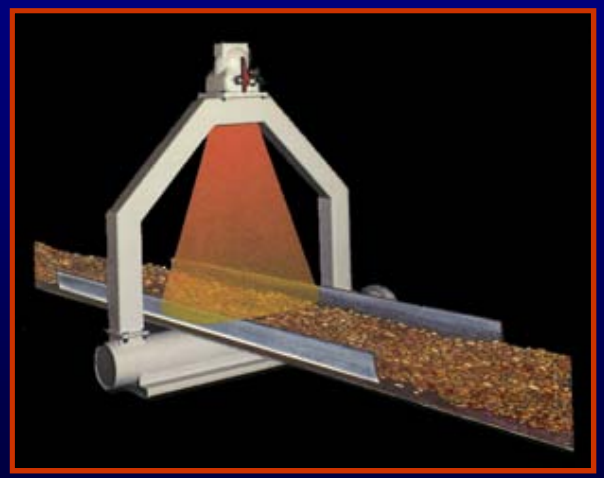


(not always perpendicular to the pipe)


Front View
CAUTION
RADIOACTIVE MATERIALS
Detector
Hinge which allows detector arm to rotate outward
Cesium Source
Work entailed welding to install cleanout line
Rad Warning sign not present at time of work

Gauge Installed on Conveyor Belt





Could someone get between the radiation beam and the detector?

Sample Process Control Gauges

Mineral Weight

Mineral Level

Mud Flow

Liquid Flow

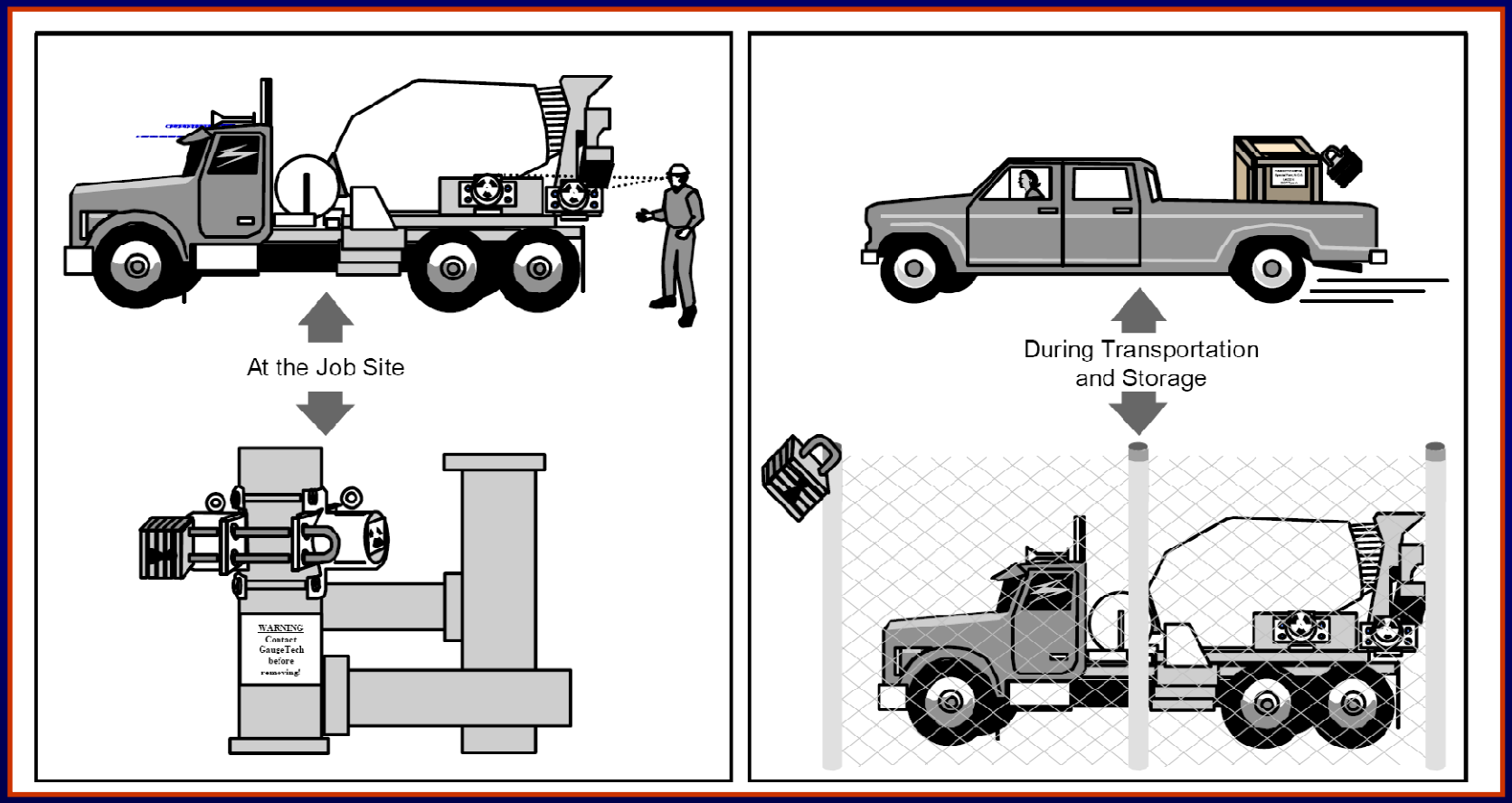
Sample Quality Control Gauges

Film Thickness

Paper Thickness

Beverage Level

Fixed Gauges at Temporary Jobsites

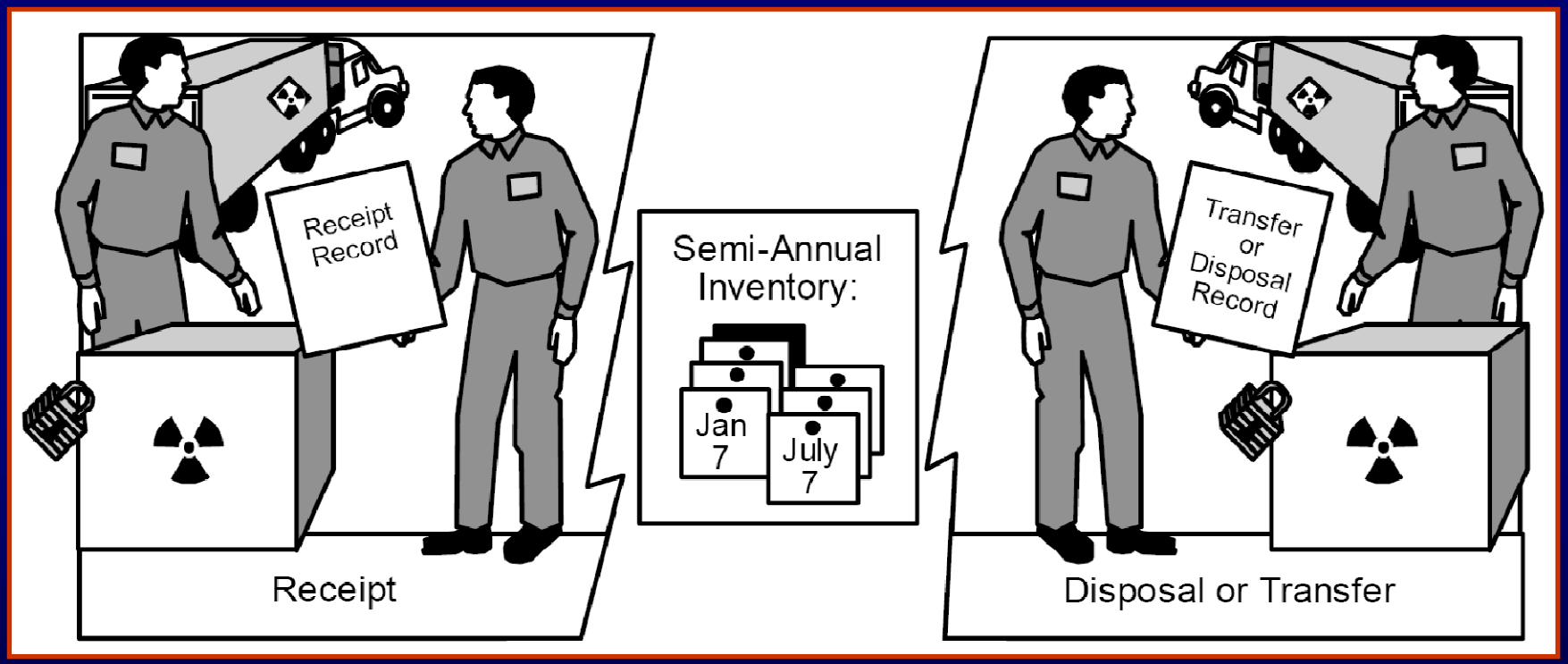


Fixed Gauges at Temporary Jobsites

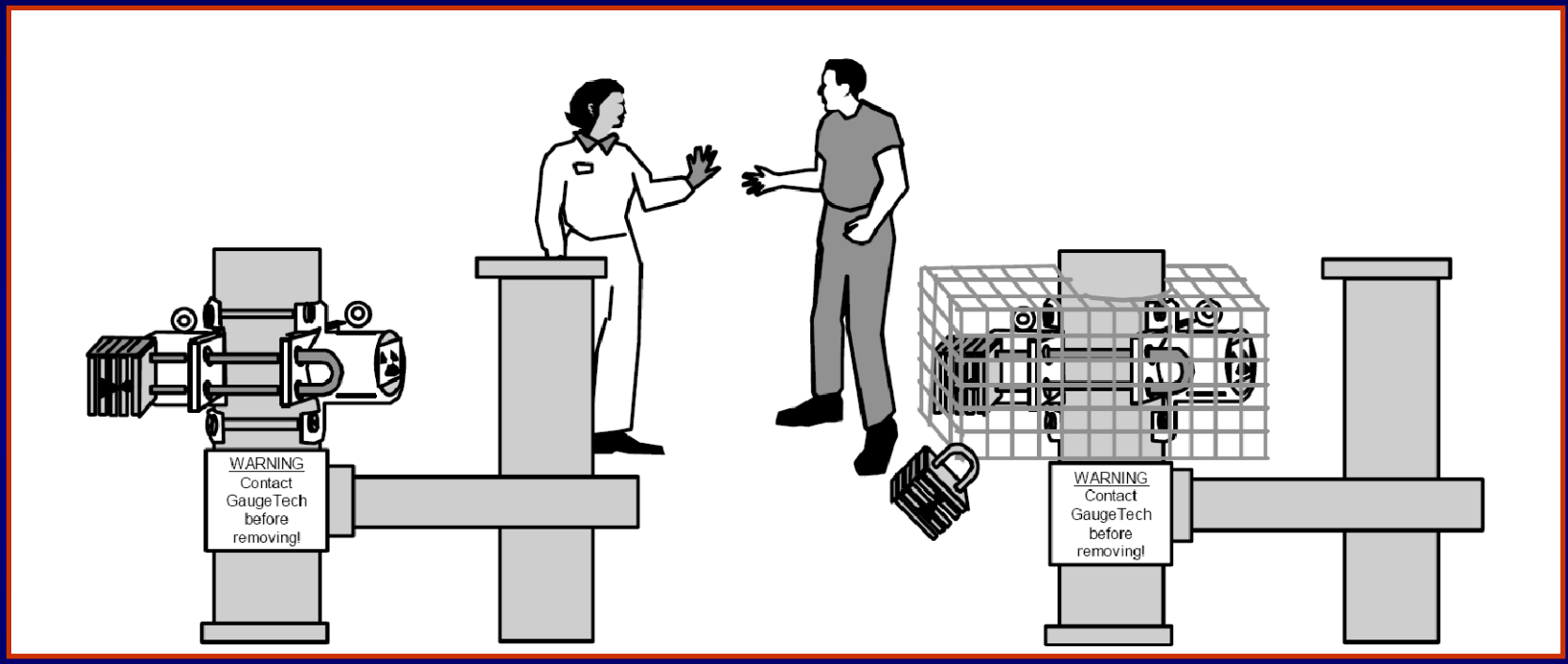
Cement Density Gauge

Receipt, Transfer & Accountability

Cradle to Grave Accountability



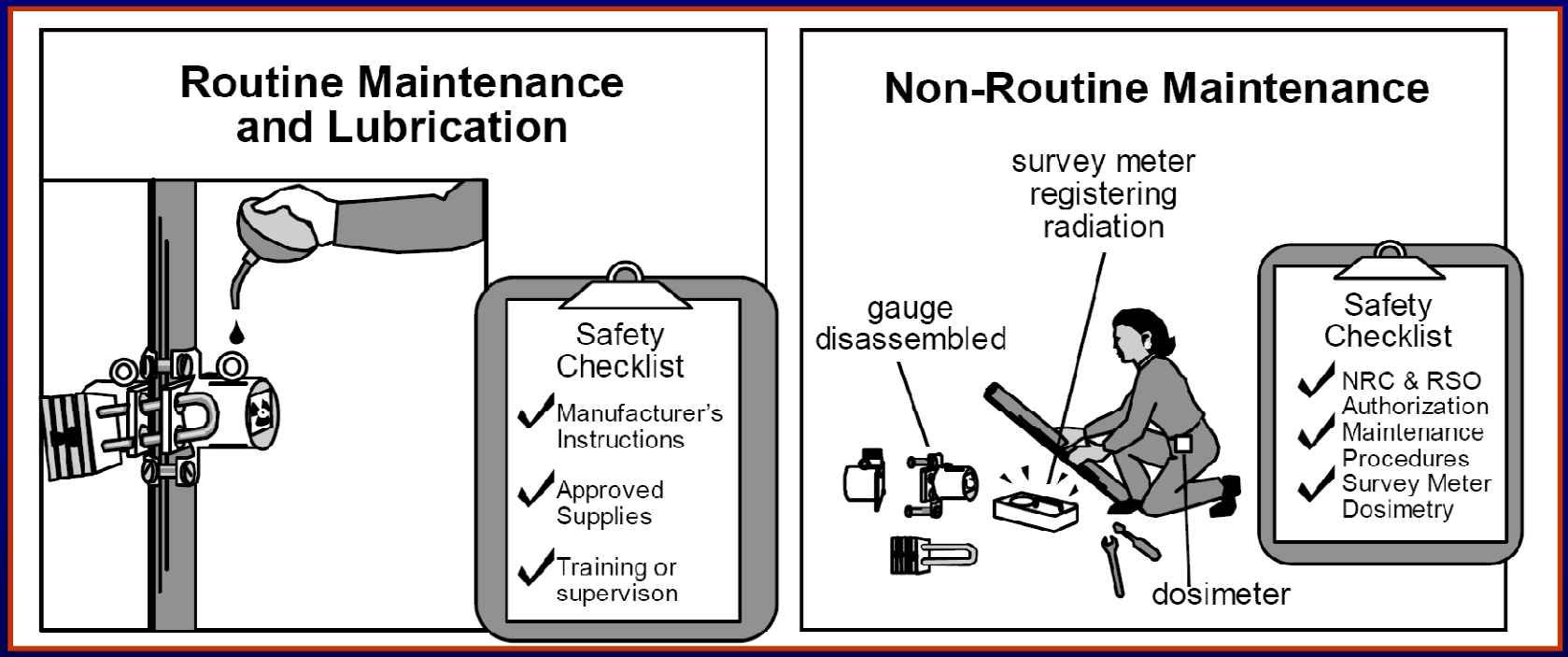
Security



- locked to prevent unauthorized use and theft
- warning sign
- shielded
- inventory record

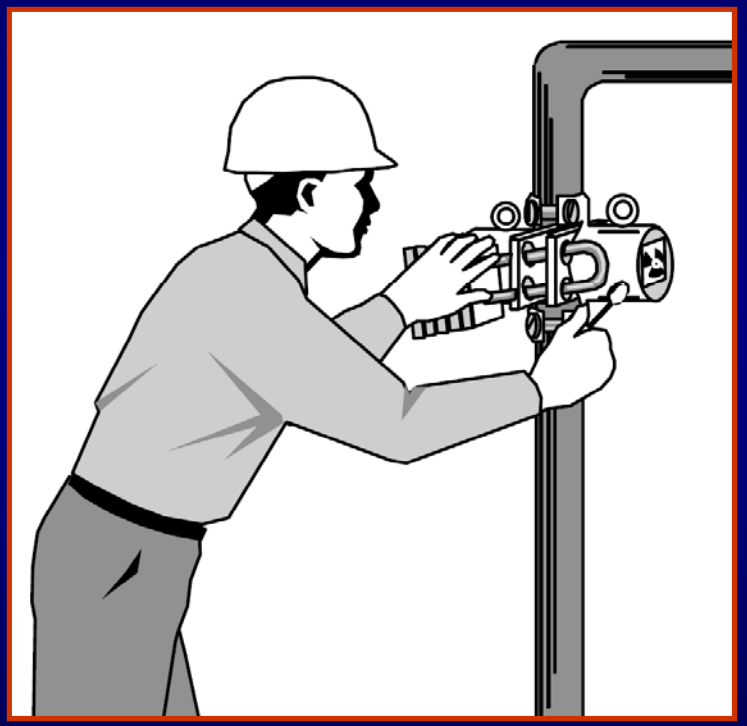
Repair & Maintenance

Fixed Gauges Routine Maintenance and Lubrication

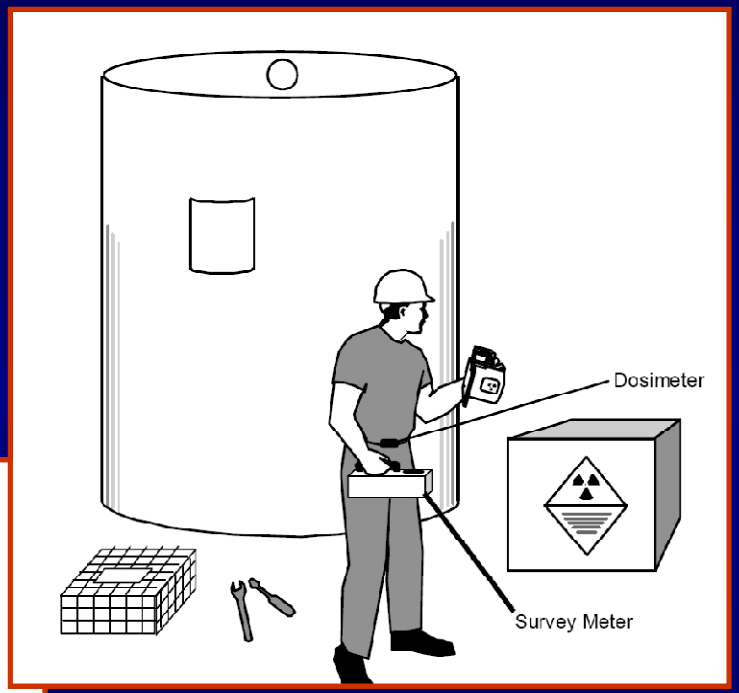


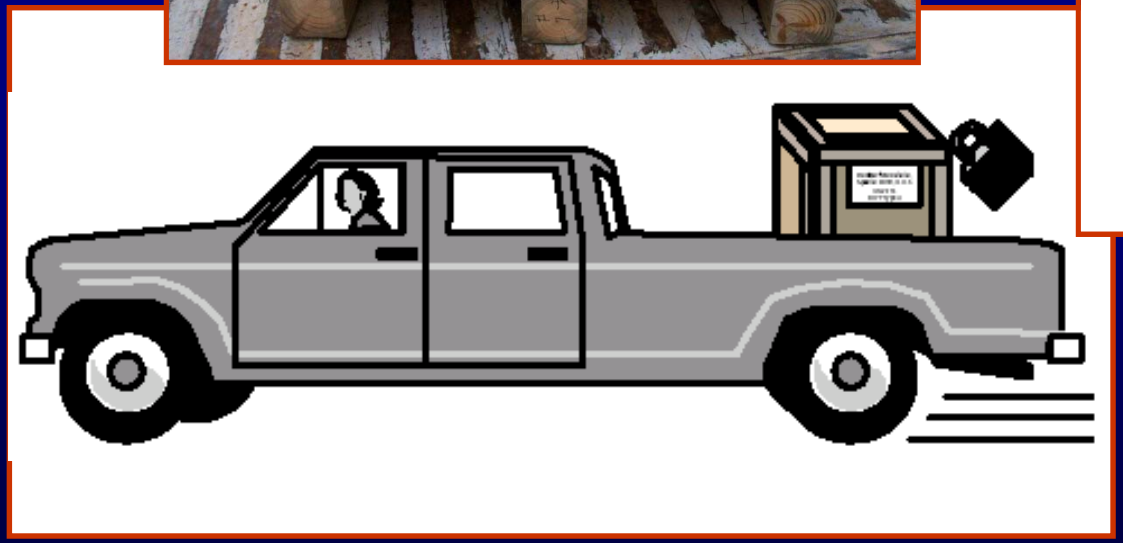
Leak Testing

- Leak tests shall be performed at the frequency required by the manufacturer or license
- Approved analysis methods and instruments shall be used
- Procedures shall exist for removing the source from service if excess contamination is found

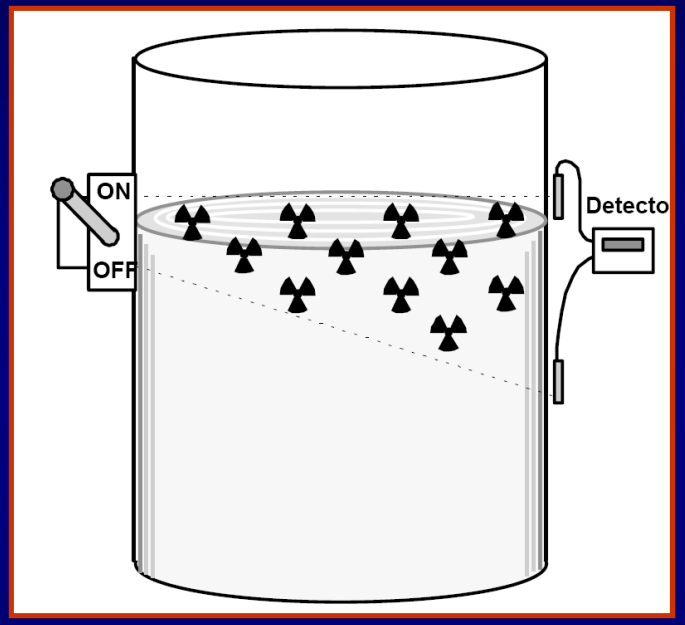


Movement / Transportation

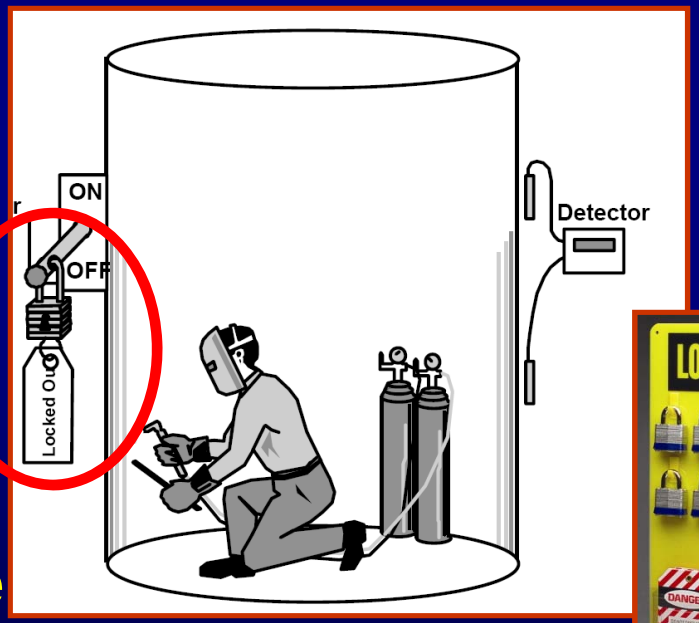




Lockout Procedures



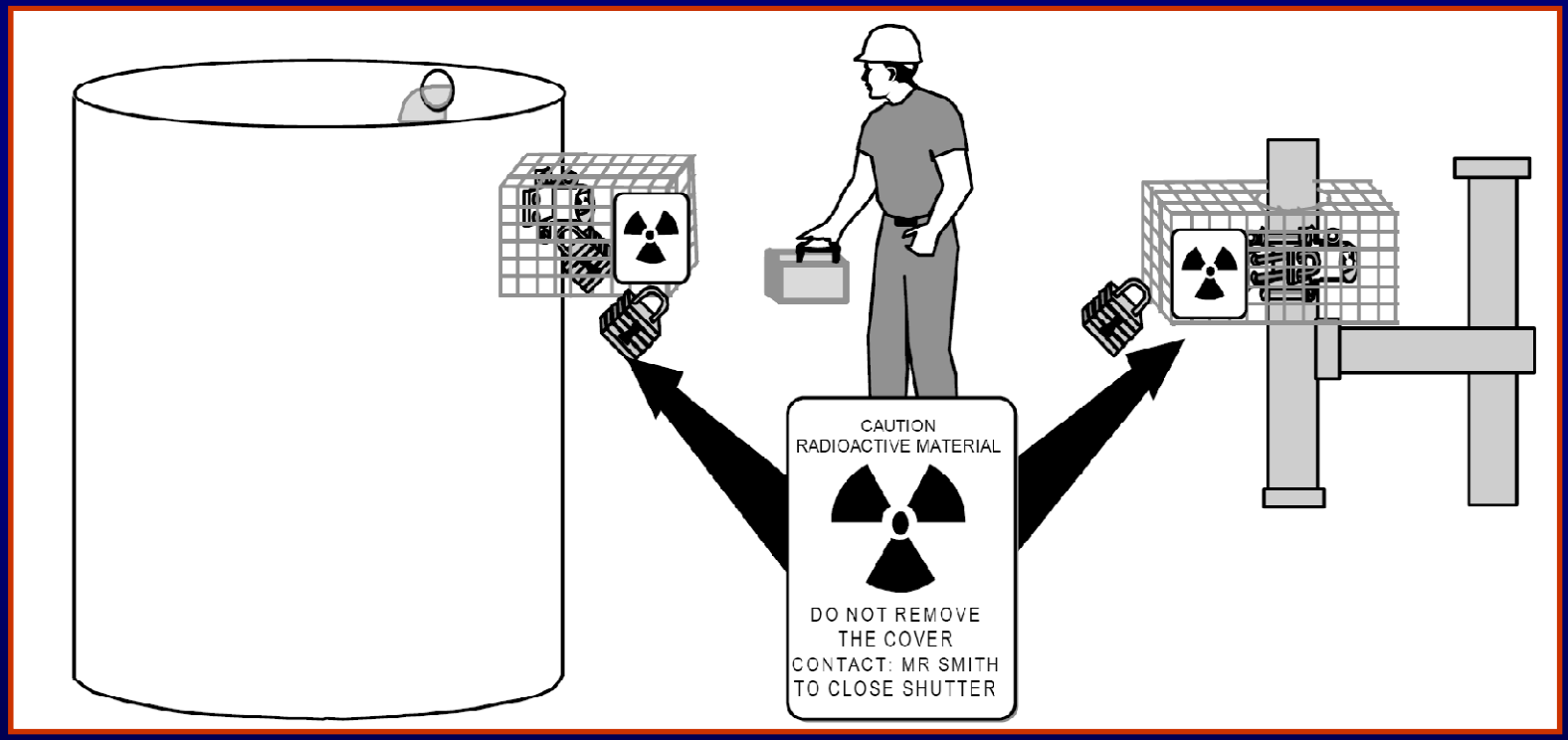
- Fixed gauges are subject to OSHA lock-out/tag-out standard specified in 29 CFR 1910.147



- Many licensees are unaware that their gauges are subject to the OSHA standard; address during inspection

Limiting Public Dose

Who is the "Public"?



Postings


RADIATION
CAUTION
RADIOACTIVE
MATERIALS
RADIATION
CAUTION
RADIOACTIVE
MATERIALS

Industrial RAM Inspection Objectives

- **PERFORMANCE - To determine if licensed activities are being performed in a manner that protects the health & safety of workers, the public & the environment**
- **COMPLIANCE - To determine compliance with regulatory requirements & license conditions**

Generic Tips

- Industrial facilities present a multitude of potential hazards, & most are non-radiological (e.g., moving vehicles, machinery, unsafe scaffolding, spills, electrical hazards, chemicals, explosives, poor lighting, noise, vibration, extreme temperatures, confined spaces)
- Be cognizant of basic OSHA regulations so that you can recognize when conditions are unsafe for others and YOU
- If in doubt about conditions at a site, err on the margin of safety - never take unnecessary risks

Generic Tips

- Most industrial facilities require completion of site-specific safety training & can require inspectors to provide their own safety gear… go prepared.
- In addition to standard OSHA protective personal equipment, it may be necessary to use safety vests, harnesses, respirators or other specialized safety equipment to gain access to areas where industrial RAM is used; use of such equipment may require additional training (HF acid areas, elemental phosphorus areas, etc…)

OSHA Gear

steel toe boots

ear plugs

safety glasses

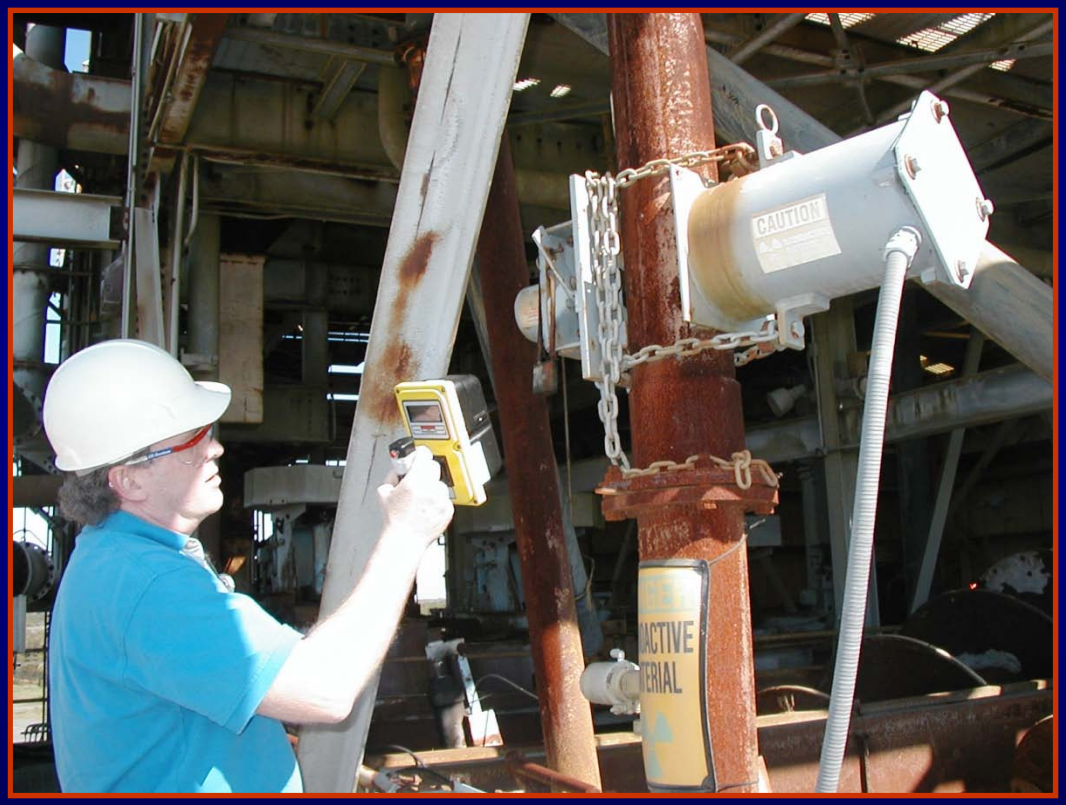
hardhat

Safety harness is required when on ladders & scaffolding

Generic Tips

- Interview as many users as possible; you will learn more from them than from the RSO
- Observe the licensee using the device, performing licensed activities; if no work is being done, ask for demonstrations (leak tests, shutter checks, maintenance, surveys, etc..)
- Users are typically not experts; sometimes they won't understand a question, so rephrase it in plain language; don't just assume they are untrained
- Cross-check records against statements

Fixed Gauge Inspections



Evaluate environmental conditions to determine what hazards (to the gauges) are present

Combine radiation measurements with inspection of the physical condition of gauge, labels, supports, etc.

Environmental Damage

Harsh conditions can obscure warning labels, damage gauge housings and supports, and compromise source shielding

Key Performance Indicators
Fixed Gauges

- **Training - Root cause of most problems**
  - **Examples**
    - **Are operators aware of user limitations?**
    - **Do operators know/follow lock-out procedures?**
    - **Do they know how to respond to an emergency?**
    - **Are there unauthorized, un-informed workers removing and/or working on gauges?**
- **Security & accountability - Especially post 9/11**
- **Operating procedures - Lapses in following lock out procedure have resulted in worker exposures**

Emergency Intervention Requirements

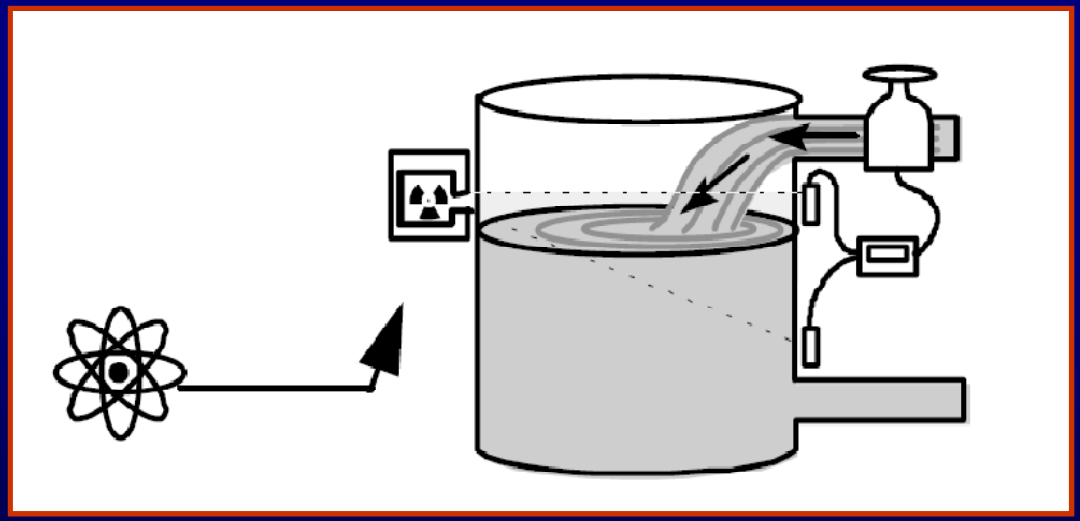
Examples of potential accidents in nuclear gauging:

- **Melting of the gauge and source**
- **Lost or stolen source**
- **Physical damage to the gauge**
- **Shutter stuck in the open or shut position**
- **Transportation accident**
- **Radiation overexposure of persons**
- **Leaking source**

Accidents Involving a Nuclear Gauge

Source - ^{137}Cs (111 GBq)

- **Source capsule was corroded by environmental conditions (sea air) which caused leakage.**



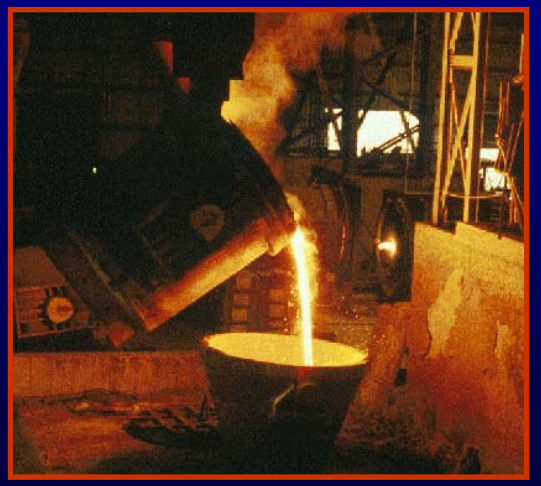
Accidents Involving a Nuclear Gauge

Source - ^{85}Kr (10 GBq)

- Servicing of the gauge with the shutter open

Source - ^{60}Co (10 GBq)

- Hot molten metal leaked out of process onto gauge and melted the shielding around the gauge

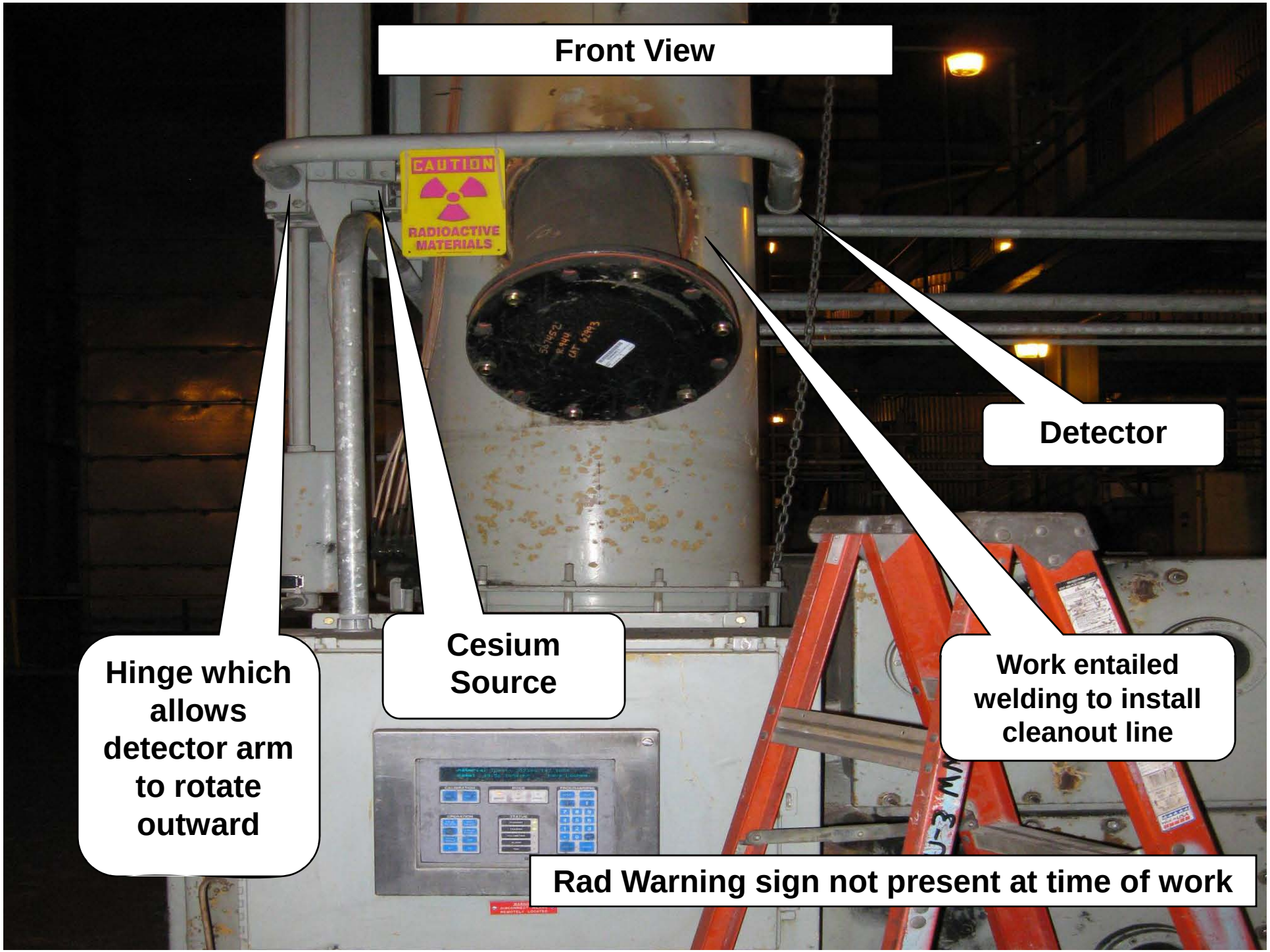


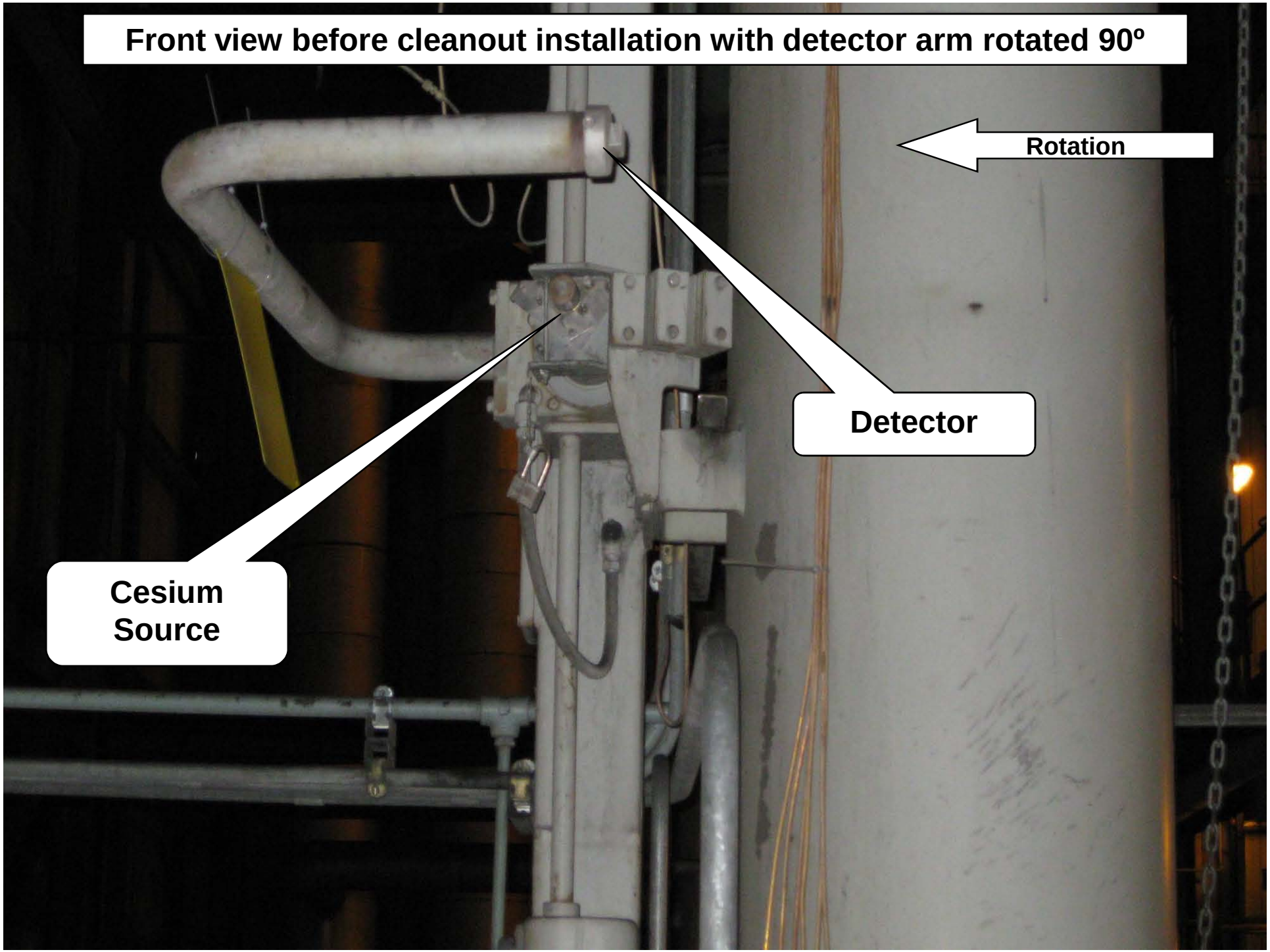
Gauge use at power plant

- Fixed nuclear gauges containing a nominal 50 millicuries of Cs-137 are used at the coal burning power plant to monitor coal flow through coal chutes.

Overexposure to several members of the public

- A group of 14 welders were working at the power plant in the immediate vicinity of the gauges.
- 6 welders received greater than 100 millirem exposure over a 10 day period.


Front View
CAUTION
RADIOACTIVE MATERIALS
Detector
Hinge which allows detector arm to rotate outward
Cesium Source
Work entailed welding to install cleanout line
Rad Warning sign not present at time of work


Front view before cleanout installation with detector arm rotated 90º
Rotation
Detector
Cesium Source


Side View showing orientation after rotation
CAUTION
RADIOACTIVE MATERIALS
Cesium Source
SECOAL

Probable Doses

RSO initially estimated doses of exposed workers to range from 60 to 1700 millirem.

After performing time motion studies and interviewing workers, the doses received by the welders were determined to be between 2 millirem and 650 millirem

The NRC's estimates of radiation exposure were slightly lower than the licensee's estimates.

Response to Event

NRC Region IV dispatched a Special Inspection Team to the Laramie River Station to determine the causes of the event and to independently verify the probable radiation exposures to the welders. The Team also verified corrective actions taken and planned to prevent recurrence.

By the conclusion of the inspection, the Team identified several apparent violations, including one that was not associated with the event. These violations included: 1) the failure to post warning signs where nuclear gauges were used, 2) overexposure of members of the public, 3) failure to report fire damage to a nuclear gauge, 4) failure to close the shutter of nuclear gauges prior to working around them, and 5) the failure to wear personnel monitoring devices when performing shutter checks on nuclear gauges.

OTHER INDUSTRIAL RAM USES

Other Industrial RAM Uses

- There are numerous applications of radioactive material in industry besides portable and fixed gauges such as ionizing devices, calibrators, self-luminous devices, diagnostic devices and R&D applications
- Let's take a look at some

Ionizers

- Smoke detectors use a small Am-241 source to ionize air molecules passing between a pair of electrodes, permitting a small current to flow between the pair
- if smoke particles from a fire enter the space, they reduce the current flow by adhering to the ionized molecules; the drop in current sets off an alarm

Ionizers
Static Eliminators

- Most consumer & commercial static eliminators use Po-210, though some commercial ones use Sr-90 - older models used Am-241 & Ra-226

Po-210 static eliminators

Ionizers
ECDs in GCs

- Gas chromatography (GC) - a technique used to separate volatile organic compounds
- Electron capture detector (ECD) used to analyze organic molecules such as PCBs & pesticides
- Most ECDs use 15 mCi Ni-63 plated/foil sources; older models used H-3 sources (few remain in operation)
- ECDs distributed as Generally Licensed (GL) or Specifically Licensed (SL) depending on source access
- Common for licensees to have a mix of GL & SL ECDs; most new ones are GL

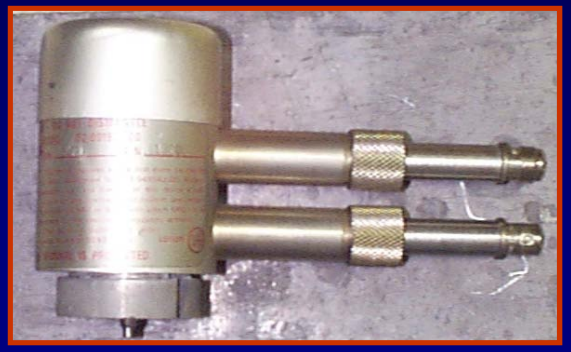
Ionizers
ECDs in GCs

analyzing samples for PCBs

ECD with 15 mCi ^{63}Ni plated foil source

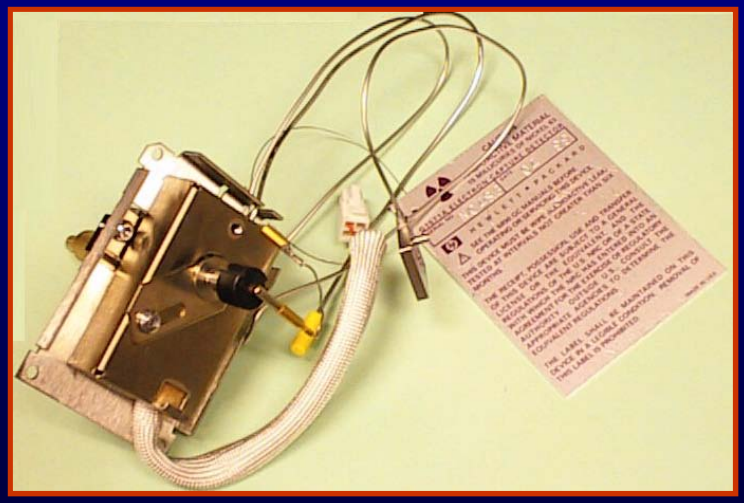
ECDs

ECD label tags are important for maintaining control - ECDs often stored outside of GCs - tags may come off

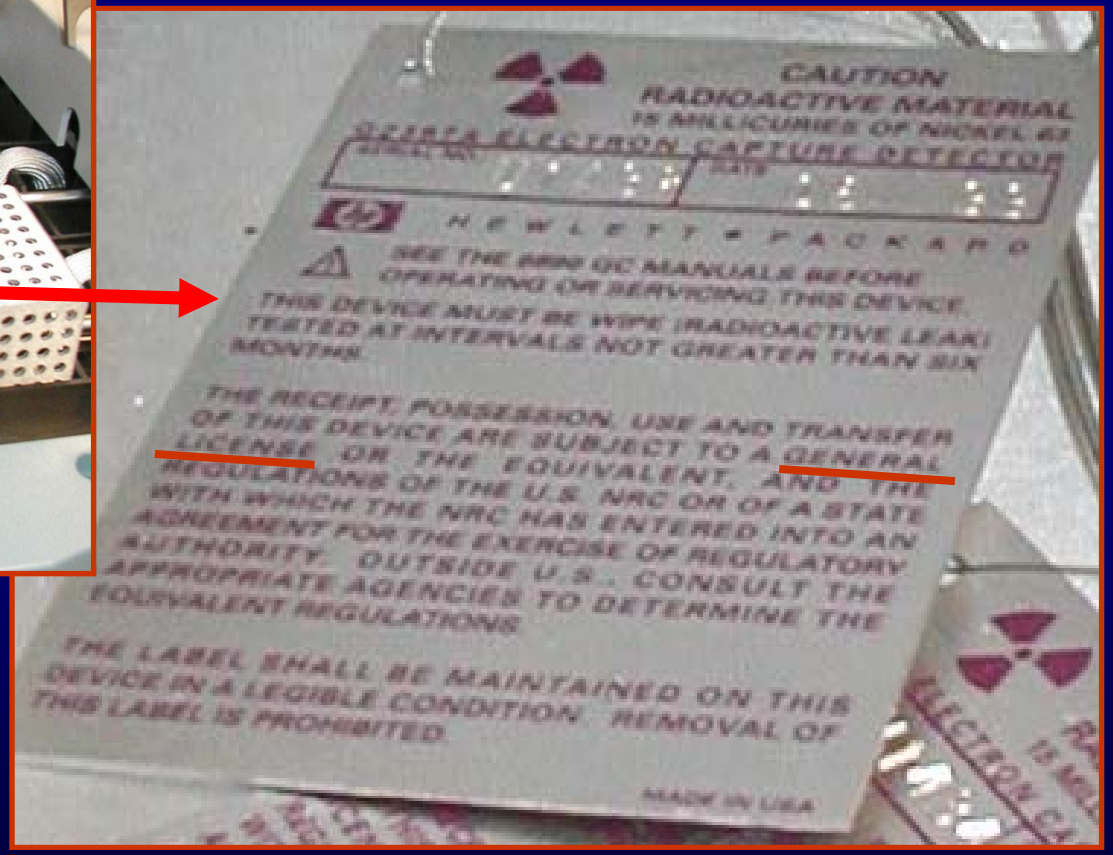


Easy to see how they can be mistaken for junk or spare parts

ECD exchange assembly



ECDs

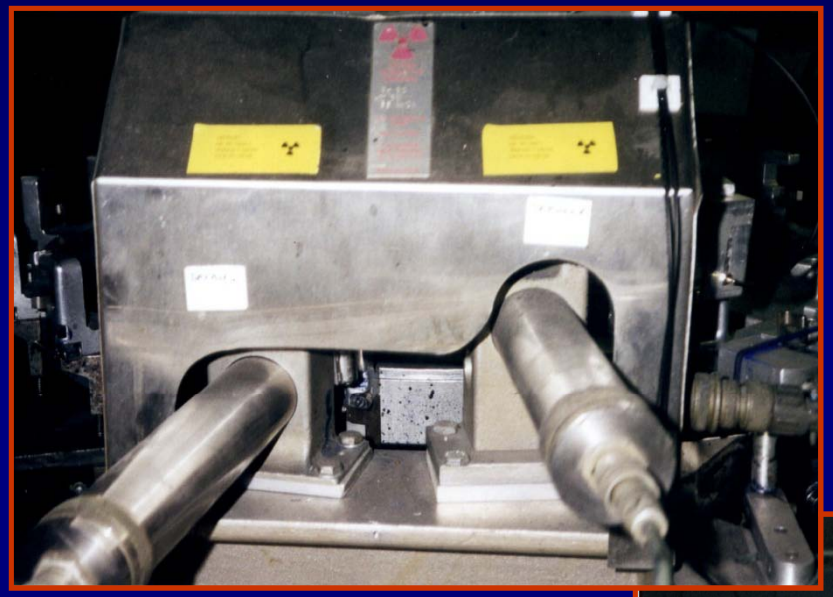


ECD General License labels

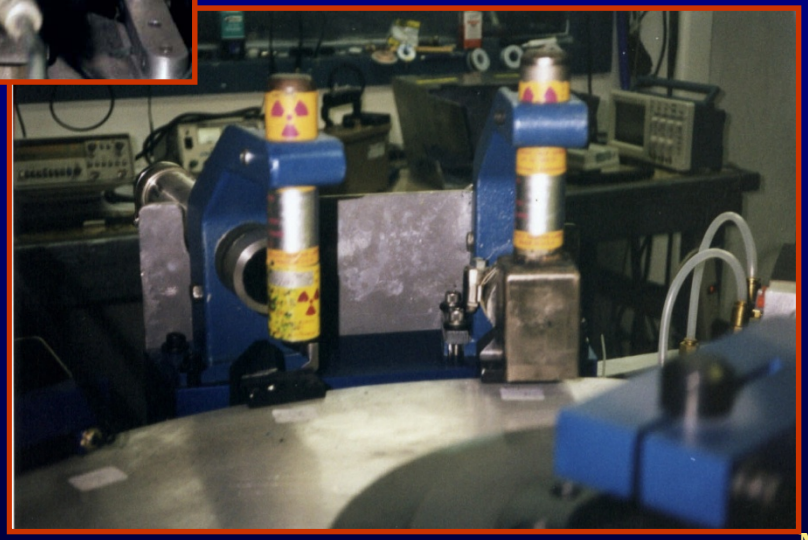
Self Luminous Devices

Tritium exit signs - even GL models contain multi-curies

Custom Applications



Sr-90 source & detector array



Grenade Fill Level Gauge

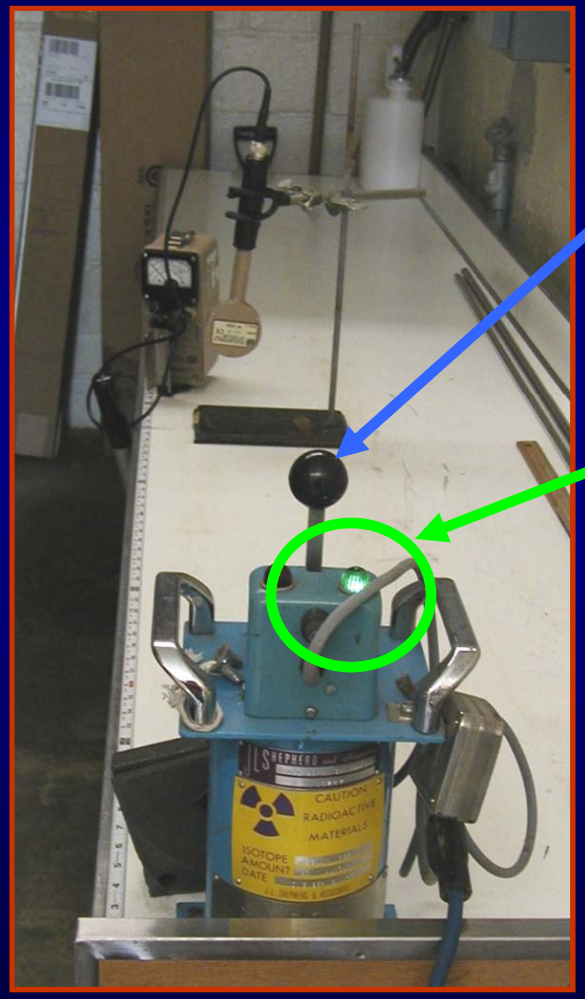
Calibrators

- Used to calibrate survey meters, alarming ratemeters, pocket dosimeters, etc.
- Typically use ^{137}Cs, though some models use ^{60}Co or, for neutron calibrations, ^{252}Cf
- Calibrators may be GL (for mCi sources) or SL (mCi & Ci sources)
- Used by instrument manufacturers, commercial calibration vendors and licensees performing calibrations in-house

Survey Meter Calibrators

shielding to reduce mR/hr

Survey Meter Calibrators

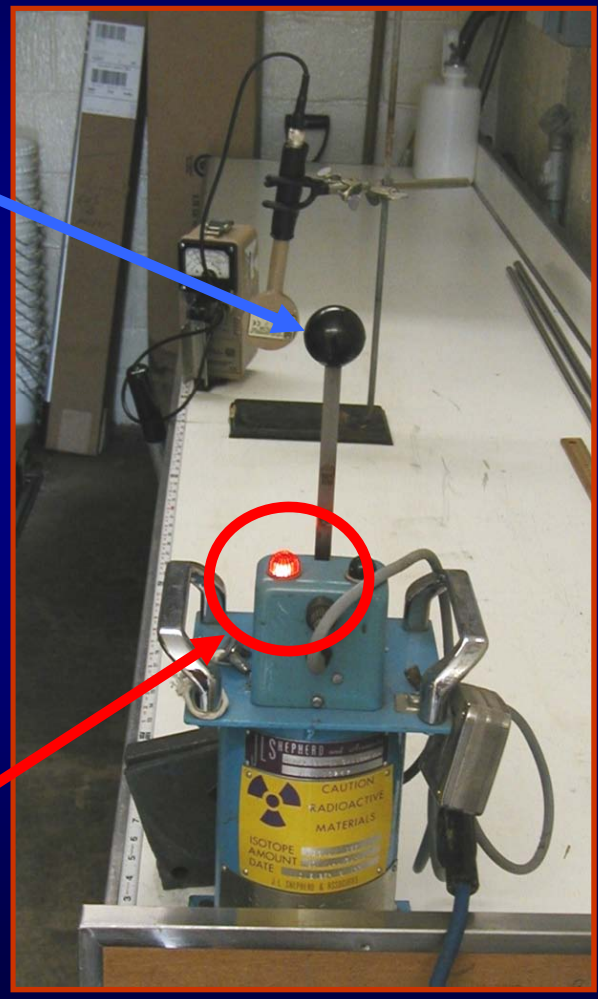


Shutter Handle

Down Up

Green Light
Shutter
Closed
(safe)

Red Light
Shutter
Open
(danger)



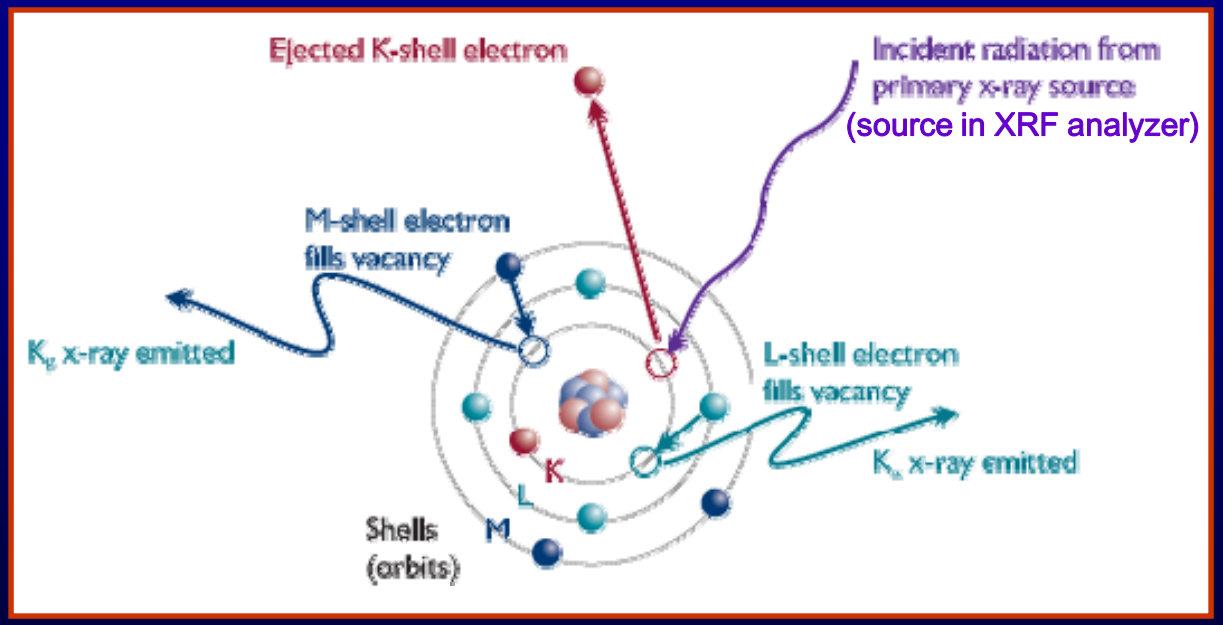
Pocket Dosimeter "Calibrators"

6-Hole PD Calibrator (Exempt)

12-Hole Pocket Dosimeter Calibrator (Generally Licensed)

XRF (X-Ray Fluorescence) Analyzers

XRF analyzers use one or more small (mCi) sources to irradiate samples - electrons, protons or x-rays emitted by the source eject inner bound orbital electrons leaving voids - as outer shell electrons fill the vacancies, the material fluoresces (emits characteristic x-rays) with specific energies enabling ID of the sample

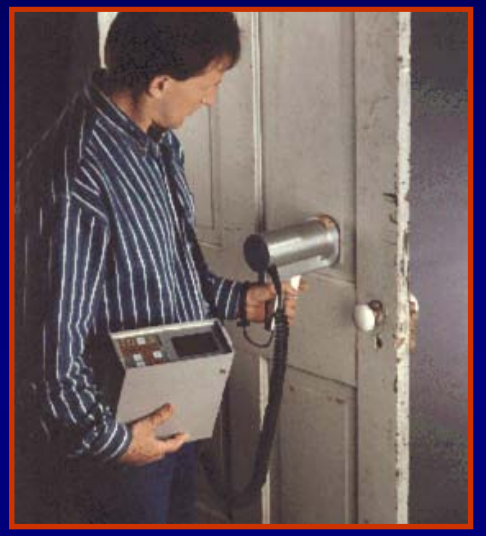


XRF Analyzers

Warrington lead paint analyzer

Common sources ^{55}Fe, ^{57}Co, ^{109}Cd, ^{153}Gd, ^{38}Pu, ^{241}Am & ^{252}Cf

Beta emitters used are ^{3}H & ^{147}Pm



Niton uses 30-50 mCi ^{109}Cd, ^{55}Fe or ^{241}Am sources

Gamma Scanners

- Co-60 (1 Ci) or Cs-137 (1.6 Ci) used to scan cargo containers for for hidden contraband
- Used by U.S. Customs Service & FL Dept. of Agriculture

Illegal immigrants detected inside truck

New concern, post 9/11: RAM could be used as a "dirty bomb" - radiological dispersion device (RDD)

Many industrial RAM sources are considered 'high risk' for an RDD (e.g., industrial radiography, irradiator & high-activity fixed gauge sources)

THE END