Chapter 8

Applications & Events

Objectives

- Understand the two types of licenses for use of radioactive material: general and specific
- Review NRC regulations for use of radioactive material and for protecting workers and members of the public found in Title 10 of the CFR
- Understand the role and significance of Agreement States
- Review the applications of radioactive materials in medicine and industry
- Understand types of events involving radioactive material

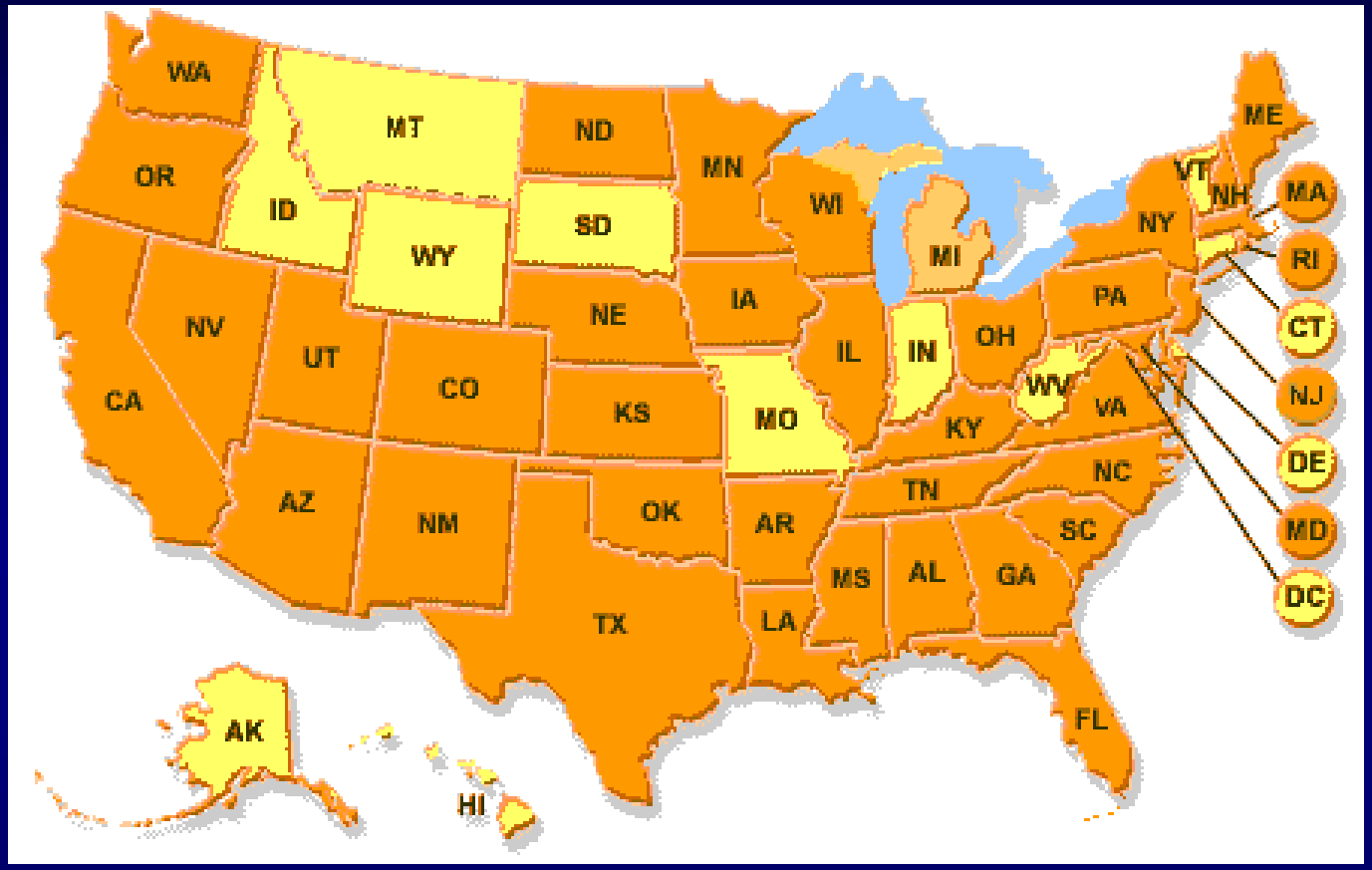
Regulations

NRC Regulations

CFR Title 10 "Energy" NRC Parts 0-199 (Note: the following list is not complete)

- Part 20, "Standards for Protection Against Radiation"
- Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material"
- Part 31, "General Domestic Licenses for Byproduct Material"
- Part 32, "Specific Domestic Licenses to Manufacture or Transfer Certain Items Containing Byproduct Material"
- Part 33, "Specific Domestic Licenses of Broad Scope for Byproduct Material"
- Part 34, "Licenses for Industrial Radiography and Radiation Safety Requirements for Industrial Radiographic Operations"
- Part 35, "Medical Use of Byproduct Material"
- Part 36, "Licenses and Radiation Safety Requirements for Irradiators"
- Part 39, "Licenses and Radiation Safety Requirements for Well Logging"
- Part 40, "Domestic Licensing of Source Material"
- Part 50, "Domestic Licensing of Production and Utilization Facilities"
- Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste"
- Part 63, "Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada"
- Part 70, "Domestic Licensing of Special Nuclear Material"

Agreement States



Agreement States	Non-Agreement States	Letter of Intent

Note: NRC maintains regulation of nuclear power plants, major fuel cycle facilities and most federal facilities (e.g. VA, Air Force, Navy) in *all* states.

Applications

Applications

- Industrial radiography
- Fixed gauges
- Portable gauges
- Well-logging
- Irradiators
- Medical and research facilities
- Fuel cycle facilities
- Commercial and research reactors
- Waste processing and disposal

Sealed Source Applications

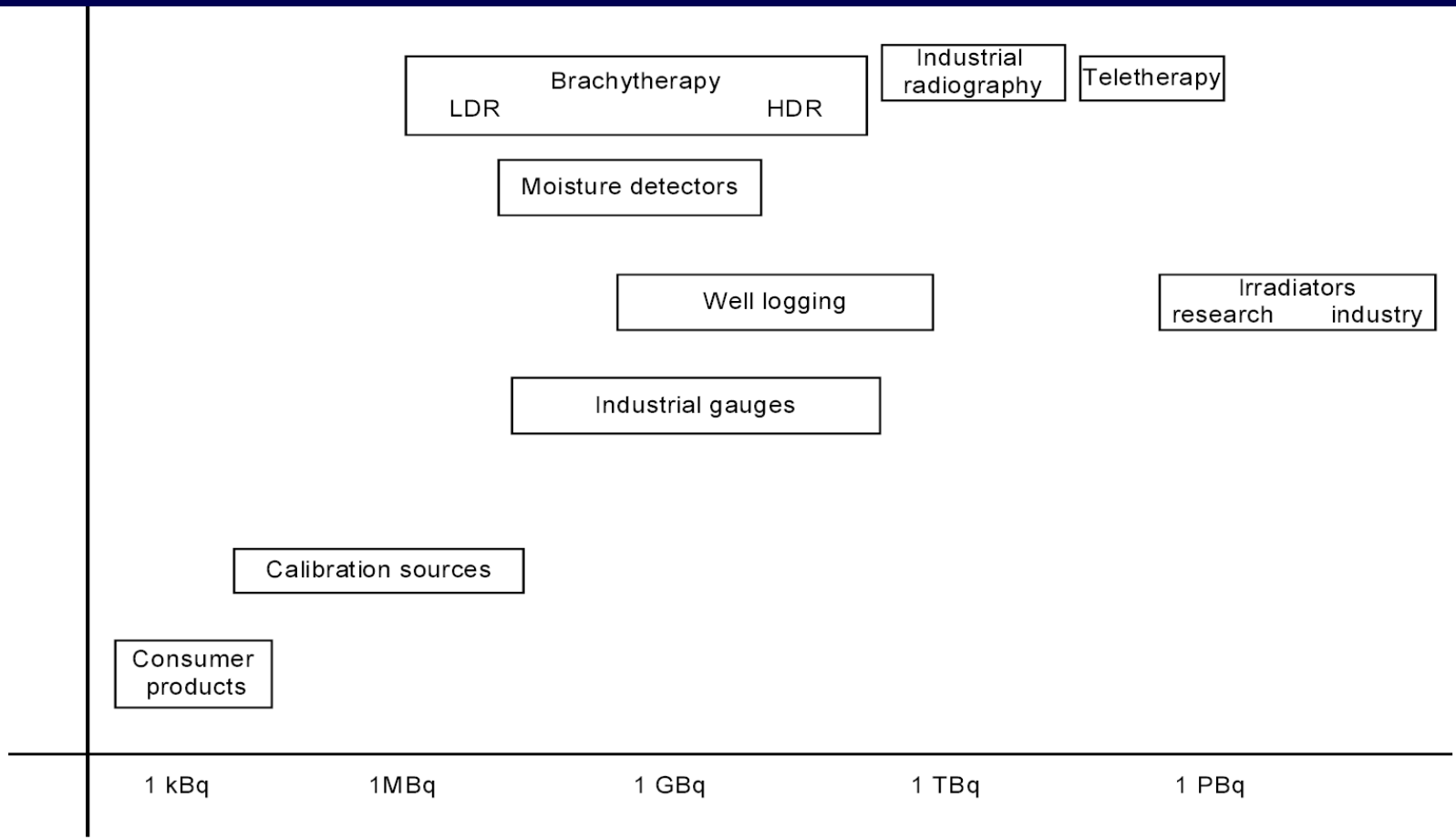
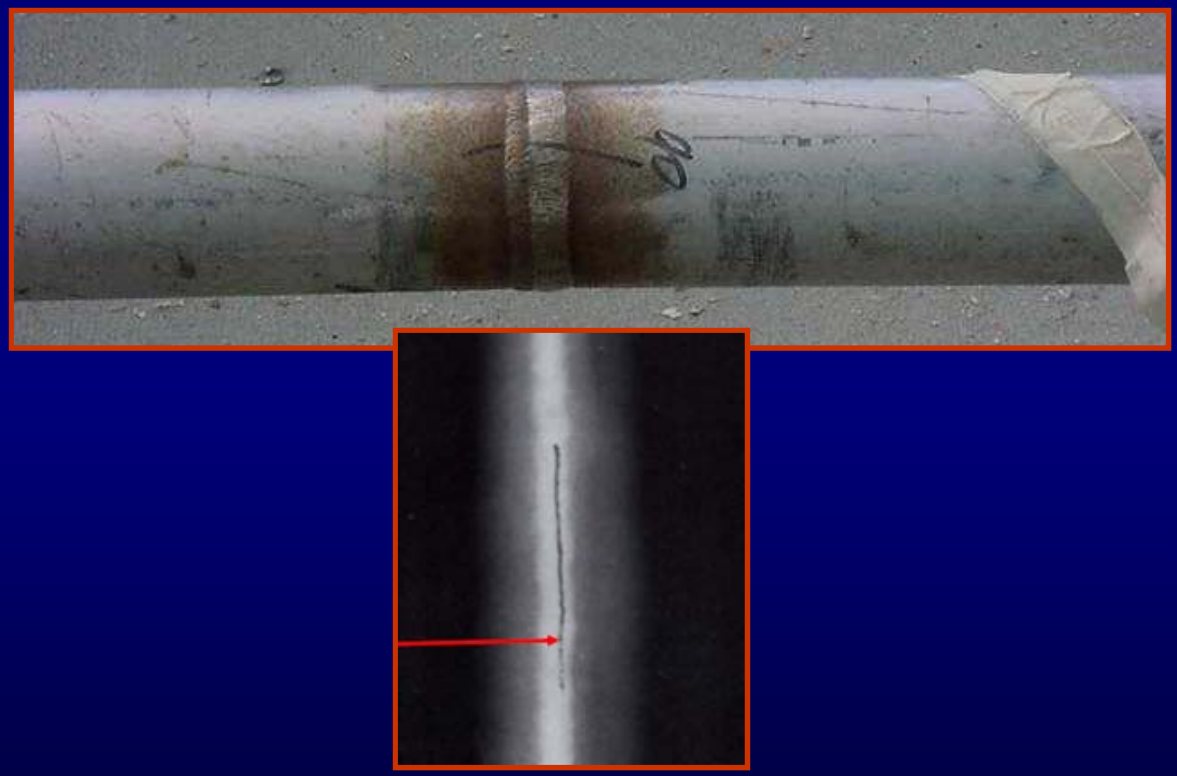


FIG. 1. Activity ranges for some important applications of sealed sources.

Industrial Radiography



Industrial Radiography

- Industrial radiography is used to take an "X-ray," of a pipe weld or other component.
- A specific license is required to conduct industrial radiography. This requires special training and operational experience.
- Radiography is subject to NRC (10 CFR 34) or Agreement State licensing.

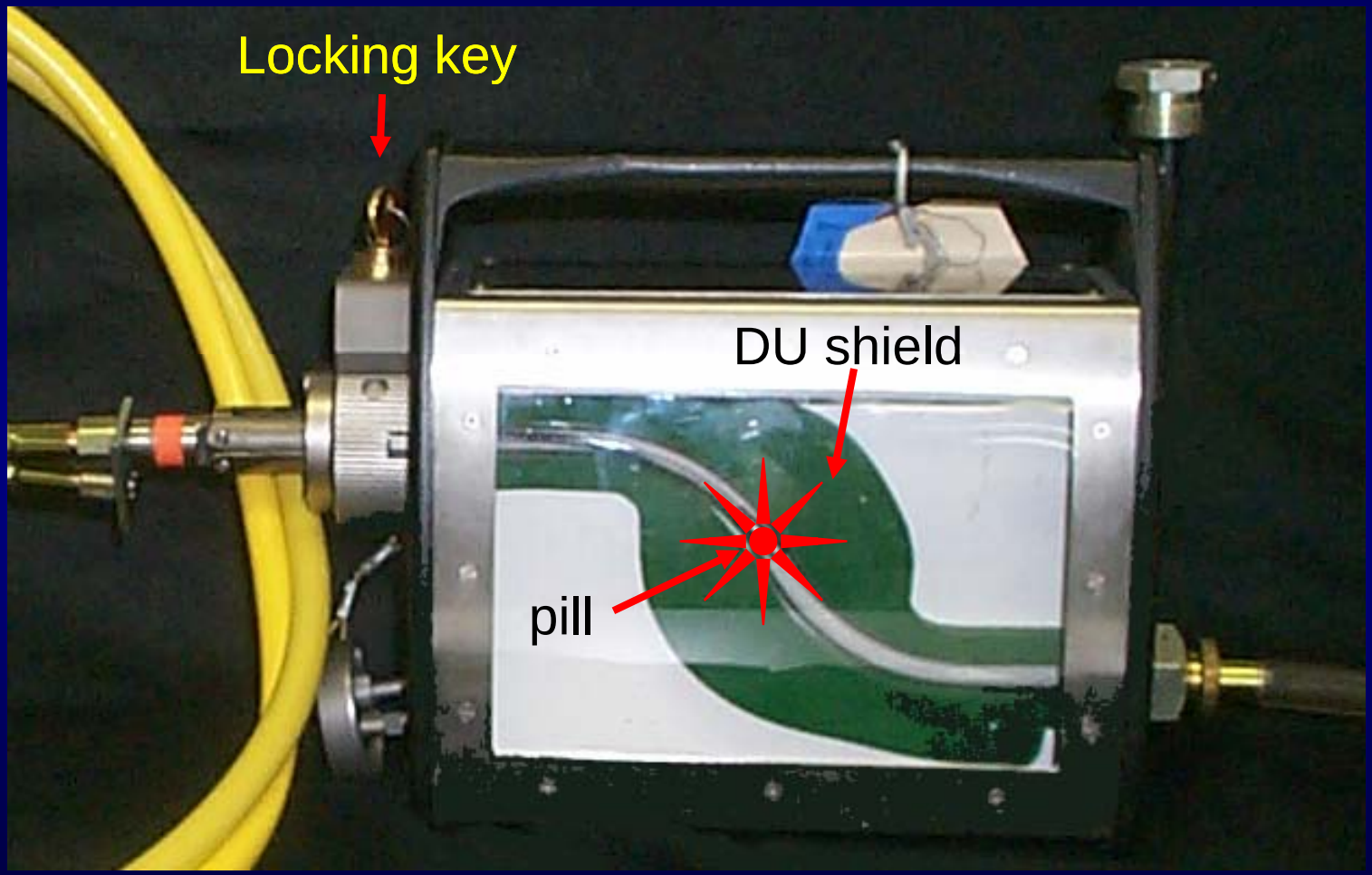
^{192}Ir Radiography Cameras

QSA Global (Sentinel) Model 660

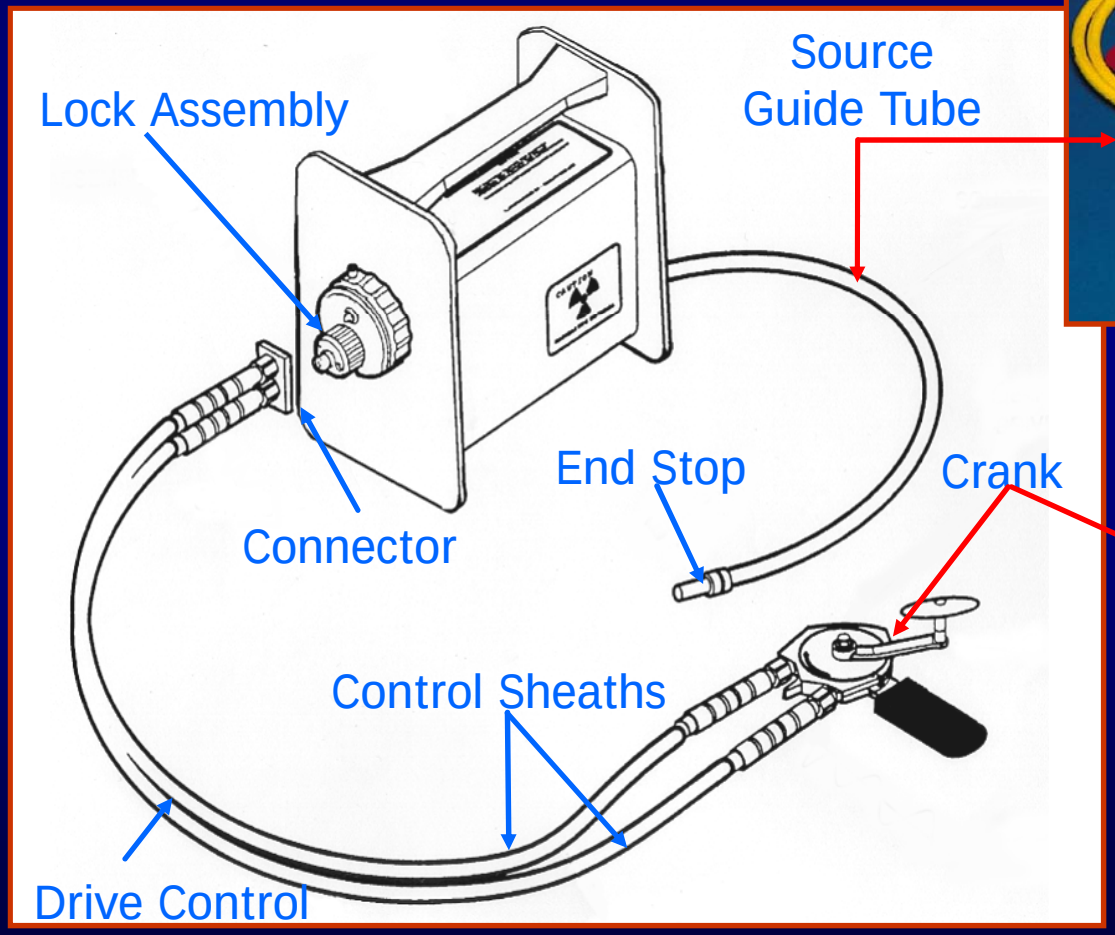
Source Production & Equipment Co. Model SPEC-150

Industrial Nuclear Co. Model IR-100

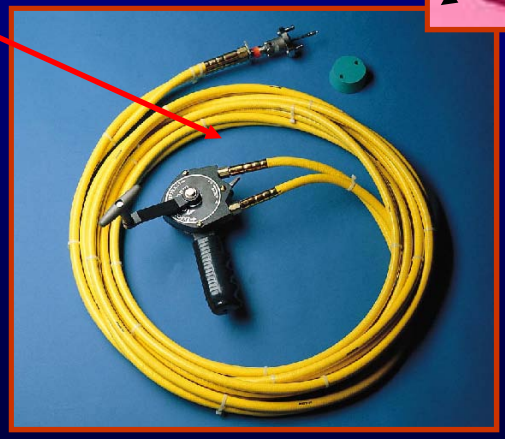
Radiography Camera Design



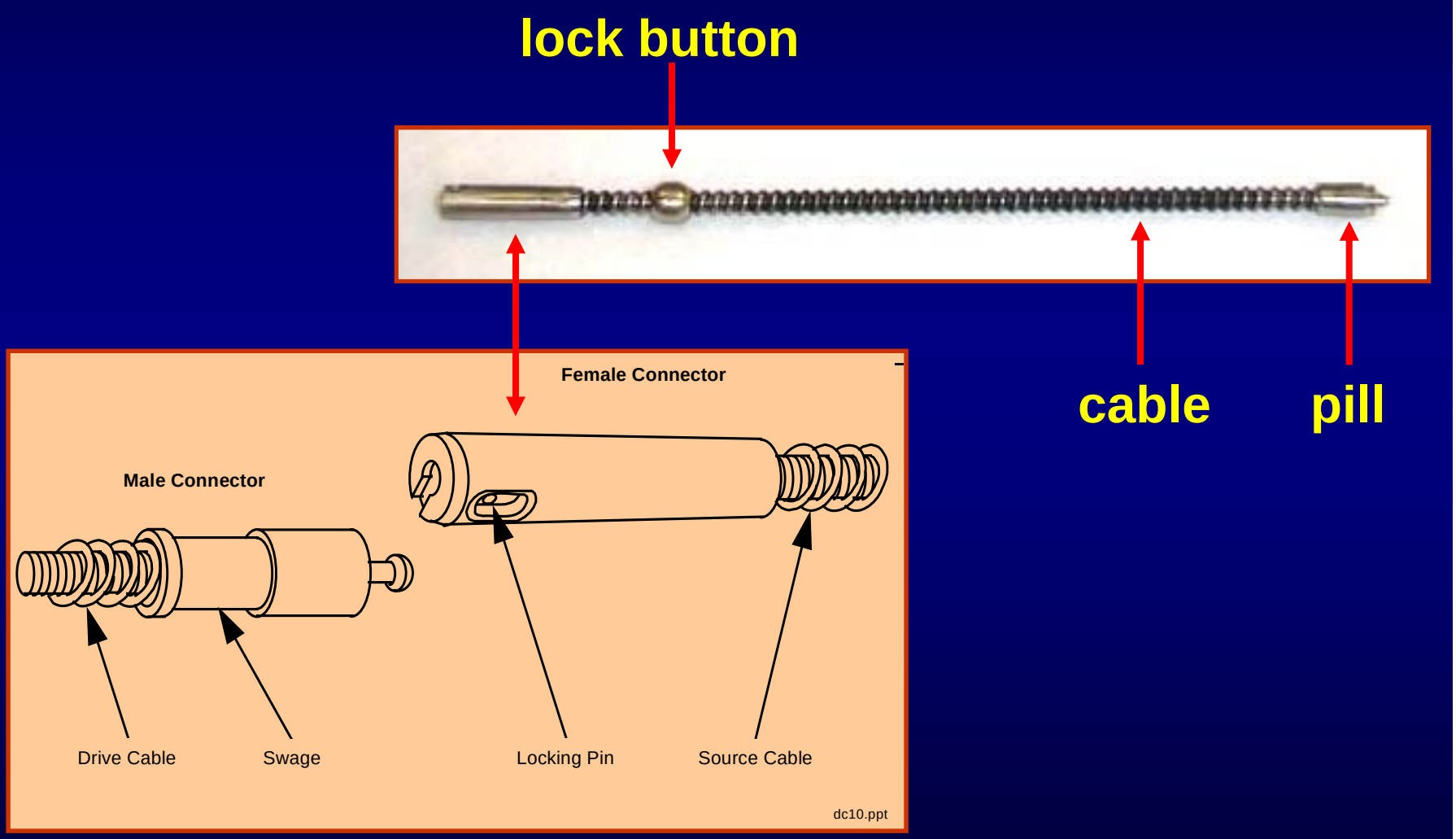
Radiography Camera & Associated Equipment



collimator

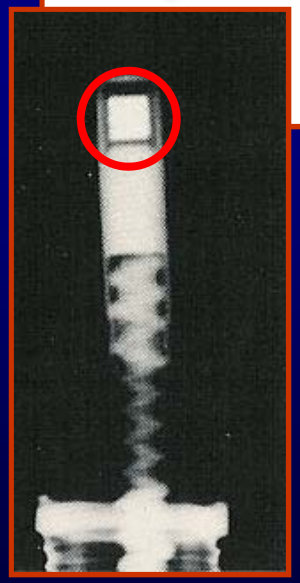


Source Assembly (Pigtail)



Sources

Ir-192 wafers & Co-60 pellets



^{60}Co Radiography Cameras

SPEC Model SPEC-300

AEA Model 741

Field Radiography (outdoors)

Welding

Setup

Crank-out

Exposure

Retract source / breakdown equipment

Field Radiography (indoors)

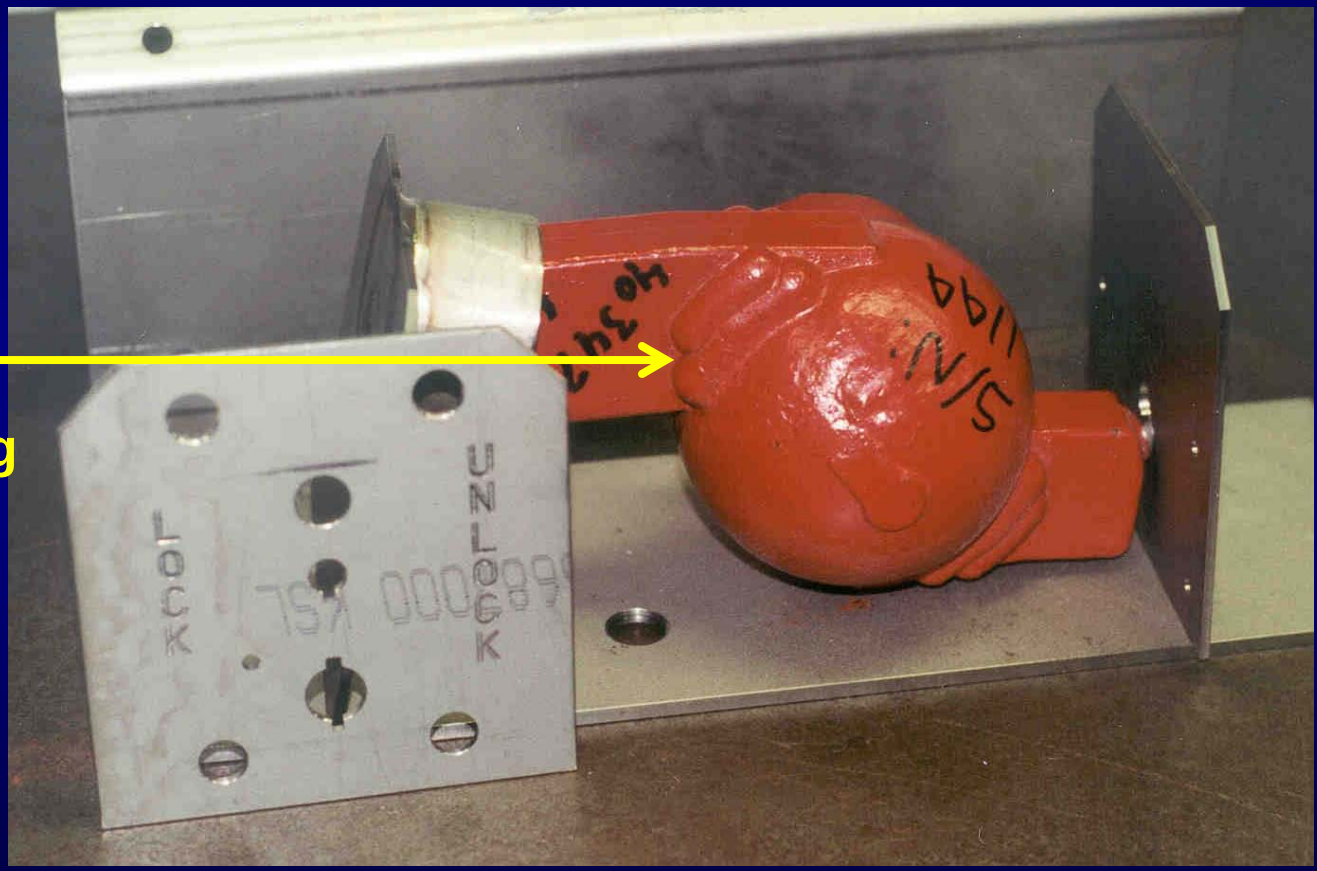
Unusual Locations

Off Shore
Oil Drilling Platform

Lay Barge
(pipe laying operation)

Camera Components

Depleted Uranium Shield containing "S" tube.



Camera Components

The Radiography Process

Radiography Event: Potential Overexposure

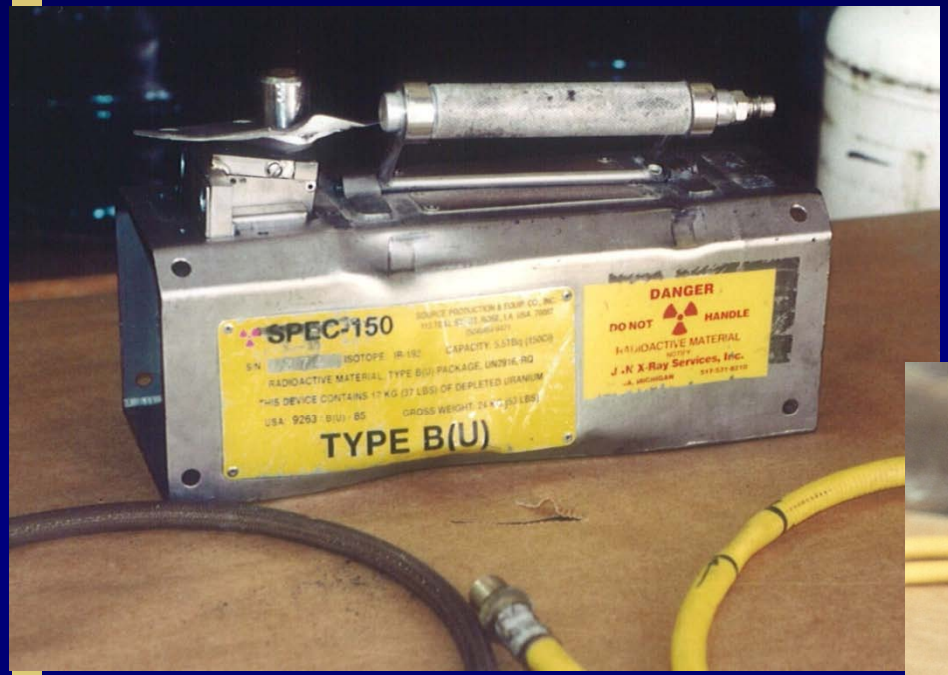
- **NEBRASKA AGREEMENT STATE REPORT:**

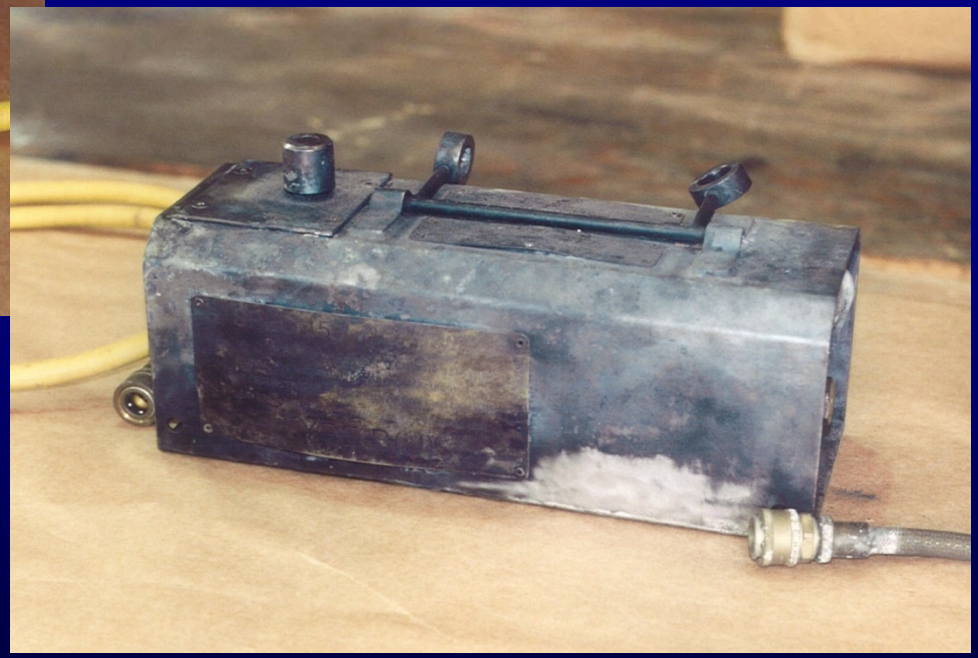
  The State of Nebraska Department of Health & Human Services, Radiation Control Program, reported that a radiographer employed by Team Industrial Services, Inc. was potentially overexposed while performing radiography at a Nebraska City, NE facility. Team Industrial Services, Inc. was performing work in Nebraska under reciprocity of their Illinois license.

  On March 7, 2008, while at the job site, the radiographer noticed that his direct-reading pocket dosimeter was off-scale. He reported this to the regional Team Industrial Services RSO and stated that he believed he just bumped the dosimeter to cause the off-scale condition. The RSO directed him to send his TLD to Landauer Laboratories for processing.

  On March 10, 2008, Landauer informed the RSO that the TLD indicated that the radiographer received 7.753 REM Deep Dose Equivalent.

Damaged Cameras





X-Ray Radiography

- X-ray machines are also used for conducting radiography. An X-ray machine has a selectable energy by varying voltage and current. When the unit is turned off, the radiation source is gone.
- These devices are not regulated by the NRC, but are regulated by state radiation protection programs.

Gauging Devices

Fixed

Portable

Portable Moisture - Density Gauges

- **Sources**
  8-10 mCi of ^{137}Cs (gamma)
  40-50 mCi of ^{241}Am:Be (neutron)

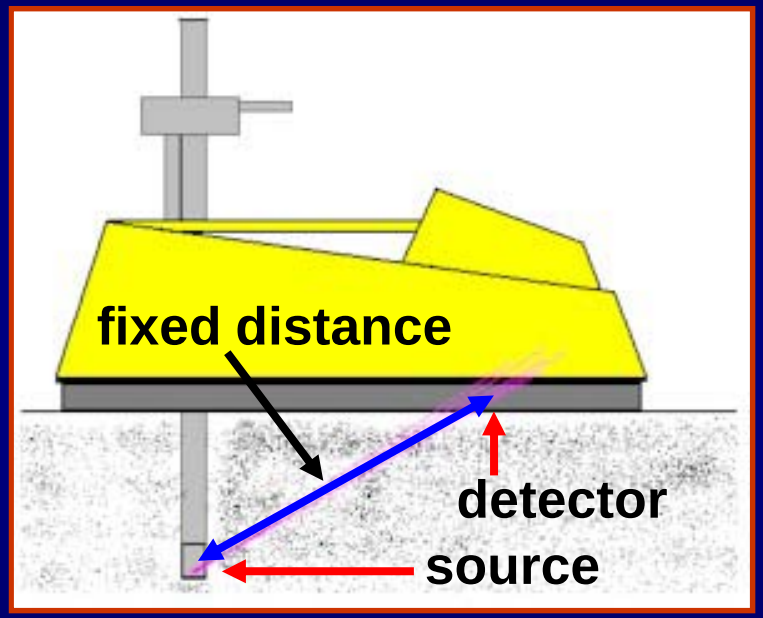
- **^{241}Am:Be produces neutrons by utilizing the alpha particles emitted by americium through the following reaction:**

$$^{9}_{4}Be + ^{4}_{2}\alpha \rightarrow ^{12}_{6}C + ^{1}_{0}n$$

Note: In ~ 10 minutes, an unshielded 10 mCi ^{137}Cs source can deliver > 50 rem to a worker's hand (some gauges contain sources with even higher activities)

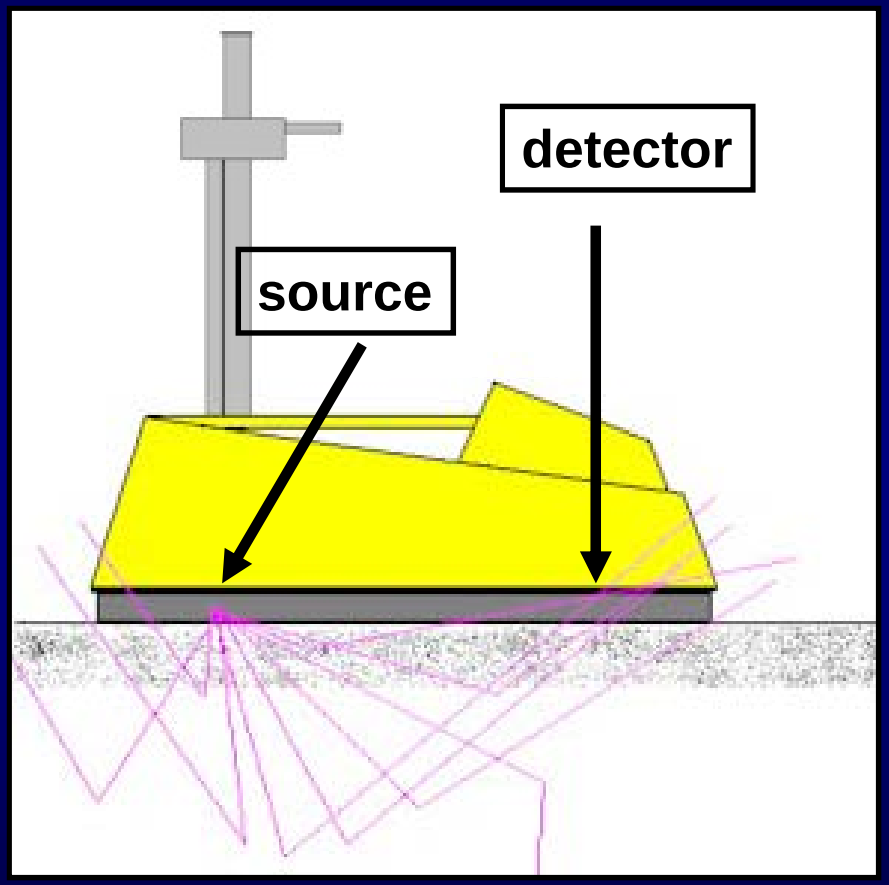
Direct Transmission

- Cs-137 source (gamma)
- method to measure soil density
- source placed beneath the surface through a punched hole - radiation travels fixed distance to detector on the base of the gauge
- density of the soil depends on amount transmitted

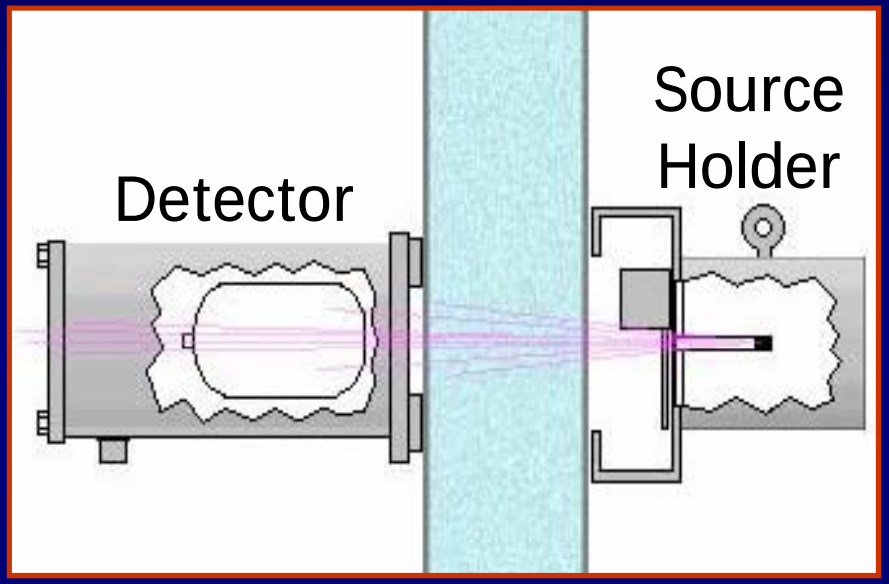


Backscatter

- gamma source (density)
- neutron source (moisture)
- both source and detector on surface
- radiation reflected (scattered) back to the gauge by material
- not sensitive beyond a depth of about 4 inches

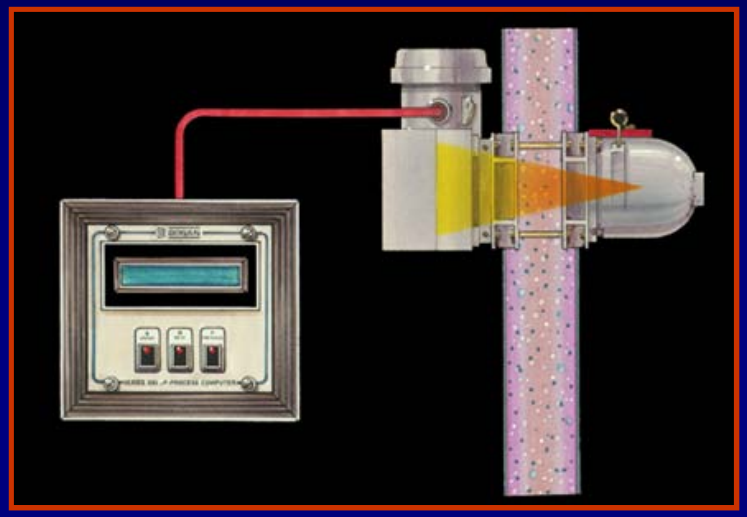


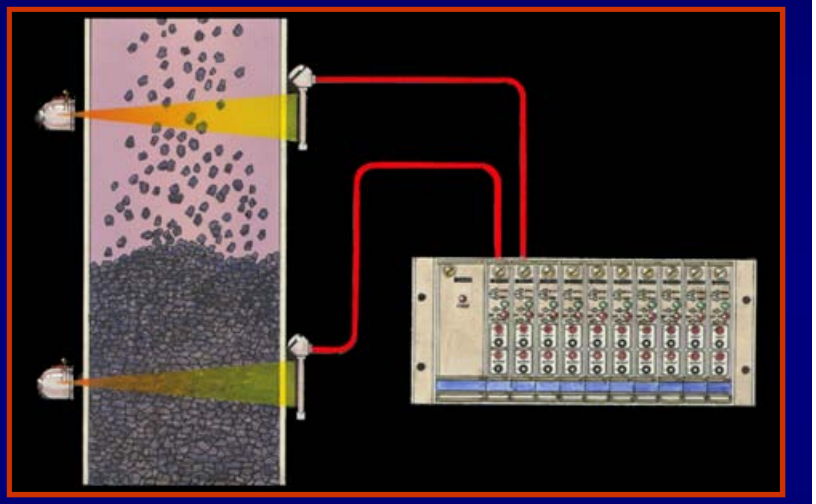
Fixed Gauges

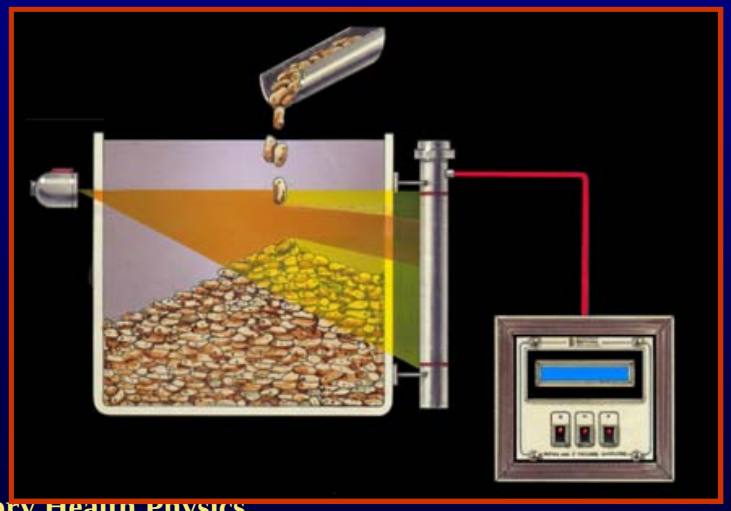


1 curie cesium-137
6 mR/min @ 1 m

Flow and Fill

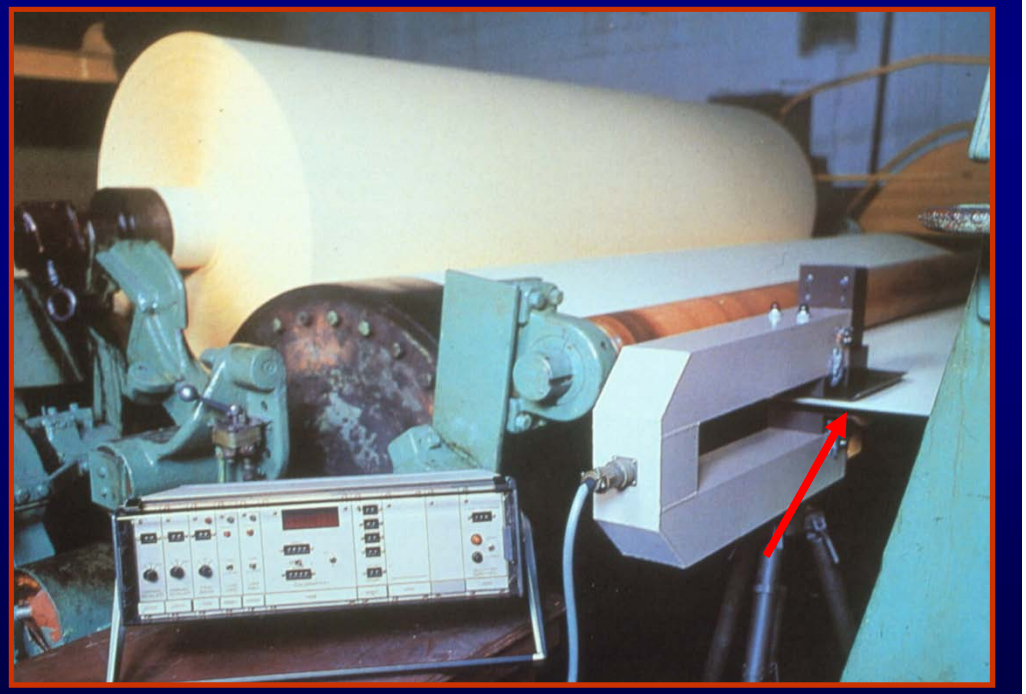




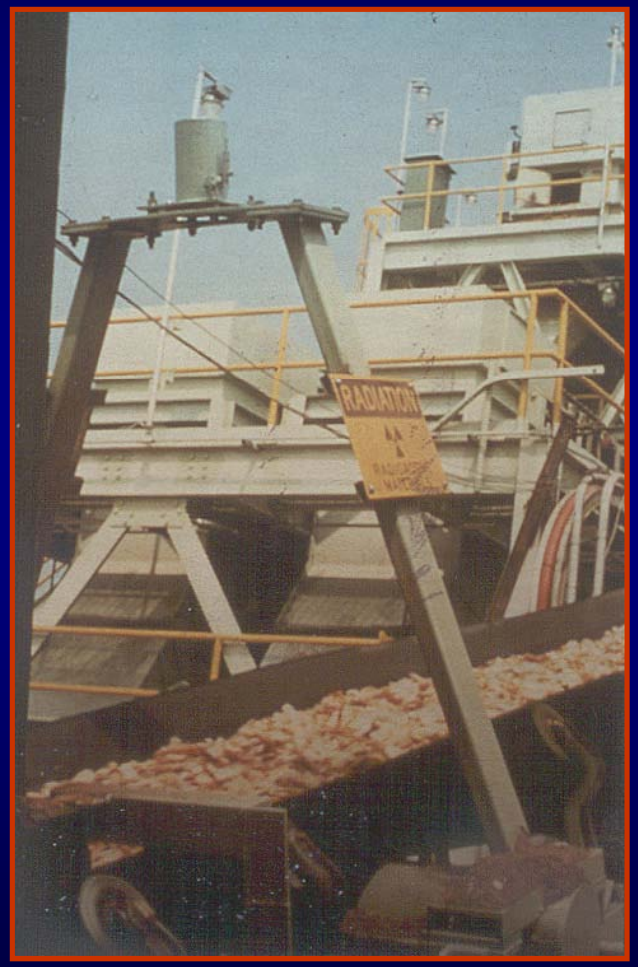


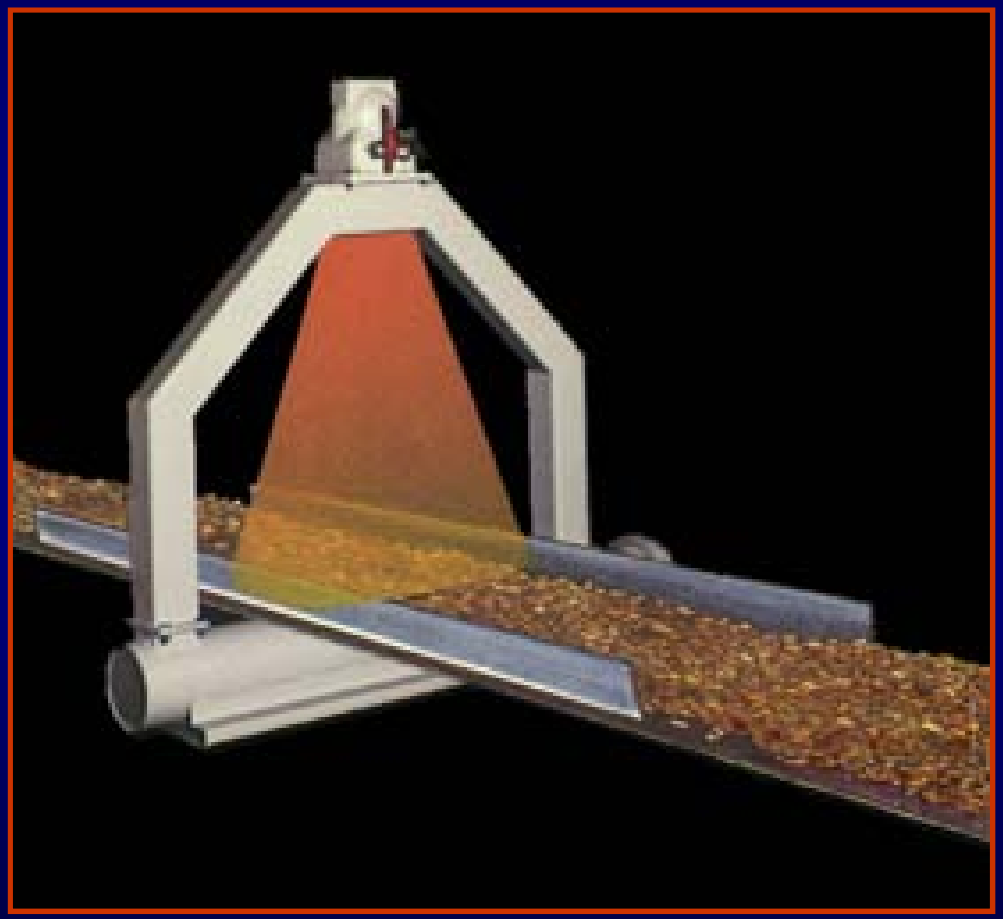
Fill Level

Product Thickness



Conveyor Belt





Event: Fixed Gauge

- **UTAH DIVISION OF RADIATION CONTROL: EQUIPMENT FAILURE TO FUNCTION AS DESIGNED**

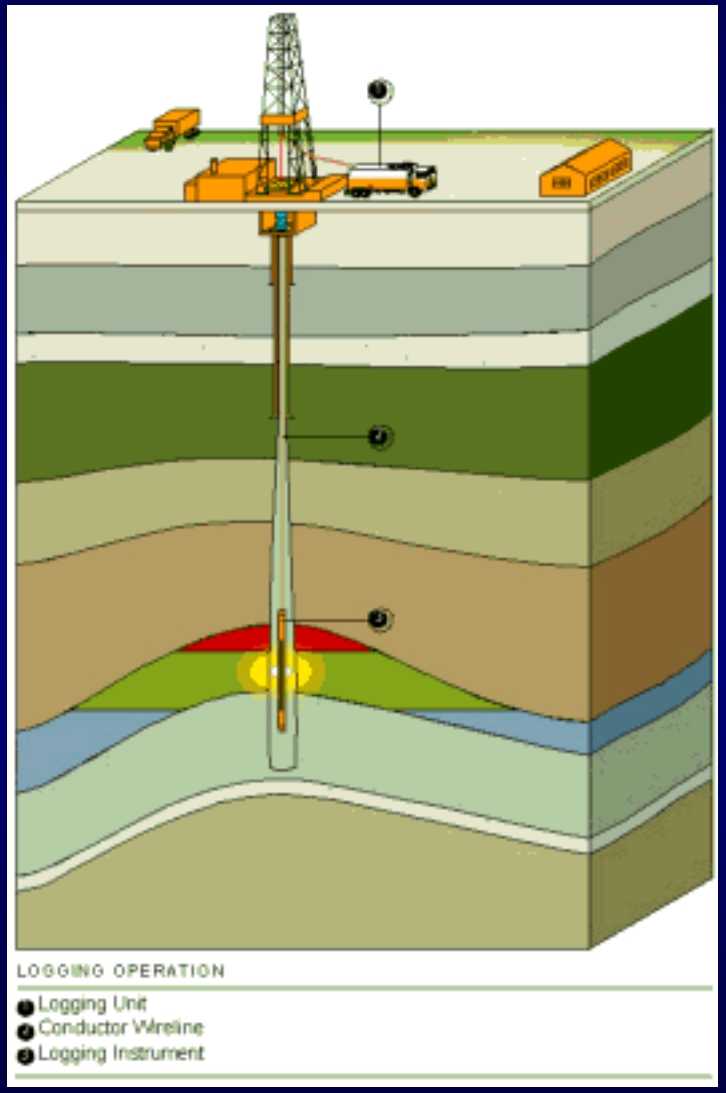
  A licensee employee, trained by the device manufacturer, was performing a device inspection (inventory/shutter check/leak test) for one of the licensee's fixed gauges (Ohmart Corporation Model SH-F2) containing 7.4 gigabecquerels (200 millicuries) of cesium-137. A screw broke off while the employee was closing the device shutter. Because the screw broke off, the shutter could not be closed.

Event: Damaged Portable Gauge

- **AGREEMENT STATE - FLORIDA BUREAU OF RADIATION CONTROL**

  The Florida Bureau of Radiation Control called to report a damaged Troxler gauge, with a source strength of 8 mCi Cs-137 and 40 mCi Am-241, is being quarantined in a church parking lot by the St. Lucie police department. An employee of the licensee had the gauge in his truck when he was involved in an accident. The impact of the crash caused the Troxler instrument to be ejected from the truck causing damage to the handle. The employee was air lifted to the local hospital in critical condition.

Well Logging



Well Logging

- Well logging is regulated by the NRC in 10 CFR Part 39.
- Sources use both gamma and neutron radiation.
- Neutron radiation is used to detect the presence of moisture or hydrogenous atoms, e.g., oil.

Well Logging

USES:

Oil Exploration
Field & Tracer Studies

TYPES:

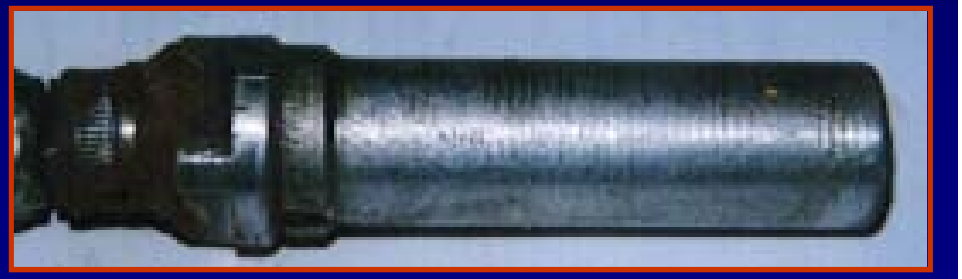
Gamma Logging
Neutron Logging
Logging While Drilling

Well Logging Tools and Vehicle

Well Logging tools
(without sources)
in transport vehicle

Well Logging tools
(without sources)
at storage facility

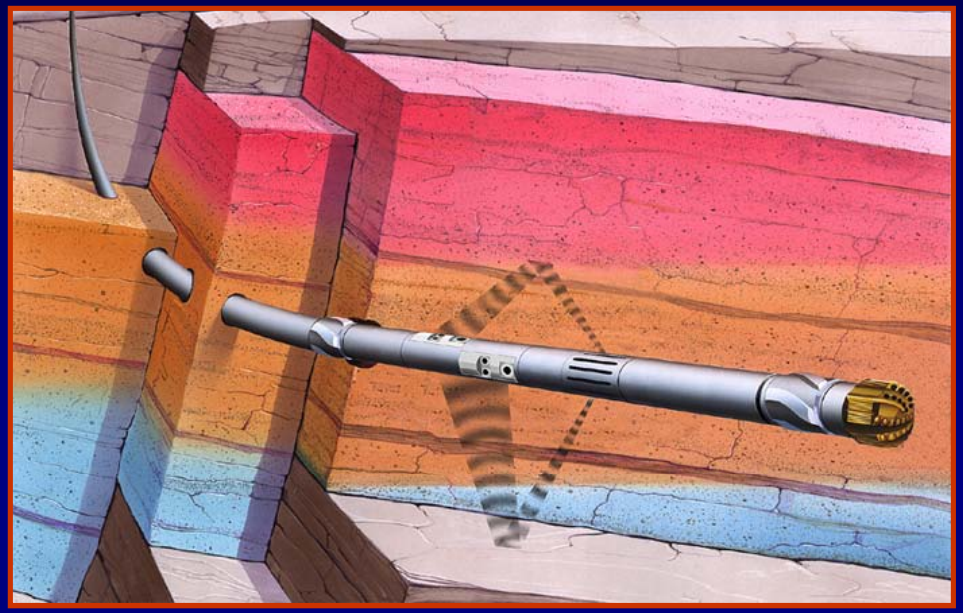
Well Logging Sealed Sources

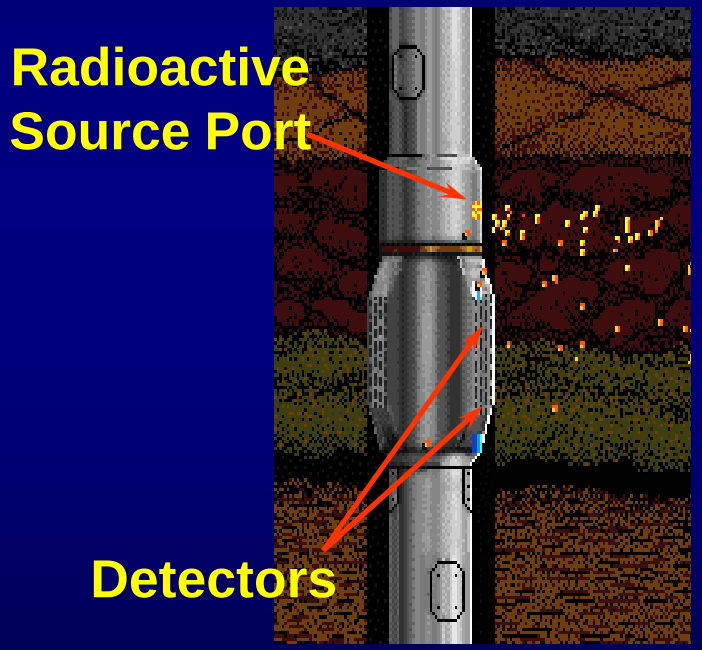


^{137}Cs

$^{241}Am:Be$

Measurement While Drilling (MWD)





Event: Well Logging

- Texas Agreement State Report: Three well logging sources abandoned downhole in a well in Galveston County, Texas
- Well logging string became stuck in a 6 3/4" wellbore over the weekend. Attempts to 'fish' for the sources were unsuccessful and the fishing tool becoming stuck in the wellbore above the well logging tool string.
- The tool string contained three sealed sources: an 18 curie Am-241/Be; a 2 curie Cs-137; and a 0.8 microcurie Cs137. The sources were declared abandoned late on October 19, 2004.
- The licensee had to seal the well with red dyed cement and placed a deflection device in the wellbore. The tool string is sitting at the bottom of the well at 9,150 feet downhole.

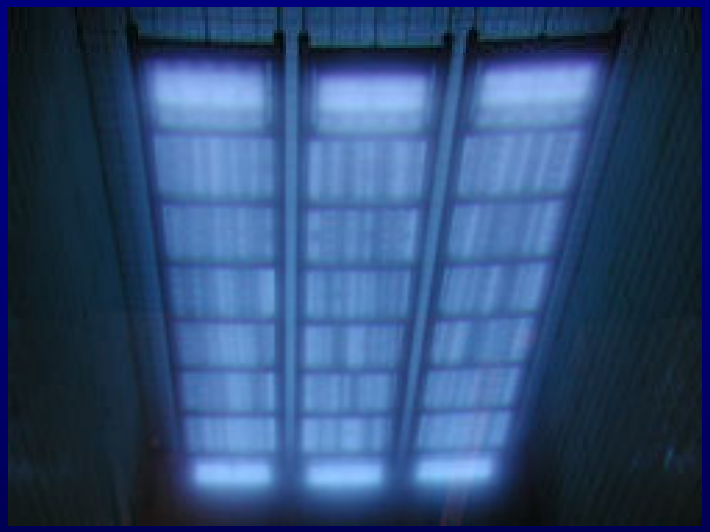
Event: Well Logging

General Information or Other	Event Number: 40863
Rep Org: TEXAS DEPARTMENT OF HEALTH Licensee: SCHLUMBERGER TECHNOLOGY CORP	Notification Date: 07/12/2004 Event Date: 07/10/2004

TEXAS AGREEMENT STATE REPORT ON DOSE TO THE PUBLIC FROM EXPOSED SEALED SOURCE

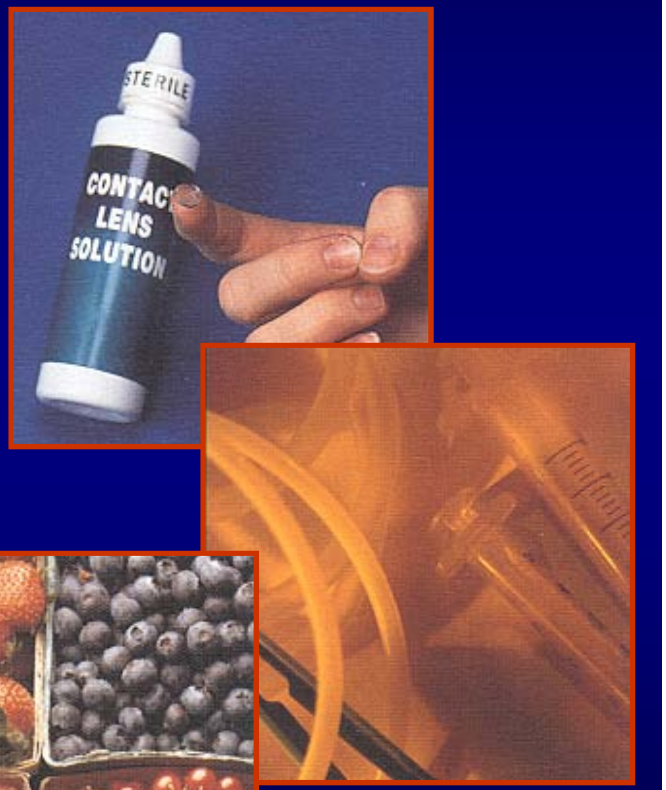
"Full investigation has been started by Schlumberger. Many details missing from initial notification. Crew using a CAPSTAR rig, without a floor were working a well site in Pecos County, Texas, from the Midland office (Subsite 042). During the evening of probably 07/09/2004 the rig was moved to a new site. When setup for work it was determined by the well loggers that a sealed 1.7 curie Cs-137 source was missing from their tool. They went back to the last site and discovered the source in a pile of mud that was located 10-15 feet from the rig location. It is suspected that the source was missing for 24-36 hours. Suspect dose to the public to the rig crew/roustabouts. The logging crew was badged. No estimates are currently available. A Schlumberger management team has been dispatched from Houston (Subsite 000) to assess dose and investigate this incident. Investigation is ongoing."

Irradiators



Irradiators

- Subject to NRC (10 CFR 36) or Agreement State licensing.
- High activity gamma sources (millions of Ci) are used to sterilize medical devices, to alter products (e.g., golf balls, flooring), or to preserve food.
- Potential for whole body lethal doses in very short time period (seconds).



Irradiator Categories

I Source always shielded

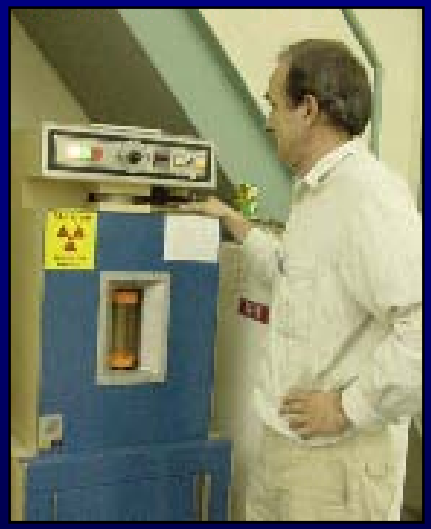
II Open beam port

III Source underwater

IV Source stored underwater, exposed in air

Category I

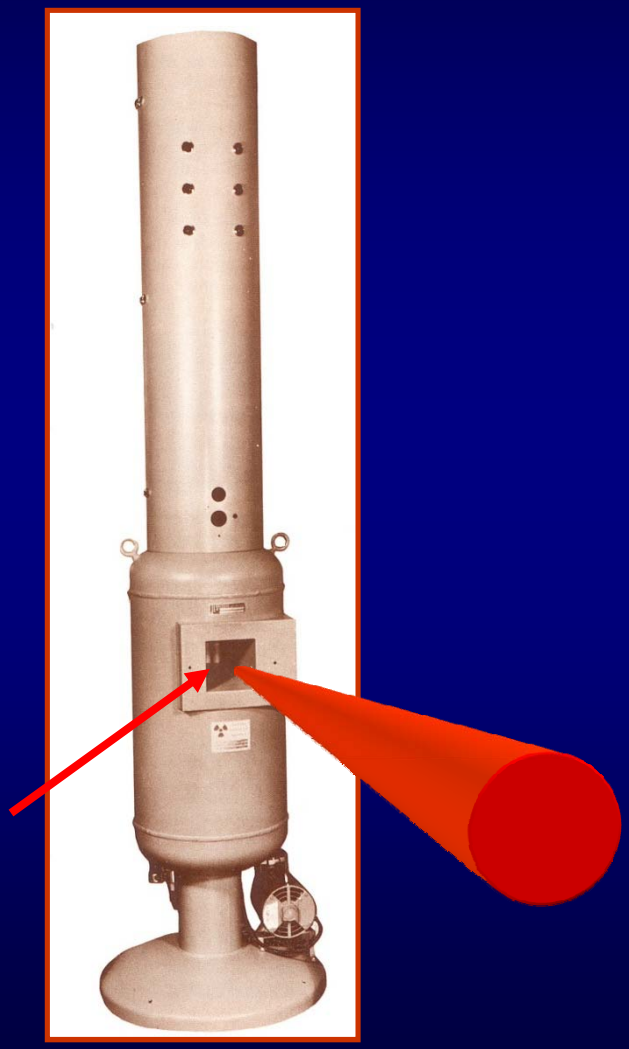
The source is completely enclosed in a dry container constructed of solid materials and is shielded at all times, and where human access to the sealed source and the volume undergoing irradiation is not physically possible



Self-Contained Dry Source Storage Irradiators

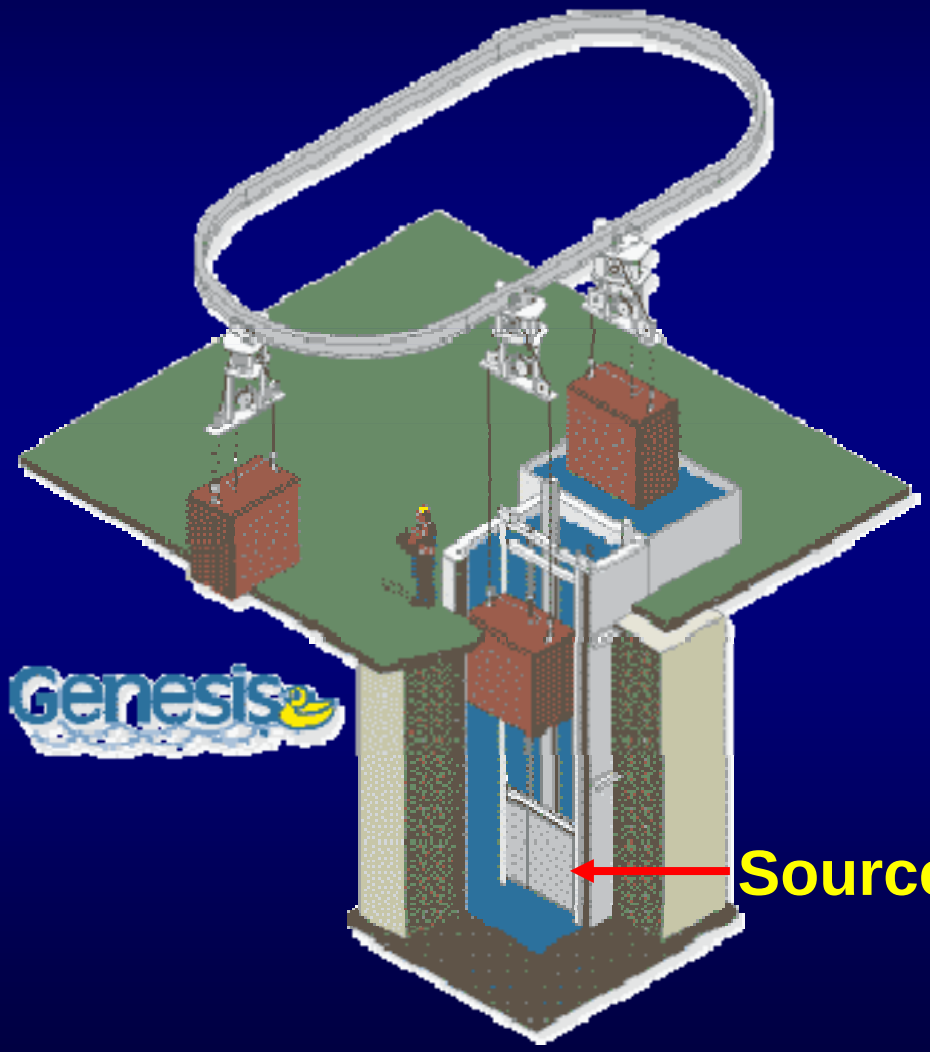
Category II

The source is enclosed in a dry container constructed of solid materials, is fully shielded when not in use and is exposed within a radiation volume that is maintained inaccessible during use by an entry control system (ANSI Std. N43.12)

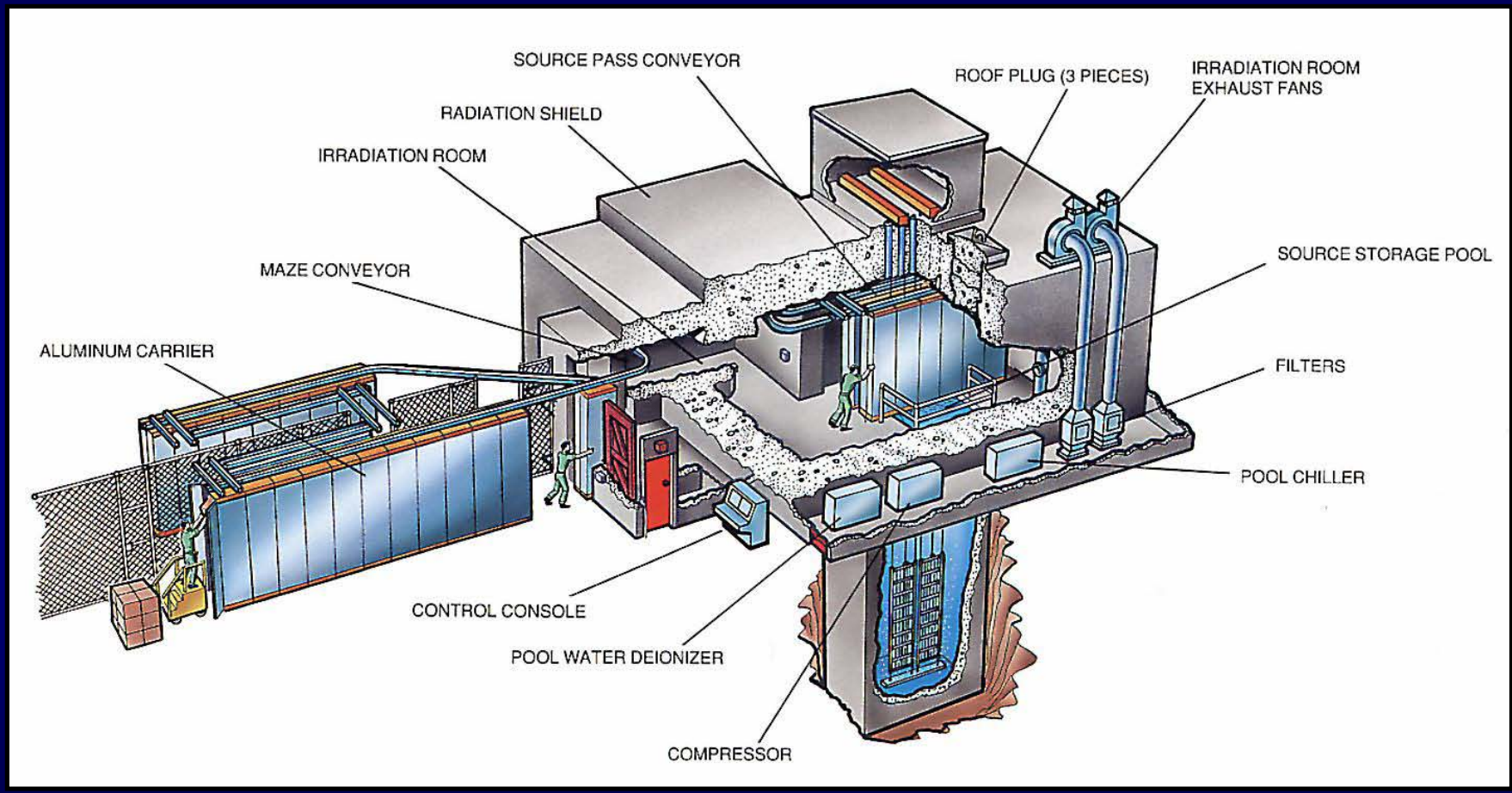


Category III

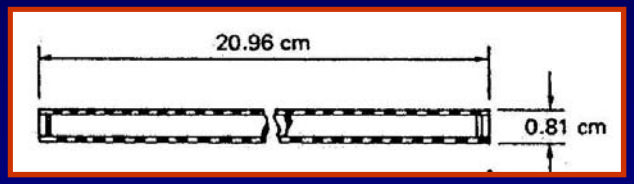
An irradiator in which the sealed source is contained in a water filled storage pool and is shielded at all times, and where human access to the source is physically restricted (ANSI Std. N43.15)



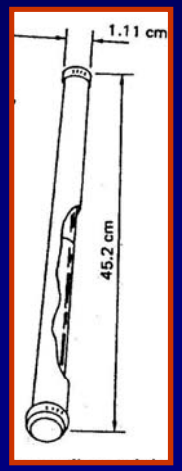
Category IV


SOURCE PASS CONVEYOR
ROOF PLUG (3 PIECES)
IRRADIATION ROOM EXHAUST FANS
RADIATION SHIELD
IRRADIATION ROOM
MAZE CONVEYOR
SOURCE STORAGE POOL
ALUMINUM CARRIER
FILTERS
POOL CHILLER
CONTROL CONSOLE
POOL WATER DEIONIZER
COMPRESSOR

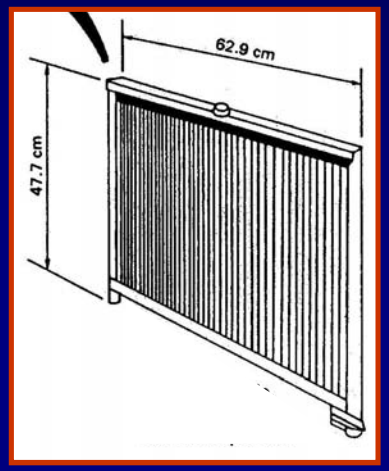
Category IV Sources



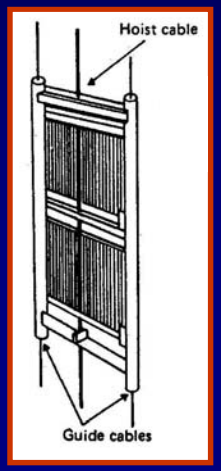
source element



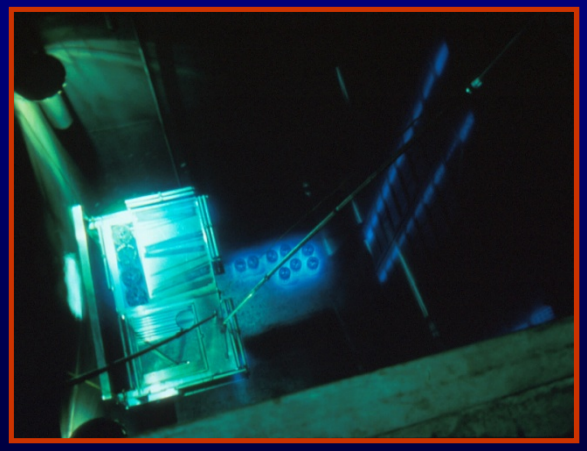
pencil



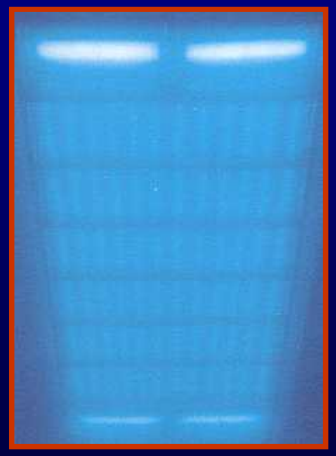
module



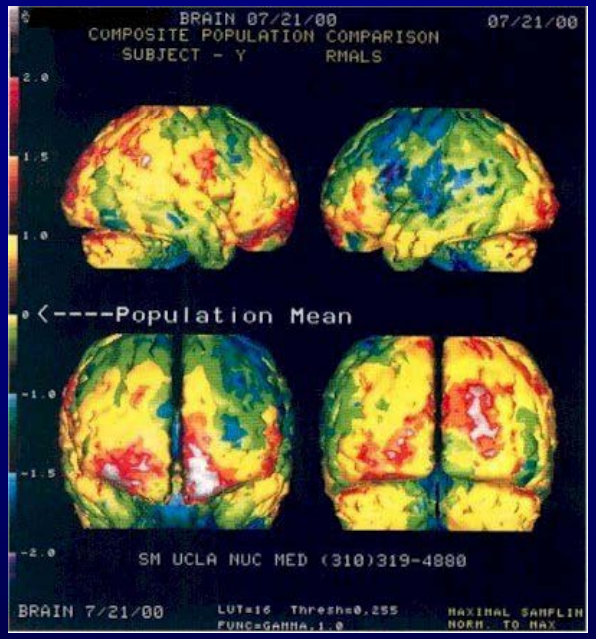
rack



source exchange



Medical Uses



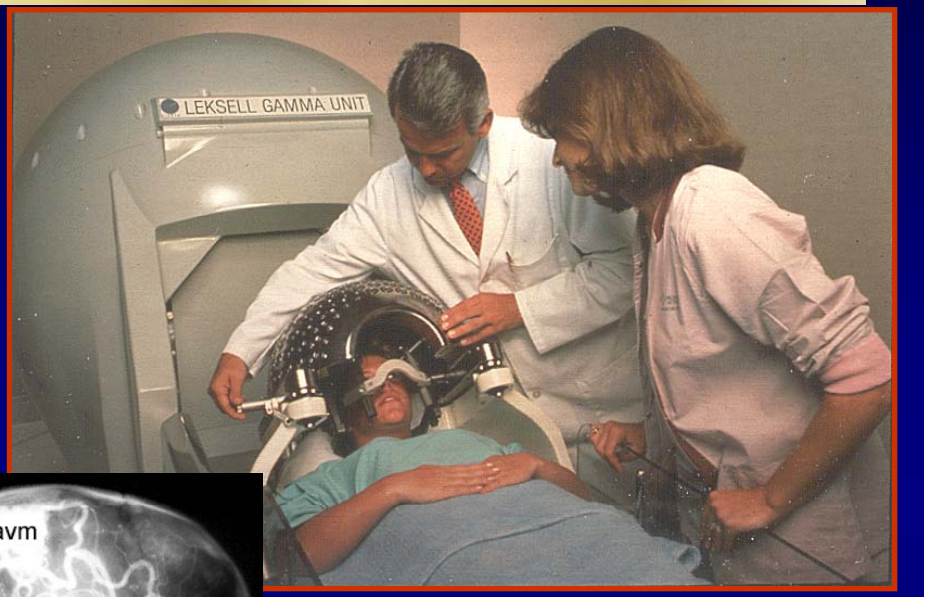
Medical Uses

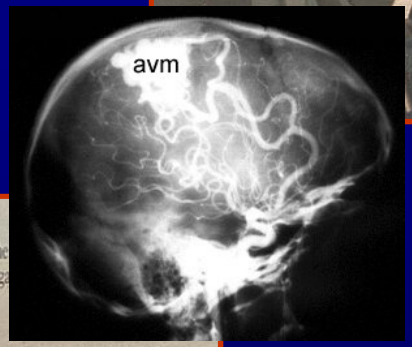
- Radionuclides are used for diagnosis and therapy.
- Brachytherapy – sources inserted into the body or body cavity, e.g., cancer treatment.
- Teletherapy – source is outside the body, radiation is administered to treat conditions.

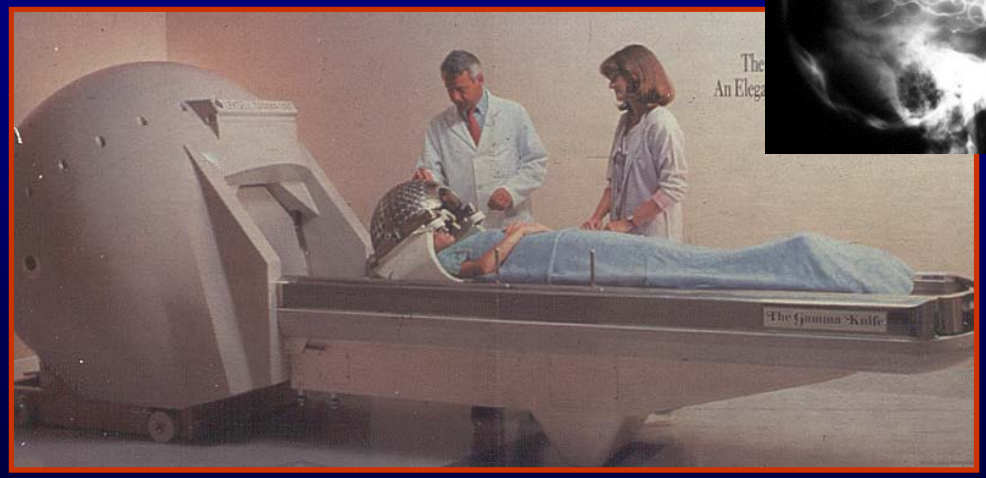
Isotope Generators

Stereotactic Radiosurgery

201 Co-60 sources about 33 Curies each







Gamma Knife

Brachytherapy

- Brachytherapy is regulated by the NRC under 10CFR35
- Brachytherapy involves implanting a radioactive source in an organ or body cavity. Some sources are retracted after a prescribe dose has been delivered. Other sources may remain permanently in an organ.
- Based on the half-life of the isotope being used, they may decay and no longer be radioactive. The activity used is selected to deliver a prescribe dose.

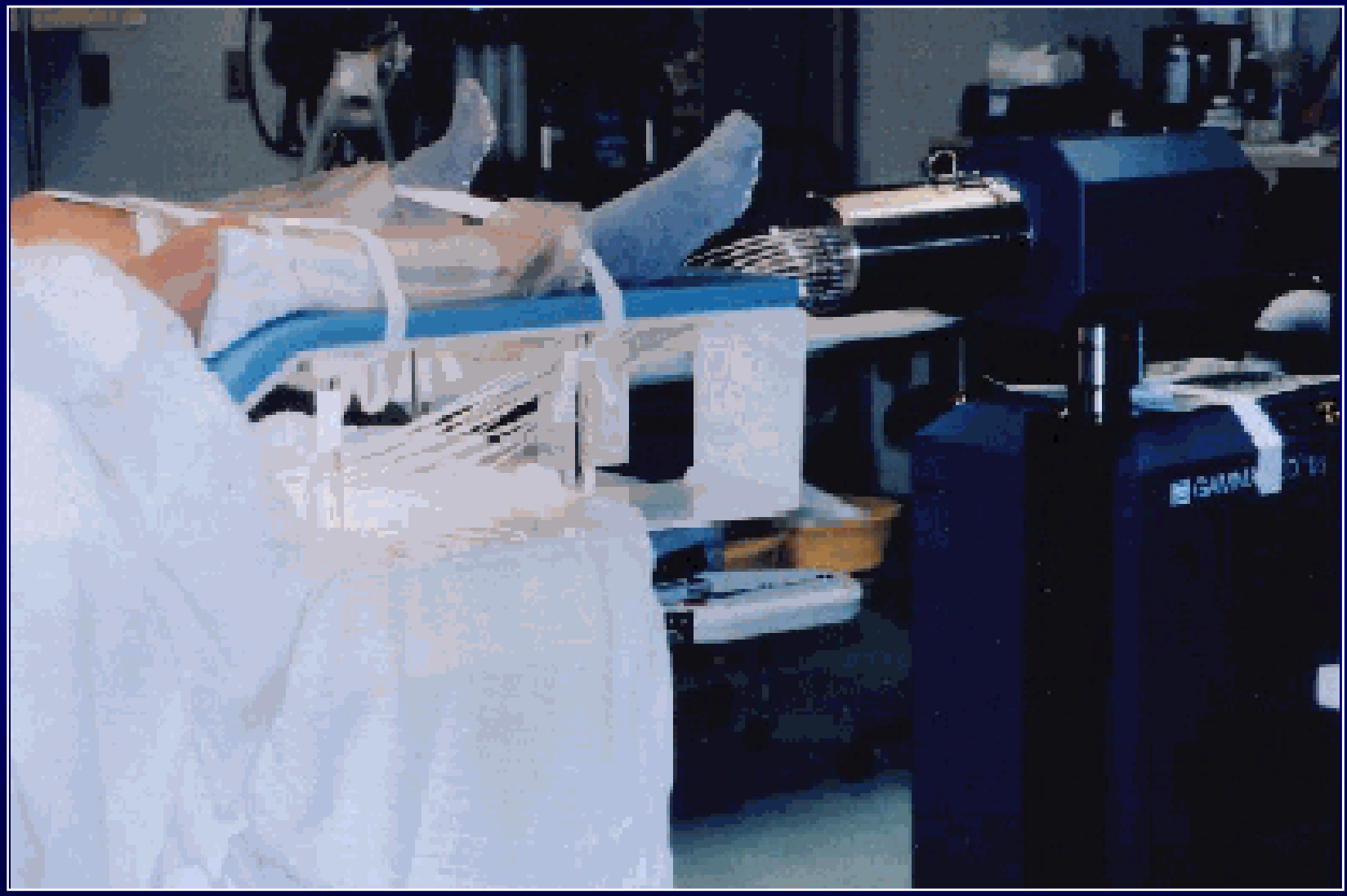
Brachytherapy: I-125 Seeds

- I-125 is used in brachytherapy because of the relatively short half life (60 days) and low energy gammas emitted (35 keV).
- The low energy photons allow the dose to be delivered in proximity to the "seeds" that contain the I-125. The seeds are implanted in an organ/tumor for cancer therapy, such as prostate cancer, and they remain in place permanently.

High Dose-rate Remote Afterloading (HDR)

Source travels from unit, through catheter (plastic guide tube) into patient

Prostate HDR



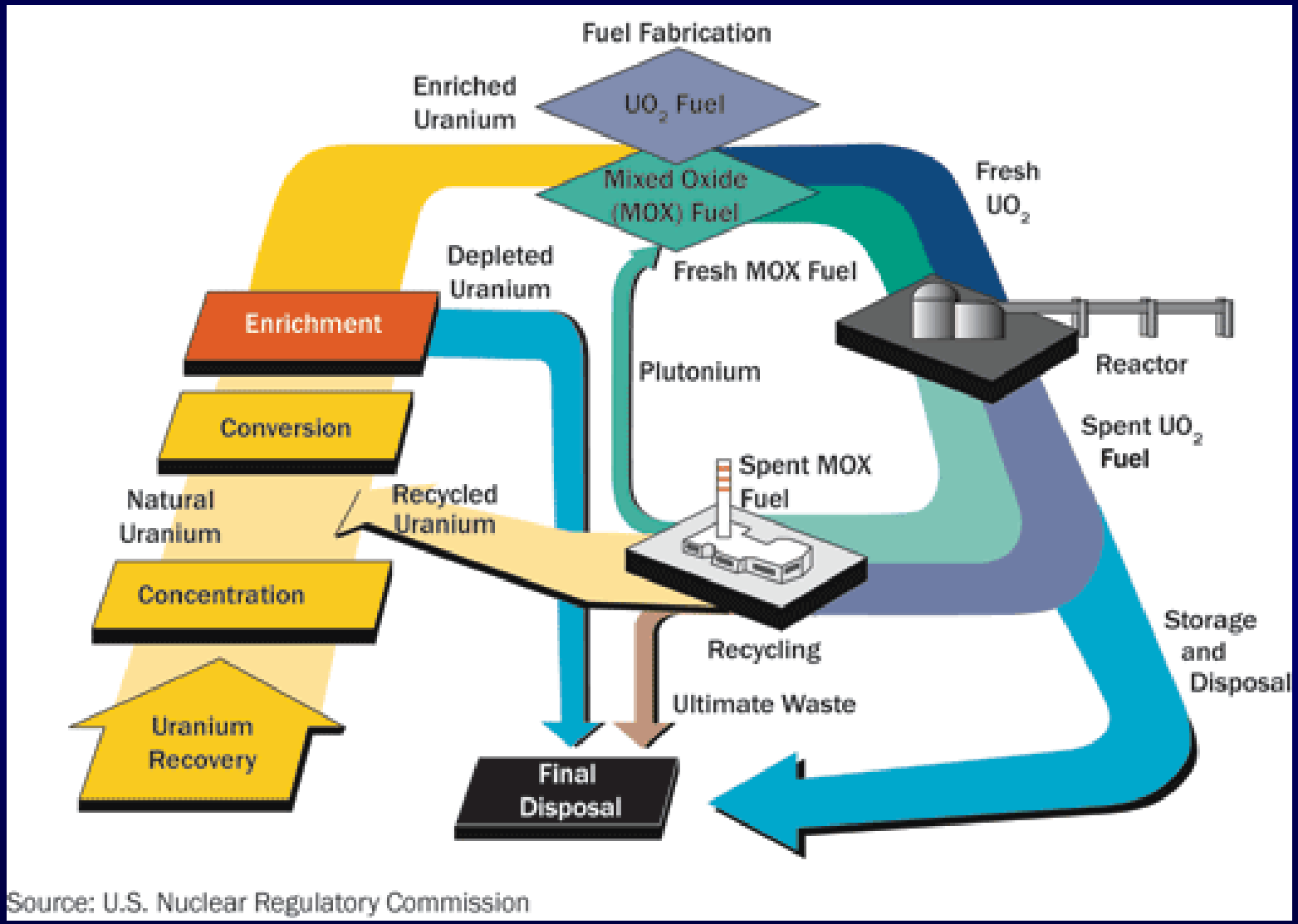
Brachytherapy Misadministration

- On April 21, 2006, the Arkansas Department of Health and Human Services was notified of a possible medical misadministration, which had been identified during the post-implant CT of a prostate implant patient. Based upon the CT scan, the facility determined that the I-125 seeds had been implanted in the incorrect area. The post-implant treatment plan generated on April 24, 2006, indicated that a dose greater than 50 rem had been delivered to an unintended area of tissue.

- Post-implant dosimetry imaging determined that the 84, I-125 seeds with average activity of 0.219 mCi on March 28, 2006, were misplaced approximately 4 cm inferior to their intended position. The post-implant dose calculation determined that a dose of 108 Gy (10,800 rad), which was consistent with the prescribed dose, had been delivered to the incorrect area.

Selective Internal Radiation Therapy (SIRT)

Fuel Cycle


Fuel Fabrication
Enriched Uranium
UO_2 Fuel
Mixed Oxide (MOX) Fuel
Fresh UO_2
Depleted Uranium
Fresh MOX Fuel
Enrichment
Plutonium
Reactor
Conversion
Spent UO_2 Fuel
Spent MOX Fuel
Natural Uranium
Recycled Uranium
Concentration
Storage and Disposal
Recycling
Ultimate Waste
Uranium Recovery
Final Disposal
Source: U.S. Nuclear Regulatory Commission

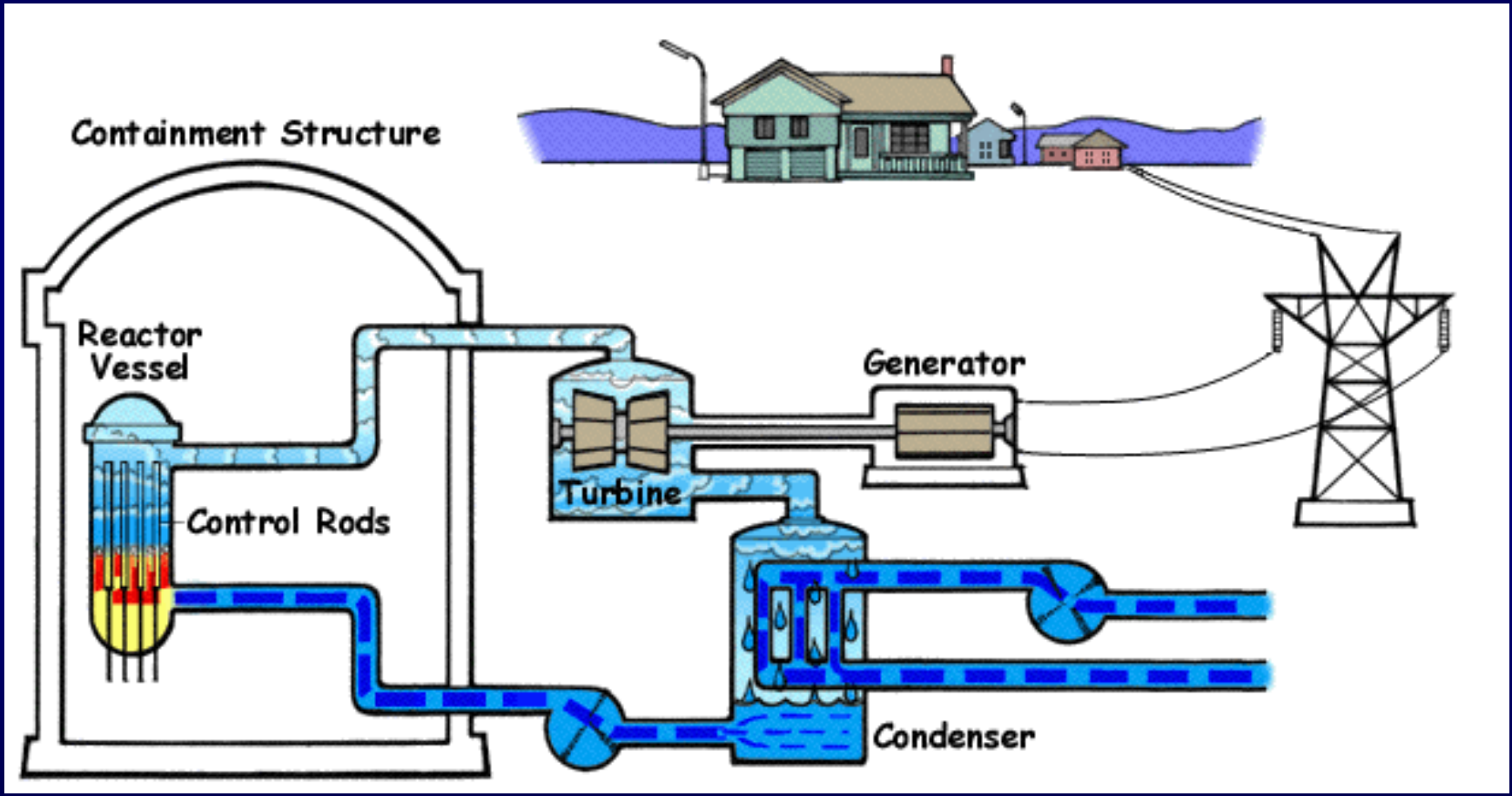
Fuel Cycle

- Uranium recovery to extract (or *mine*) uranium ore, and concentrate (or *mill*) the ore to produce "yellowcake"
- Conversion of yellowcake into uranium hexafluoride (UF_6)
- Enrichment to increase the concentration of uranium-235 (U^{235}) in UF_6
- Deconversion to reduce the hazards associated with the depleted uranium hexafluoride (DUF_6), or “tailings,” produced in earlier stages of the fuel cycle
- Fuel fabrication to convert enriched UF_6 into fuel for nuclear reactors
- Use of the fuel in reactors (nuclear power, research, or naval propulsion)
- Interim storage of spent nuclear fuel
- Recycling (or *reprocessing*) of high-level waste (currently not done in the U.S.)[1]
- Final disposition (disposal) of high-level waste

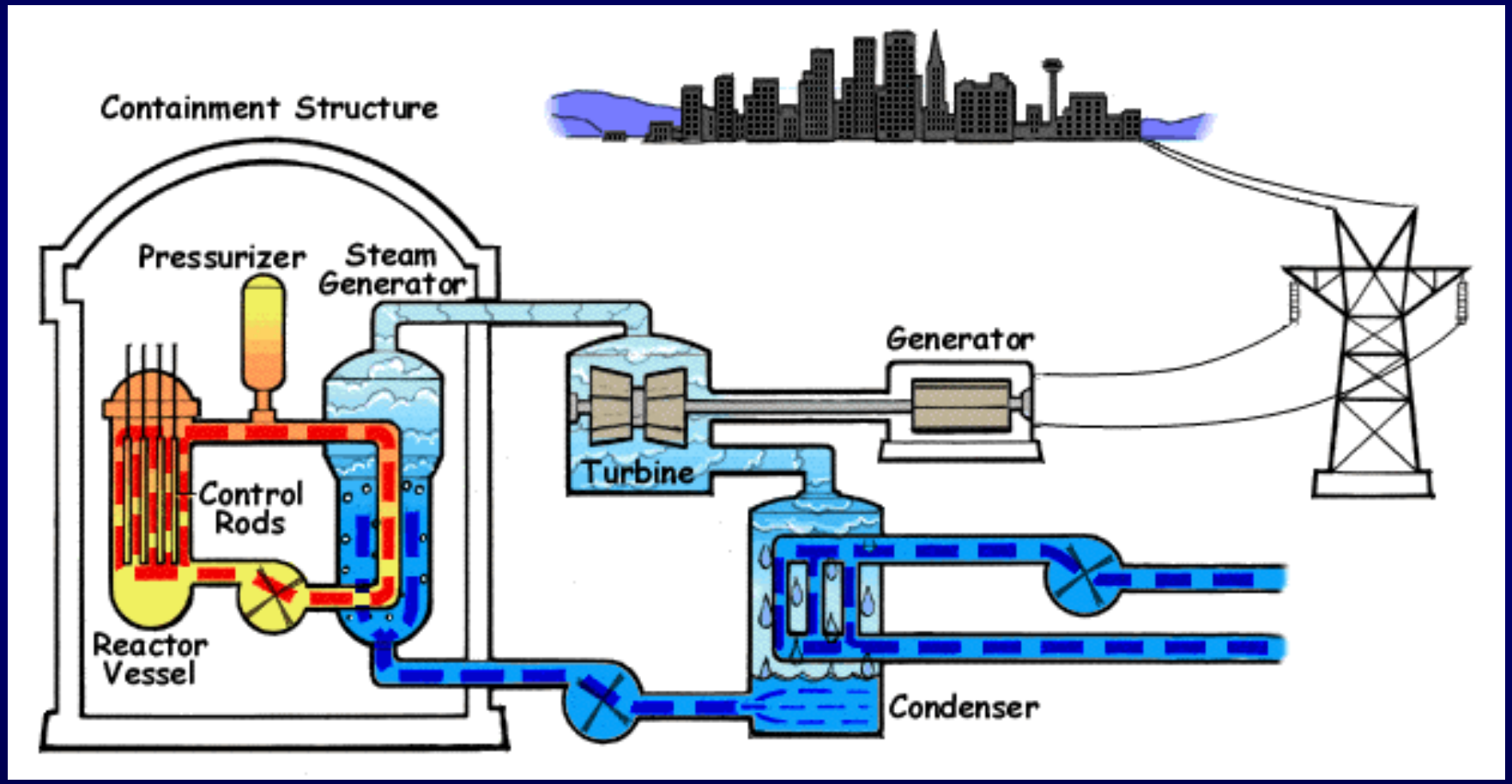
Power Reactors

- Reactors utilize fission of U-235 atoms. The energy released from this reaction is used to heat water. Natural uranium is 0.7% U-235, and is enriched to about 5% U-235 for commercial reactors.
- Water heated by the fission process is used to produce steam. This is done directly in a boiling water reactor (BWR) and indirectly in a pressurized water reactor (PWR). About 2/3 of the reactors in the US are PWRs.
- The steam is used to turn a turbine that is connected to a generator to produce electricity.
- A 1000 MWe reactor produces electricity valued at $50,000/hour (based on 5 cents per kW-hr).

BWR Conceptual Diagram

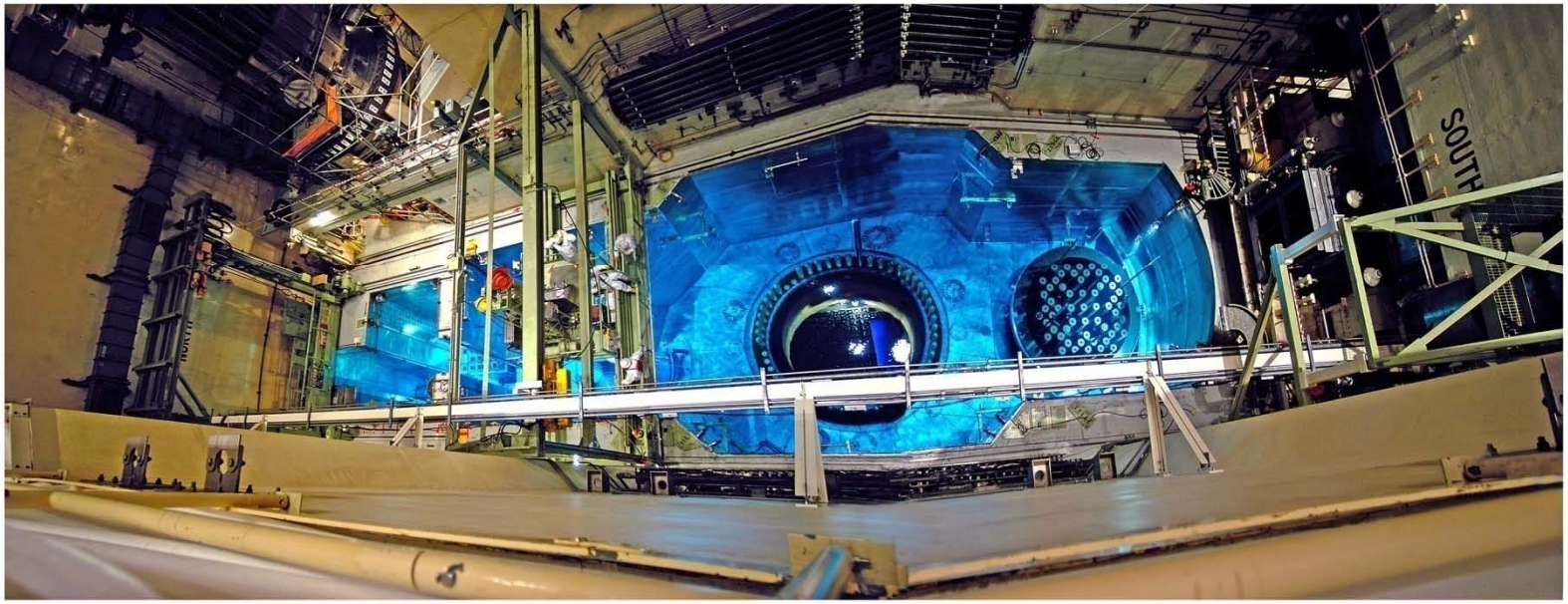


PWR Conceptual Diagram

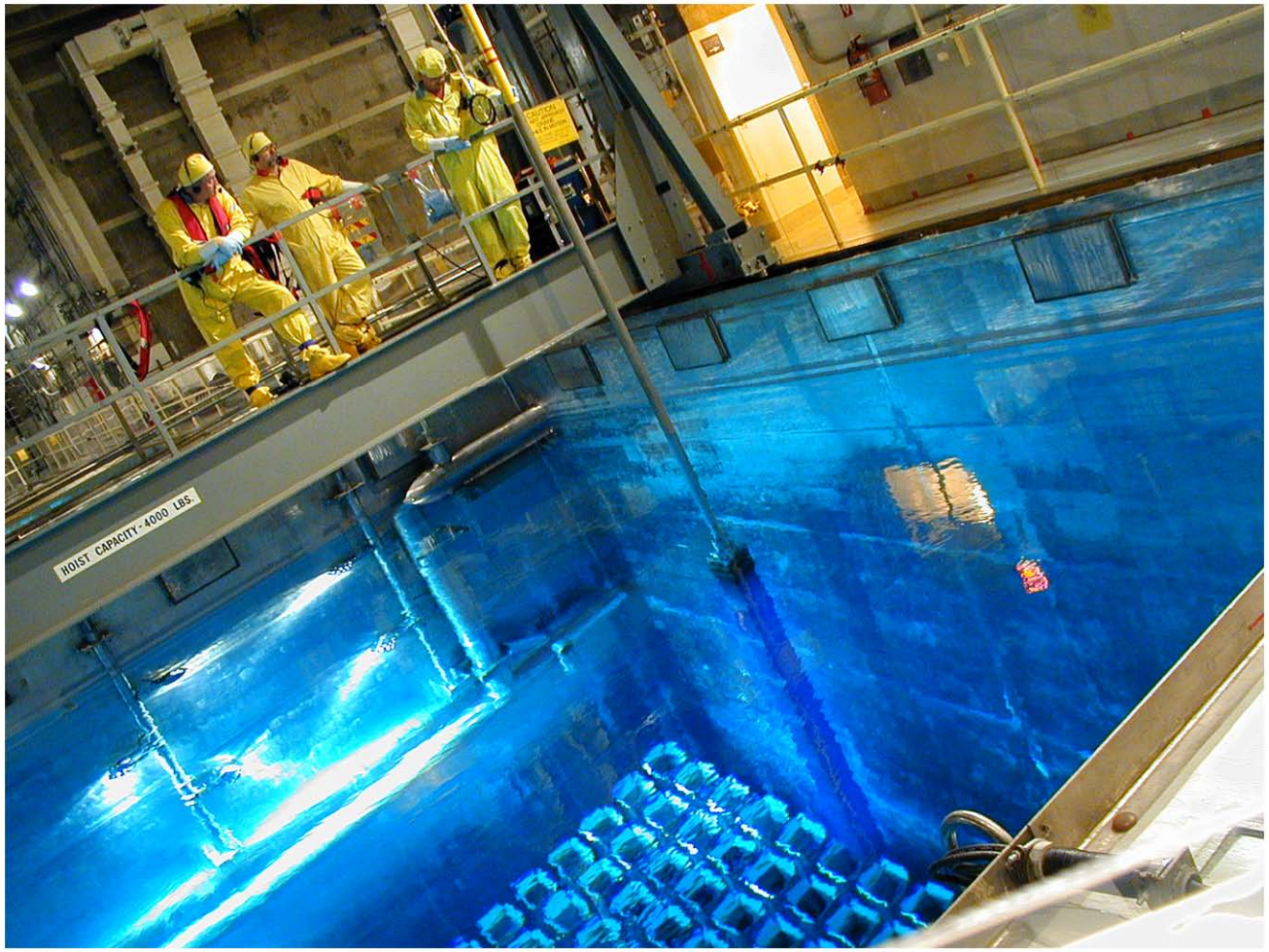


Comanche Peak – Dual Unit PWR

Reactor Core



Spent Fuel Pool



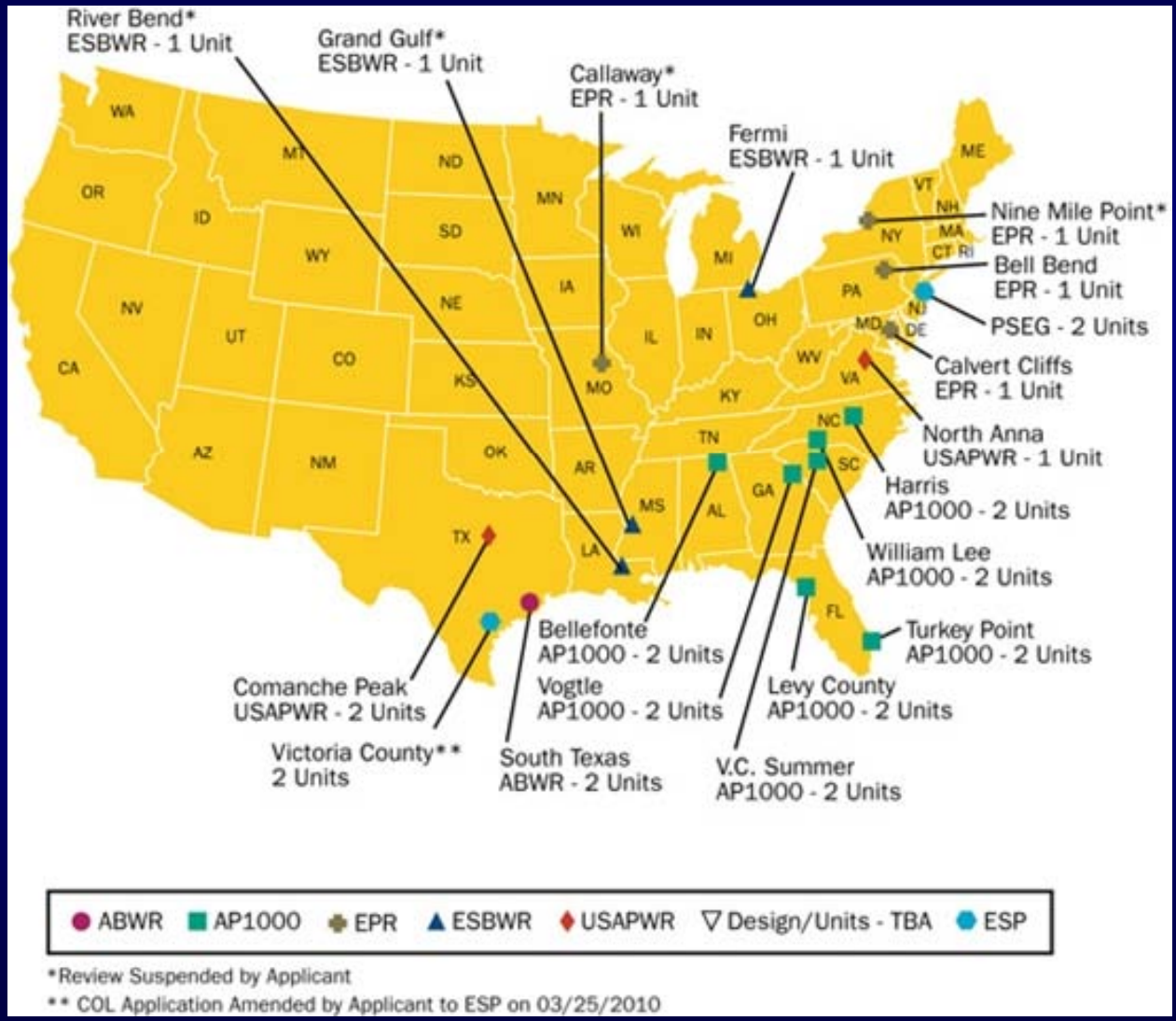
Radiation Dose Rates

Examples of radiation dose rates encountered in commercial reactors:

Location:	Dose rate (rad/hr):
Spent fuel (in pool)	**100,000 – 1,000,000**
Radwaste Resin Tank	**5,000**
Steam generator channel head	**10-40**
TIPS and cables-incore reactor instrumentation	**1 – 100,000**
Thimbles	**50,000**
Reactor cavity	**> 1,000**

- Reg. Guide 8.38, Rev. 1, May 2006

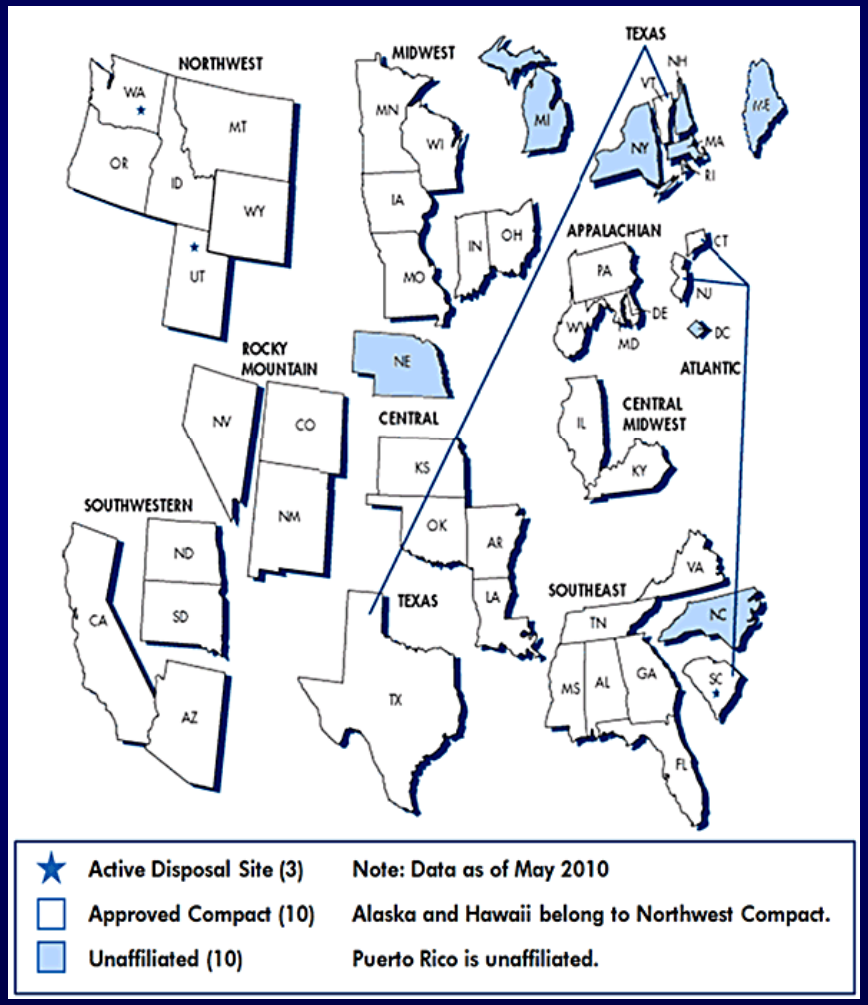
New Reactors



Waste Disposal

Low Level Radioactive Waste Disposal Compacts

- Disposal of low-level radioactive waste in near-surface disposal facilities is regulated by the NRC (since 1982; 10 CFR 61).
- There are 3 classes of low-level radwaste, A, B, and C. Class is based on the activity, concentration, and half-life of the isotopes in the waste.
- Congress established "Compact" system (LLW Policy Act of 1980) to encourage states to collaborate in disposal of low level waste.
- The facility in Barnwell, SC closed June 2008 to all but the Atlantic Compact member states.

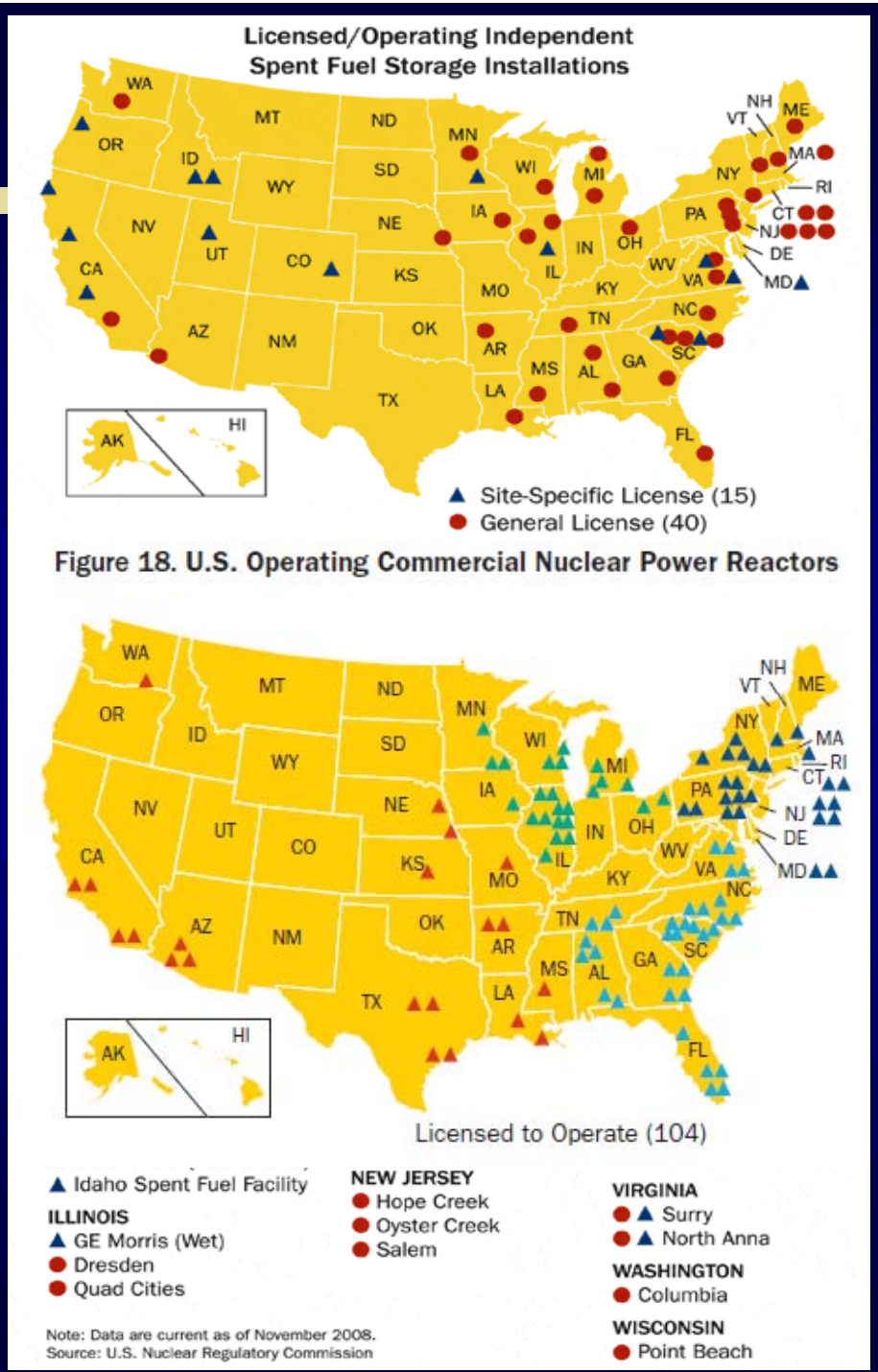


Low Level Radioactive Waste Disposal

Barnwell, SC

High Level Waste: ISFSI Storage Sites

- Dry cask storage allows spent fuel that has already cooled in the spent fuel pool for at least one year to be surrounded by inert gas inside a container called a cask.
- Storage may be by either a general or specific license.
- Casks are typically steel cylinders that are either welded or bolted closed. The steel cylinder provides a leak-tight containment of the spent fuel.
- Each cylinder is surrounded by steel, concrete, or other material to provide radiation shielding to workers and members of the public.
- Some cask designs can be used for both storage and transportation.



ISFSI Operations

Nuclear Waste Future?

January 29, 2010

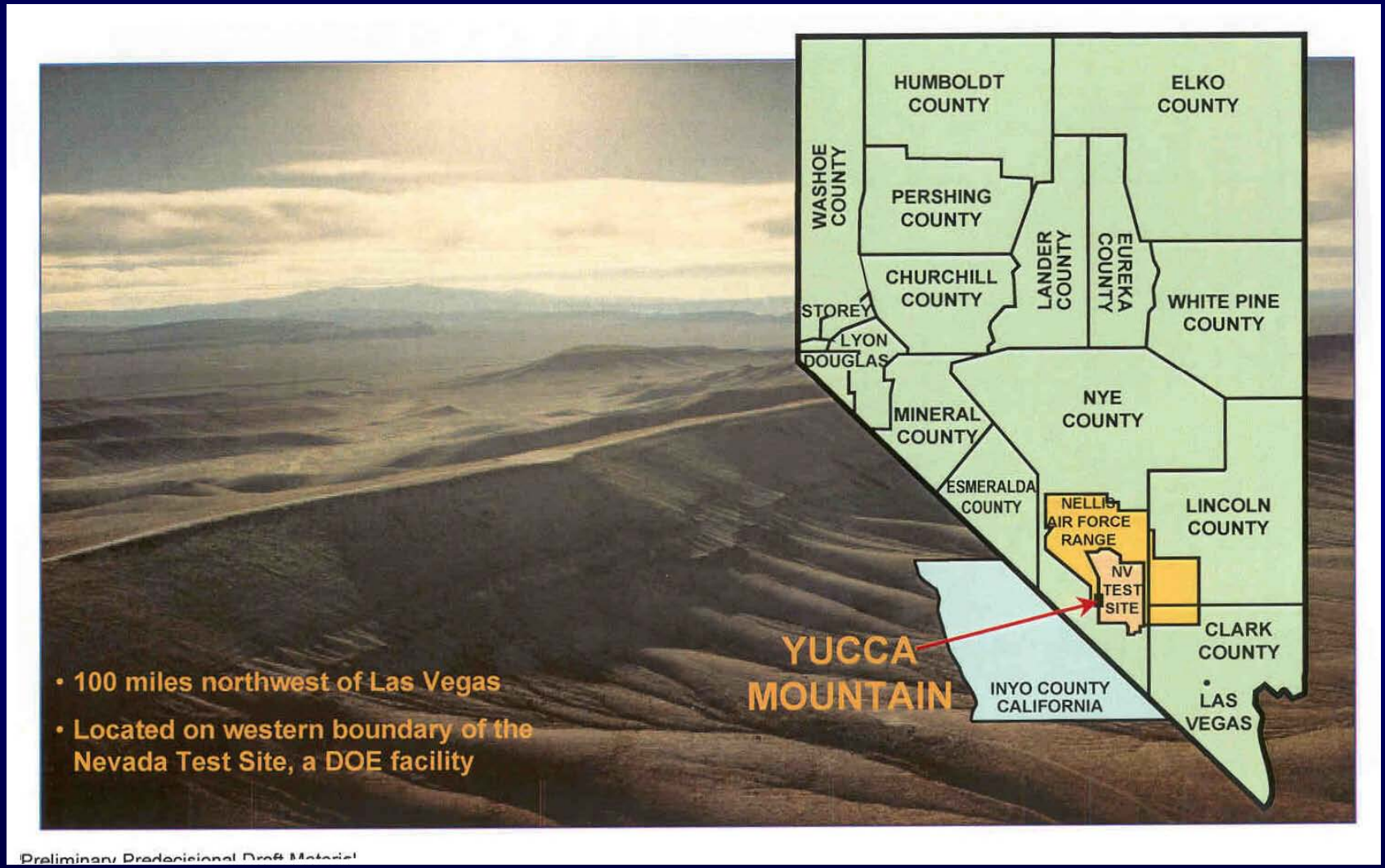
Secretary Chu Announces Blue Ribbon Commission on America's Nuclear Future

The Commission, led by Lee Hamilton and Brent Scowcroft, will provide recommendations on managing used fuel and nuclear waste

WASHINGTON, D.C. – As part of the Obama Administration's commitment to restarting America's nuclear industry, U.S. Secretary of Energy Steven Chu today announced the formation of a Blue Ribbon Commission on America's Nuclear Future to provide recommendations for developing a safe, long-term solution to managing the Nation's used nuclear fuel and nuclear waste. The Commission is being co-chaired by former Congressman Lee Hamilton and former National Security Advisor Brent Scowcroft.

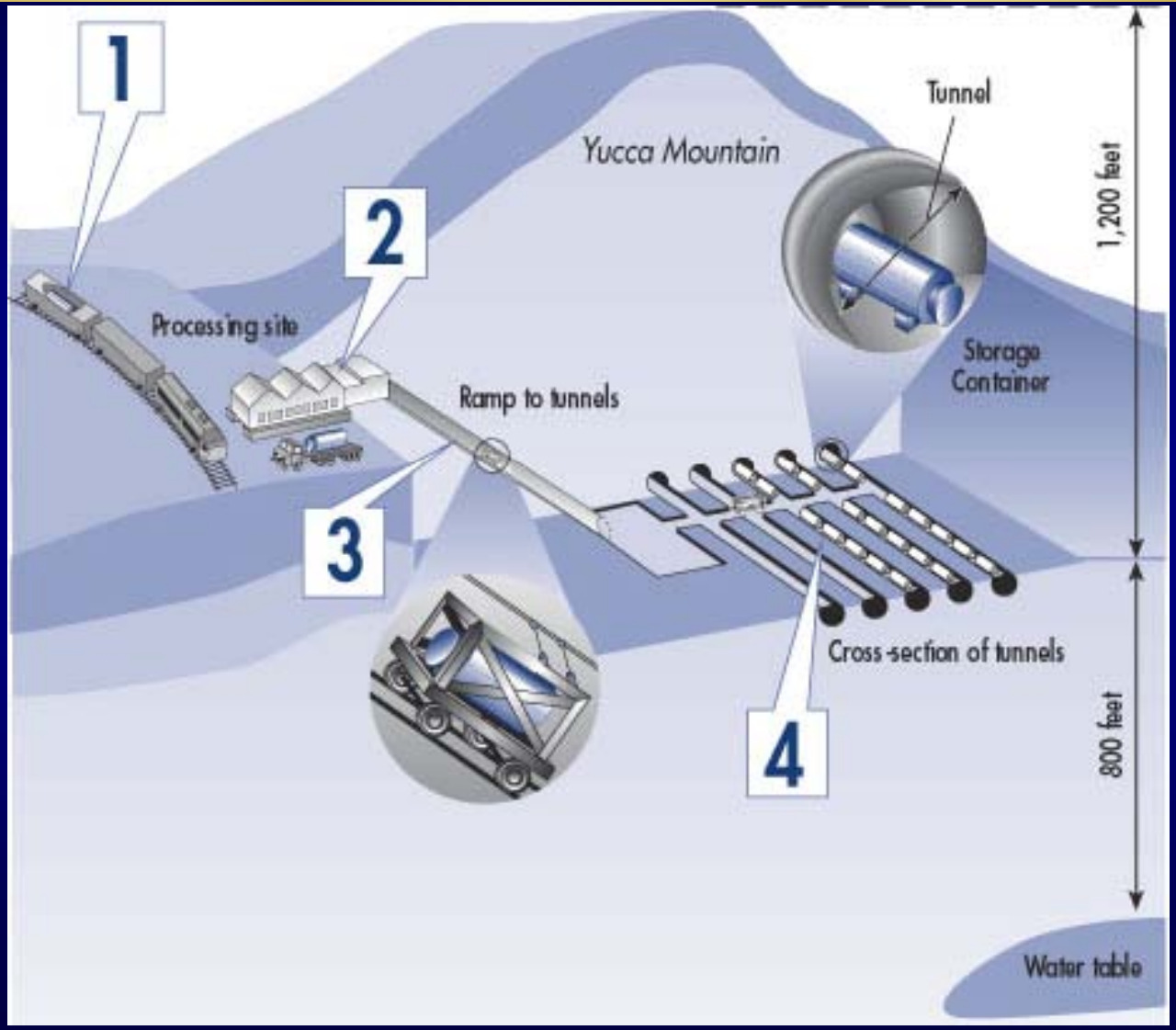
In light of the Administration's decision not to proceed with the Yucca Mountain nuclear waste repository, President Obama has directed Secretary Chu to establish the Commission to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle. The Commission will provide advice and make recommendations on issues including alternatives for the storage, processing, and disposal of civilian and defense spent nuclear fuel and nuclear waste.

Yucca Mountain

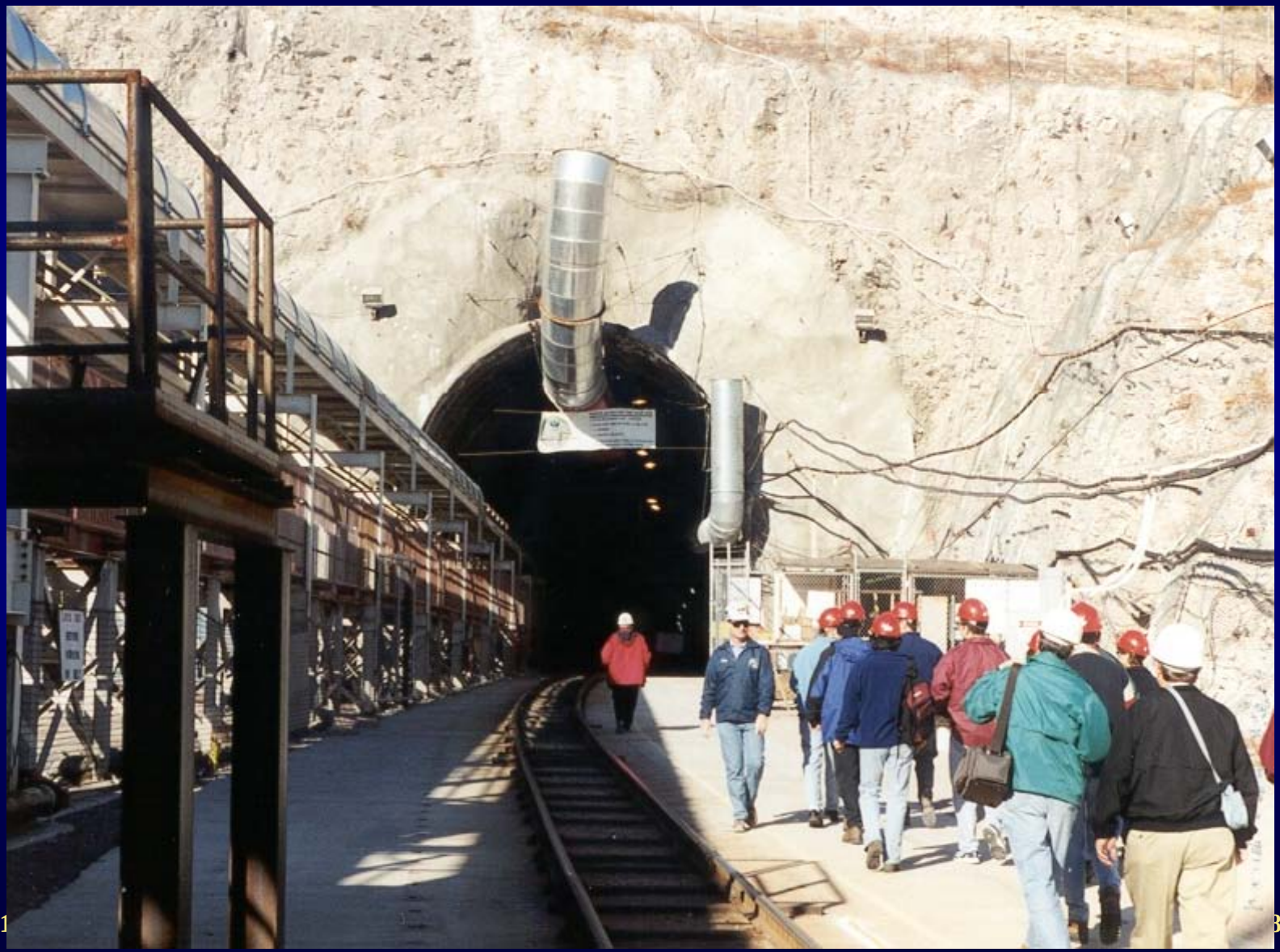


[Preliminary Predecisional Draft Material]

Yucca Mountain Conceptual Design



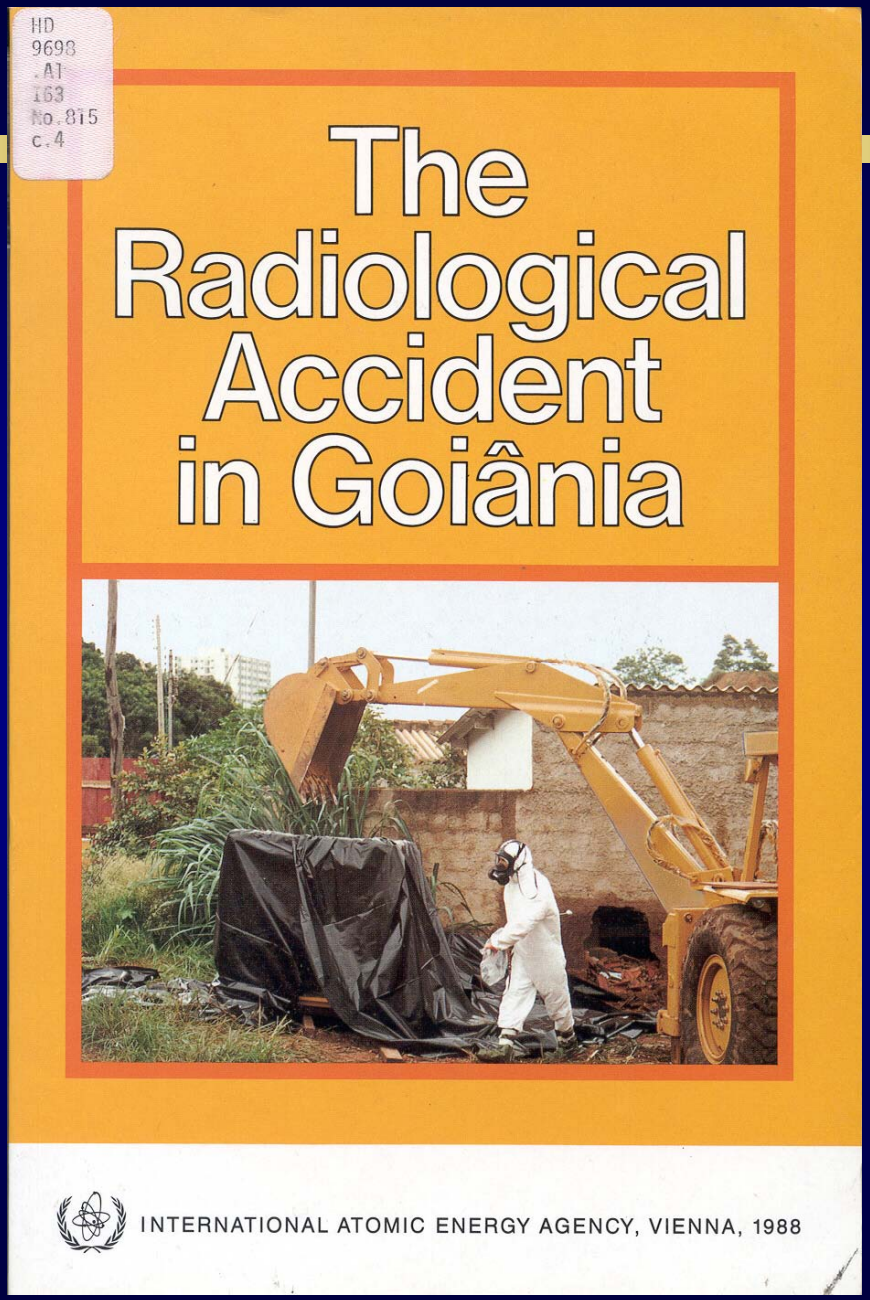
North Portal

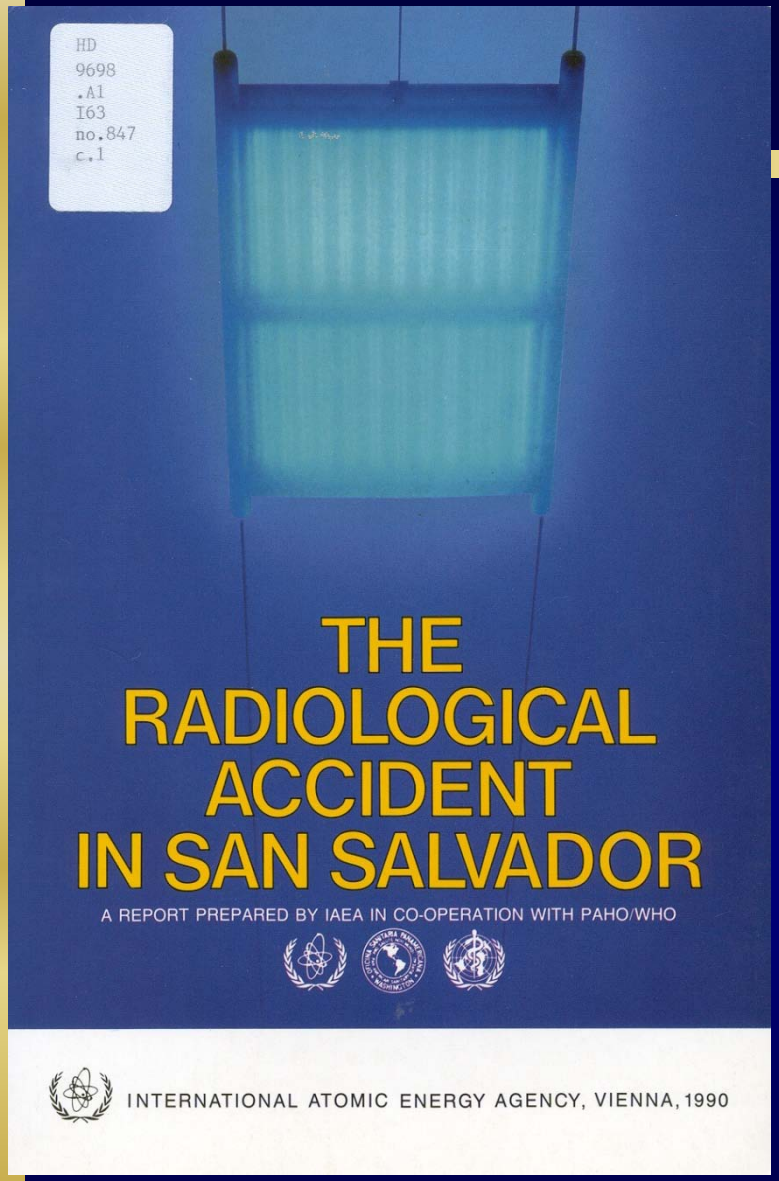


Tunnel Boring Machine at Yucca Mt.

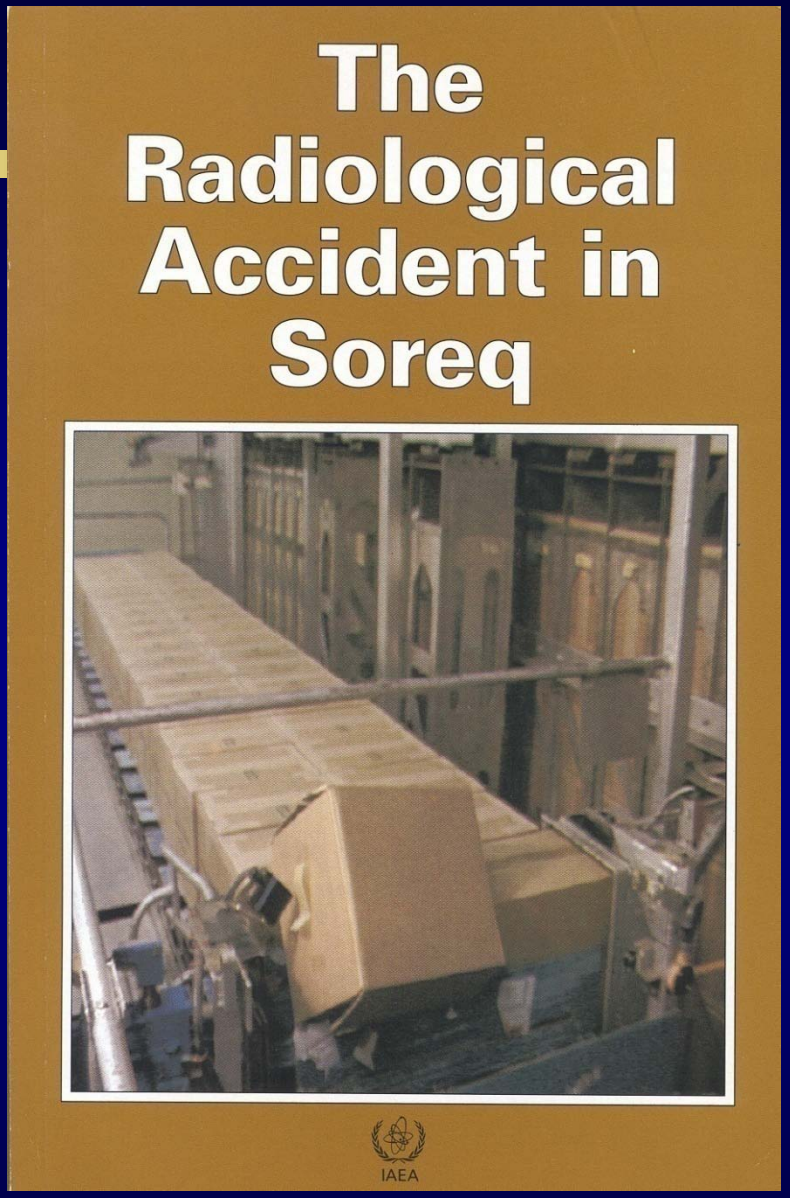
INCIDENTS/ACCIDENTS

Brazil
September
1987





IRRADIATORS



(El Salvador 2/89)

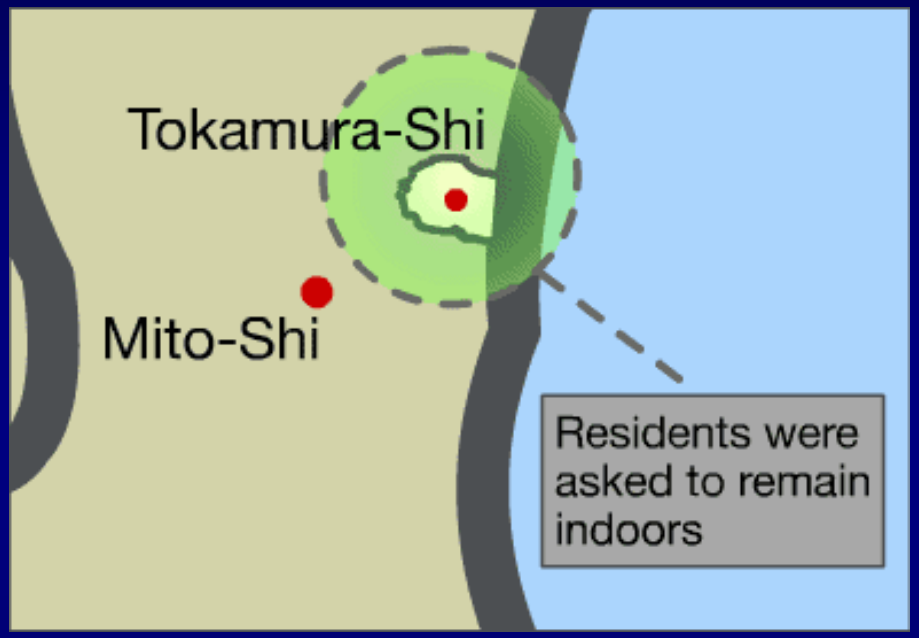
(Israel 6/90)

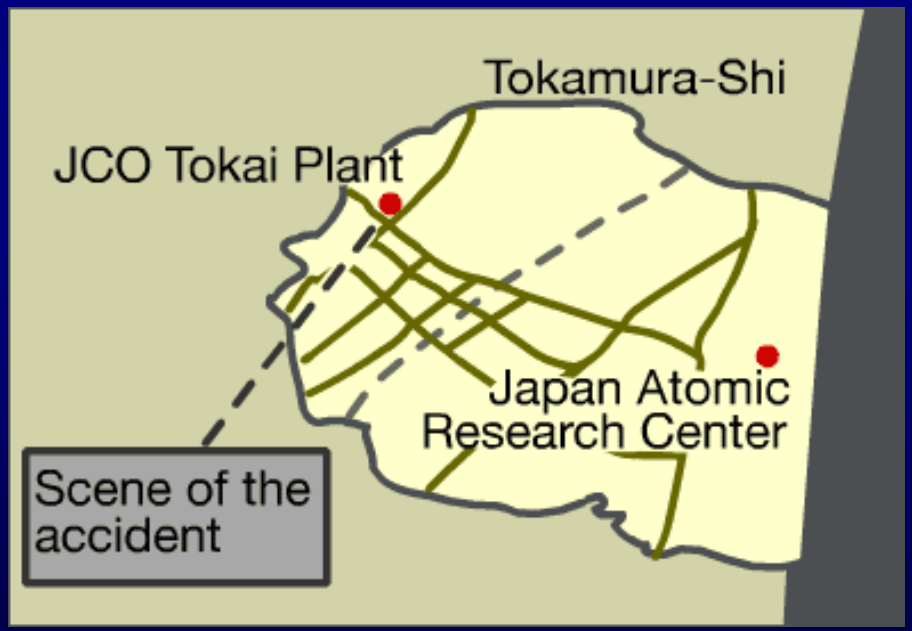
Tokaimura Criticality Accident

- In September 30, 1999, three workers at a uranium conversion facility were involved in a criticality accident resulting from procedural violations. The doses were about 350 cGy, 800 cGy, and 1500 cGy as determined from Na-24 from whole body counts.

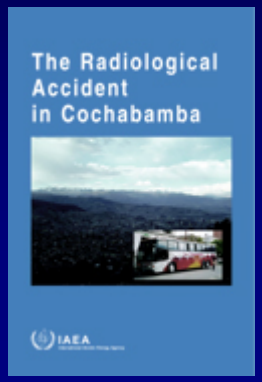
- Radioactivity resulting from the accident was released to the environment and onitoring of the public was conducted.

Tokaimura Criticality Accident





And There Are Others…



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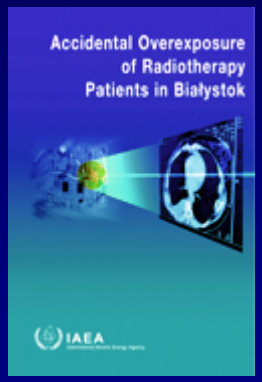

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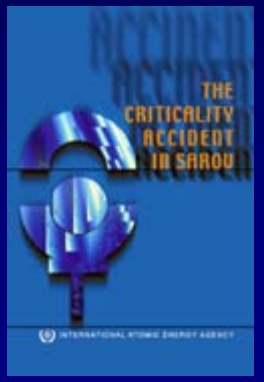

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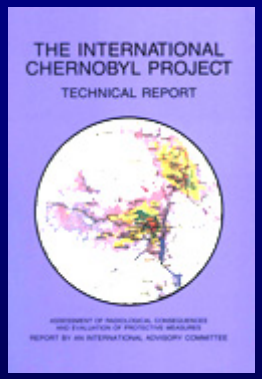

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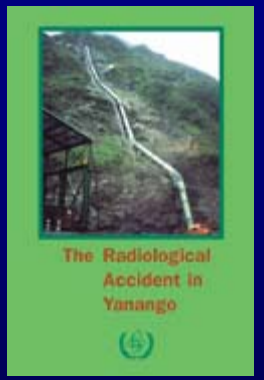

8.

NUREG–1405

Inadvertent Shipment of a Radiographic Source from Korea to Amersham Corporation, Burlington, Massachusetts

(8/90)

U.S. Nuclear Regulatory Commission

Reprinted August 1990

NUREG–1480

Loss of an Iridium–192 Source and Therapy Misadministration at Indiana Regional Cancer Center Indiana, Pennsylvania, on November 16, 1992

U.S. Nuclear Regulatory Commission

NUREG–1535

Ingestion of Phosphorus-32 at Massachusetts Institute of Technology, Cambridge, Massachusetts, Identified on August 19, 1995

U.S. Nuclear Regulatory Commission

QUESTIONS?

END OF APPLICATIONS & EVENTS

Review

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- What isotope is used in fixed process flow gauges?
- What is the difference between brachytherapy and teletherapy?
- What isotope is used in high dose rate afterloaders?

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- What material is used to shield radiation in industrial radiography "cameras?"
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- What is the process called where radioactive materials are used to sterilize objects?

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