The Disaster Environment

What do you do?
What do you do?
How most of us feel about radiation until we understand the principles of safe use:
## Incident Stay-Time Table

<table>
<thead>
<tr>
<th>METER</th>
<th>DOSE RATE (METER READING)</th>
<th>5.0 mSv (500 MREM = 0.5 REM)</th>
<th>50 mSv (5,000 MREM = 5 REM)</th>
<th>250 mSv (25,000 MREM = 25 REM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-range survey meter (CD V-700)</td>
<td>0.02 mSv/hr (2 mR/hr)</td>
<td>250 hr</td>
<td>2,500 hr</td>
<td>12,500 hr</td>
</tr>
<tr>
<td></td>
<td>0.05 mSv/hr (5 mR/hr)</td>
<td>100 hr</td>
<td>1,000 hr</td>
<td>5,000 hr</td>
</tr>
<tr>
<td></td>
<td>0.10 mSv/hr (10 mR/hr)</td>
<td>50 hr</td>
<td>500 hr</td>
<td>2,500 hr</td>
</tr>
<tr>
<td></td>
<td>0.25 mSv/hr (25 mR/hr)</td>
<td>20 hr</td>
<td>200 hr</td>
<td>1,000 hr</td>
</tr>
<tr>
<td></td>
<td>0.50 mSv/hr (50 mR/hr)</td>
<td>10 hr</td>
<td>100 hr</td>
<td>500 hr</td>
</tr>
<tr>
<td>High-range survey meter (CD V-715)</td>
<td>5 mSv/hr (0.5 R/hr)</td>
<td>1 hr</td>
<td>10 hr</td>
<td>50 hr</td>
</tr>
<tr>
<td></td>
<td>0.01 Sv/hr (1.0 R/hr)</td>
<td>0.5 hr (30 min)</td>
<td>5 hr</td>
<td>25 hr</td>
</tr>
<tr>
<td></td>
<td>0.20 Sv/hr (20 R/hr)</td>
<td>108 sec</td>
<td>15 min</td>
<td>75 min</td>
</tr>
<tr>
<td></td>
<td>0.50 Sv/hr (50 R/hr)</td>
<td>36 sec</td>
<td>6 min</td>
<td>30 min</td>
</tr>
</tbody>
</table>
What are we not talking about? At least not much Non-Ionizing Radiation
Non-Ionizing Radiation from High to Low Frequency
Radiation and Radioactive Material are a Natural Part of Our Lives

- We are constantly exposed to low levels of radiation from outer space, earth, and the healing arts.
- Low levels of naturally occurring radioactive material are in our environment, the food we eat, and in many consumer products.
- Some consumer products also contain small amounts of man-made radioactive material.
Unstable Atoms Decay

• The number of “decays” that occur per unit time in the radioactive material tell us how radioactive it is.
  – Units include Curies (Ci), decays per minute (dpm), and Becquerels (decays per second).

• When an unstable atom decays, it **transforms** into another atom and releases its excess energy in the form of radiation. Radiation can be
  – Electromagnetic radiation (like X or gamma rays), and
  – Particles (like alpha, beta, or neutron radiation)

• Sometimes the new atom is also unstable, creating a “decay chain”
How Unstable Is It?

• The “Half-Life” describes how quickly Radioactive Material decays away with time.

It is the time required for half of the unstable atoms to decay.

• Some Examples Example:
  – Some natural isotopes (like uranium and thorium) have half-lives that are billions of years,
**Half Life Calculation**

The time required for the amount of radioactive material to decrease by one-half

\[ N_t = N_o \left( \frac{1}{2} \right)^{t/T_{1/2}} \]
## Some Isotopes & Their Half Lives

<table>
<thead>
<tr>
<th>ISOTOPE</th>
<th>½ Life</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium</td>
<td>billions of years</td>
<td>Natural uranium is comprised of several different isotopes. When enriched in the isotope of U-235, it’s used to power nuclear reactor or nuclear weapons.</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>5730 y</td>
<td>Found in nature from cosmic interactions, used to “carbon date” items and as radiolabel for detection of tumors.</td>
</tr>
<tr>
<td>Cesium-137</td>
<td>30.2 y</td>
<td>Blood irradiators, tumor treatment through external exposure. Also used for industrial radiography.</td>
</tr>
<tr>
<td>Hydrogen-3</td>
<td>12.3 y</td>
<td>Labeling biological tracers.</td>
</tr>
<tr>
<td>Iridium-192</td>
<td>74 d</td>
<td>Implants or &quot;seeds&quot; for treatment of cancer. Also used for industrial radiography.</td>
</tr>
<tr>
<td>Molybdenum-99</td>
<td>66 h</td>
<td>Parent for Tc-99m generator.</td>
</tr>
<tr>
<td>Technicium-99m</td>
<td>6 h</td>
<td>Brain, heart, liver (gastroenterology), lungs, bones, thyroid, and kidney imaging, regional cerebral blood flow, etc..</td>
</tr>
</tbody>
</table>
The Amount of Radioactivity is NOT Necessarily Related to Size

• Specific activity is the amount of radioactivity found in a gram of material.

• Radioactive material with **long half-lives** have **low specific activity**.

  1 gram of Cobalt-60 *has the same activity as* 1800 tons of natural Uranium
Four Primary Types of Ionizing Radiation:

Alpha Particles: 2 neutrons and 2 protons
They travel short distances, have large mass
Only a hazard when inhaled
Four Primary Types of Ionizing Radiation: Beta Particles

Beta Particles: Electrons or positrons having small mass and variable energy. Electrons form when a neutron transforms into a proton and an electron or:
Four Primary Types of Ionizing Radiation:

Gamma Rays

Gamma Rays (or photons): Result when the nucleus releases Energy, usually after an alpha, beta or positron transition
Four Primary Types of Ionizing Radiation:

X-Rays

X-Rays: Occur whenever an inner shell orbital electron is removed and rearrangement of the atomic electrons results with the release of the elements characteristic X-Ray energy.
Four Primary Types of Ionizing Radiation:

Neutrons

Neutrons: Have the same mass as protons but are uncharged

They behave like bowling balls
Four Primary Types of Ionizing Radiation

- Alpha particles
- Beta particles
- Gamma rays (or photons)
- X-Rays (or photons)
- Neutrons
Shielding for $\alpha$, $\beta$ and $\gamma$

BASIC CONCEPT is to:

Place materials between the source and person to absorb some or all of the radiation
DNA and Radiation
Ionizing Radiation at the Cellular Level

- Causes breaks in one or both DNA strands or;

- Causes Free Radical formation
3Cellular Effects

Cell death
Cell repair
Cell change

Is this change good or bad?
Our Bodies Are Resilient

- DNA damage is most important and can lead to cell malfunction or death.

- Our body has ~ 60 trillion cells
  - Each cell takes “a hit” about every 10 seconds, resulting in tens of millions of DNA breaks per cell each year.
  - BACKGROUND RADIATION causes only a very small fraction of these breaks (~ 5 DNA breaks per cell each year).

- Our bodies have a highly efficient DNA repair mechanisms
Dividing Cells are the Most Radiosensitive

• Rapidly dividing cells are more susceptible to radiation damage.

• Examples of radiosensitive cells are:
  – Blood forming Cells
  – The intestinal lining
  – Hair follicles
  – A fetus

This is why the fetus has a exposure limit (over gestation period) of 500 mrem (or 1/10\textsuperscript{th} of the annual adult limit)
At HIGH Doses, We KNOW Radiation Causes Harm

• High Dose effects seen in:
  – Radium dial painters
  – Early radiologists
  – Atomic bomb survivors
  – Populations near Chernobyl
  – Medical treatments
  – Criticality Accidents

• In addition to radiation sickness, increased cancer rates were also evident from high level exposures.
## Effects of ACUTE Exposures

<table>
<thead>
<tr>
<th>Dose (Rads*)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-50</td>
<td>First sign of physical effects (drop in white blood cell count)</td>
</tr>
<tr>
<td>100</td>
<td>Threshold for vomiting (within a few hours of exposure)</td>
</tr>
<tr>
<td>320 - 360</td>
<td>~ 50% die within 60 days (with minimal supportive care)</td>
</tr>
<tr>
<td>480 - 540</td>
<td>~50% die within 60 days (with supportive medical care)</td>
</tr>
<tr>
<td>1,000</td>
<td>~ 100% die within 30 days</td>
</tr>
</tbody>
</table>
Old Terms

- **Roentgen** - Based on the quantity of electrical charges produced in air by X or Gamma photons. $1R = 2$ billion pr.

- **RAD** - Radiation Absorbed Dose is the work energy resulting from the absorption of one ROENTGEN or $6.24 \times 10^5$ Mev.
More Old Terms

• **REM** - Roentgen Equivalent Mammal is equal to the absorbed dose in RADS multiplied by a quality factor

  • **Quality Factors**
    • Beta = 1
    • Gamma & X ray photons = 1
    • Alpha = 10
    • Neutrons = 20
New Terms

International Units have replaced the RAD and REM

GRAY (Gy) = 100 RAD
SIEVERT (Sv) = 100 REM

Same Quality Factors apply to the Sv
Units of Radioactivity

- Curie (Ci) = 2.22 E12 dpm or 3.7E10 dps
- Becquerel (Bq) = 1 dps
- Maximum Dose/year = 5 REM or 50 mSv
- Maximum Dose/year for Declared Pregnant Woman & Minors = 0.5 REM or 5 mSv
# Annual Dose Limits

**External/Internal Exposure Limits for Occupationally Exposed Individuals**

<table>
<thead>
<tr>
<th>Location</th>
<th>Adult ($\geq$ 18 yrs)</th>
<th>Minor (&lt; 18 yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body*</td>
<td>5000 mrem/yr</td>
<td>500 mrem/yr</td>
</tr>
<tr>
<td>Lens of eye</td>
<td>15000 mrem/yr</td>
<td>1500 mrem/yr</td>
</tr>
<tr>
<td>Extremities</td>
<td>50000 mrem/yr</td>
<td>5000 mrem/yr</td>
</tr>
<tr>
<td>Skin</td>
<td>50000 mrem/yr</td>
<td>5000 mrem/yr</td>
</tr>
<tr>
<td>Organ</td>
<td>50000 mrem/yr</td>
<td>5000 mrem/yr</td>
</tr>
</tbody>
</table>
## Typical Doses

<table>
<thead>
<tr>
<th>Source of Radiation</th>
<th>Dose (mrem/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Dose to US Public from All sources</td>
<td>360</td>
</tr>
<tr>
<td>Average Dose to US Public from Natural Sources</td>
<td>300</td>
</tr>
<tr>
<td>Average Dose to US Public from Medical Uses</td>
<td>53</td>
</tr>
<tr>
<td>Coal Burning Power Plant</td>
<td>0.2</td>
</tr>
<tr>
<td>Average dose to US Public from Weapons Fallout</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Average Dose to US Public from Nuclear Power</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Occupational Dose Limit for Radiation Workers</td>
<td>5,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source of Radiation</th>
<th>Dose (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coast to coast Airplane roundtrip</td>
<td>5</td>
</tr>
<tr>
<td>Chest X ray</td>
<td>8</td>
</tr>
<tr>
<td>Dental X ray</td>
<td>10</td>
</tr>
<tr>
<td>Head/neck X ray</td>
<td>20</td>
</tr>
<tr>
<td>Shoe Fitting Fluoroscope (not in use now)</td>
<td>170</td>
</tr>
<tr>
<td>CT (head and body)</td>
<td>1,100</td>
</tr>
<tr>
<td>Therapeutic thyroid treatment (dose to the whole body)</td>
<td>7,000</td>
</tr>
</tbody>
</table>
Radiation is a type of energy; Contamination is material

- Exposure to *Radiation* will not contaminate you or make you radioactive
- *Contamination* is Radioactive Material spilled someplace you don’t want it.
- Radioactive contamination emits radiation
- Contact with *Contamination* can contaminate you with the material
Radiation Protection

- Decrease Time
- Increase Distance
- Increase Shielding
Current Locations of Spent Nuclear Fuel and High-Level Radioactive Waste Destined for Geologic Disposition

Symbols do not reflect precise locations

Nuclear Sites
63 commercial reactors operating
9 commercial reactors shutdown
2 commercial SNF pool storage
43 research reactors
13 DOE nuclear materials
1 Navy fuels

131 Sites in 39 States

Current Storage Locations (and Number of Locations)

- Commercial Reactors (72 sites in 33 states), including:
  - 104 operating reactors, and
  - 14 shutdown reactors with SNF on site

- Commercial SNF Pool Storage (Away-From-Reactor) (2)

- Commercial Dry Storage Sites (16)

- Naval Reactor Fuel (1)

- Research Reactors (43 sites in 26 states), including:
  - 36 operating reactors, and
  - 11 shutdown reactors with SNF on site

- DOE-Owned SNF and HLW (10)

- Commercial HLW (1)

- Surplus Plutonium (6)

Waste Quantities Projected through 2046
(in Metric Tons, except for HLW)

- Commercial SNF up to 105,000
- DOE-Owned SNF 2,500
  including:
  - Naval Reactor Fuel 65
  - Foreign Research Fuel 16
- Surplus Plutonium 50
- HLW Glass (canisters) ~22,000

As of January 2002
Something Extra

- Irradiating Food
- Radon
- Dirty Bombs
Radioactive Material Production, Transportation, and Use
Radioactive Material Production, Transportation, and Use

• The creation, shipping, and use of radioactive material is **highly regulated** (IAEA, NRC, DOT, etc…).

• High Activity Sources can **only** be produced by sophisticated methods (e.g. reactors & accelerators).

• High activity sources can only be obtained after special licensing to ensure their **safe use** and their **security**.
Shielding Requirements Limit

Portability

• For gamma sources: the higher the activity, the more shielding you require to transport the source.

Small radiography sources:
  • typically 0.1 Ci to 200 Ci.
  • 30 – 50 Lbs

Medium radiography sources:
  • Hundreds of Ci
  • 200 - 400 Lbs

Large industrial source:
  • 9,000 Ci
  • 3 tons of shielding
High Activity Radioactive Material

- Spent Nuclear Fuel & High Level Waste
- Radioisotope Thermoelectric Generators (RTG)
- Medical & Radiographic sources

Fuel Assembly

1 - 10 kiloCi (when spent)

1 - 500 kiloCi (when spent)

10 - 100 kiloCi

0.01 - 0.2 kiloCi

1 - 10 kiloCi
Spent Fuel

- Currently stored “onsite” at locations throughout the country.
- Spent Fuel containers extremely rugged and made to withstand extreme accident conditions.
- For thirty years, > 5,000 highly-radioactive fuel assemblies have been shipped without radiation release (despite several accidents).
- Security measures are taken.
Radioisotope Thermoelectric Generators (RTG)

Self heated Plutonium 238

• The heat generated by the radioactive decay is used to generate electricity
• Used when maintenance free power is need for decades (satellites, ocean bottom, and arctic applications)
• RTGs most often made from Sr-90 (0.46 kW/kg) or Pu-238 (0.54 kW/kg).
Portable Radiography Sources

- “Top strength” industrial radiography sources can burn fingers and cause radiation sickness within a few minutes.
- Effects drop off dramatically with distance. Outside of 3 meters, acute effects rare even after hours of exposure.
- Sources are constructed to meet rigorous testing standards. A typical source is encapsulated in two (2) TIG welded Stainless Steel Capsules.
- Source Material itself is often metal (Cobalt or Iridium) or embedded on non-soluble ceramics or “microspheres” to prevent inhalation of radioactive material if the source encapsulation is breached.
Facility Based Irradiators

- These sources can have 10 to 100 times more radioactivity than radiography sources.
- Found in food irradiators, medical sterilizers, etc..
- The shielded enclosures that hold the sources weigh more than a ton.
- Difficult to remove source from the facility or equipment.
High Activity Source Transportation

Containers that ship high activity sources are meant to withstand very punishing accident conditions.

- **FREE DROP**: A 30-foot free drop onto a flat, un-yielding surface so that the package’s weakest point is struck.
- **PUNCTURE**: A 40-inch free drop onto a 6-inch diameter steel rod at least 8 inches long, striking the package at its most vulnerable spot.
- **THERMAL**: Exposure of the entire package to 1475° for 30 minutes.
- **IMMERSION**: Immersion of the package under 50 feet of water for at least 8 hours.
Conclusion:

Radioactive Material Production, Transportation, and Use

• High Activity Radioactive Material is highly regulated.

• Industrial Sources are very robust and made not to leak.

• When dangerous quantities are shipped, the material is put in a container capable of withstanding harsh accident conditions.

• Very high activity industrial/medical sources are facility based and difficult to remove.
How Might High Activity Radioactive Material be Misused?

- Expose people to an external source of radiation.
- Disperse radioactive material using conventional means.
- Explosively Disperse radioactive material [a “Dirty Bomb”].
- Create a Nuclear Weapon (this requires special nuclear material).
Potential consequences of dispersal of radioactive material into...

Facility ventilation systems
- Inhalation (Internal) Dose hazard
- Interruption of ‘normal life’
- Expensive cleanup costs

The general environment ("dirty bombs", crop dusters, fire, sprayer, etc..)
- Low likelihood of acute radiological effects
- May require population shelter or evacuation
- May be difficult to clean outdoor areas

Water supplies
- High Dilution
- Individually significant doses would not likely result.
WHAT IS A ‘DIRTY BOMB’?

- A “Dirty Bomb” is conventional explosives combined with radioactive material with the intention of spreading the radioactive material over a relatively large area.

- This is NOT a nuclear explosion, the radioactive material does not enhance the explosion.

- Very few deaths would be expected from acute radiological exposure (the greatest hazard would likely be from the effects of the conventional explosives).

- The contamination will hamper emergency response efforts and can delay hospital treatment.
External Exposures

- Focused radiation or localized contamination can result in radiation effect to specific areas on the body.

- Whole body exposure can result from:
  - A passing radioactive cloud or smoke
  - A large, distant point source
  - Exposure from contamination deposited on the ground
Internal Exposures

• Once radioactive material is deposited in the body, it can expose the person from within.

• The magnitude of the dose will depend on many factors:
  – How much material was deposited,
  – How it got into the body (ingestion, inhalation, absorption, or injection)
  – Chemical form of the radioactive material,
  – the radiation it produces,
  – How quickly it decays, and
  – How quickly the body eliminates the material
Internal Exposures

- Dose from internal depositions are usually expressed by summing dose that will be received over the next 50 years from a one time internal deposition.
  - Referred to as Committed Effective Dose Equivalent (CEDE).
  - This dose calculation/estimate takes into account factors on the previous slide.
  - Even with a large CEDE, there may or may not be acute effects from the exposure.

Do not use internal doses to predict acute exposure effects like nausea and vomiting.
Types of Exposure & Health Effects

• **Acute Dose**
  – Large radiation dose in a short period of time
  – Large doses may result in observable health effects
    • Early: Nausea & vomiting
    • Hair loss, Fatigue, & medical complications
    • Burns and wounds heal slowly
  – Examples: Medical Exposures and accidental exposure to sealed sources

• **Chronic Dose**
  – Radiation dose received over a long period of time
  – Body more easily repairs damage from chronic doses
  – Does not usually result in observable effects
  – Examples: Background Radiation and Internal Deposition

Inhalation
The Human Factor

• Concerns about radiation and contamination often produce an exaggerated emotional response.
  – Can’t detect it with our 5 senses
  – Associated with cancer
  – Reminiscent of “cold war” fears
  – Science difficult to understand
  – Out of our control

• Possible results may be…
  – Unexposed people saturating the medical community
  – Health and economic effects from long term anxiety or depression in the community
Conclusion:
Misuse of Radioactive Material

• High activity sources can cause health effects, but only to those in close proximity.

• Acute health effects from distributed radioactive material unlikely without prolonged, high-concentration exposure.

• Radiation or contamination will hinder response efforts.

• Denial of facilities and areas will have a major cost effect.

• Public anxiety and it’s effects may be the primary lasting health effect.
First Responder Considerations
A Case Study: Goiania, Brazil 1987

- When a hospital changed locations, a radiation therapy unit was temporarily left behind.

- Scrap metal hunters found the unit and dismantled it for scrap metal (~ Sept 18th).

- The 1.4 kiloCi (1,400 Ci) Cs-137 source containment was breached during the process.

- Pieces of source distributed to family and friends.

- Everyone was impressed by “the glowing blue stones.” Children & adults played with them.

- Serious radiological accident recognized on Sept 29th when Acute Radiation Syndrome symptoms were recognized by hospital staff.
Initial Response

112,000 people (10% of Goiania’s population) were surveyed at an Olympic Stadium.

- 250 were identified as contaminated
- 50 contaminated people were isolated in a camping area inside the Olympic Stadium for more detailed screening
- 20 people were hospitalized or transferred to special housing with medical and nursing assistance
- 8 patients transferred to the Navy Hospital in Rio de Janeiro
- Residential contamination survey was initiated
Early Consequences

- Widespread contamination of downtown Goiania
- 85 residences found to have significant contamination (41 of these were evacuated and a few were completely or partially demolished)
- People cross-contaminated houses 100 miles away
- Hot Spots at 3 scrap metal yards and one house
Radiation Injuries and Uptakes

- 4 fatalities (2 men, 1 woman and 1 child)
- 28 patients had radiation induced skin injuries (they held/played with the source for extended periods)
- 50 people had internal deposition (ingestion)
Conclusions

• Long and expensive clean-up effort.

• Profound *psychological* effects such as fear and depression on large populations

• Isolation and boycott of goods by neighbors
Response to a Radiological Incident ~ Contamination ~

- Monitor and isolate contaminated area

- Evacuate and “gross decon” victims (removal of outer clothing is an effective gross decontamination method)

- Avoid breathing in radioactive material
  - Shelter in place (close windows, turn off heating and A/C)
  - Evacuate, when safe to do so
  - Wear respiratory protection

- Radioactive material will not be uniformly distributed. Radiation “Hot Spots” near the source.
Response to a Radiological Incident

~ Radiation ~

- **Time:** Limit the time spent in areas of high radiation.
- **Distance:** Exposure decreases dramatically as you increase your distance from the source.
- **Shielding:** Radiation is blocked by mass. When practical, operate behind objects (fire trucks, buildings, etc.).

![Diagram showing shielding materials: Paper, Aluminum, Concrete. Alpha, Beta, Gamma rays are illustrated.]

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ARSCE 2002; WPM-A.4
Radiological Considerations for Public Protective Actions

• The EPA has developed Protective Action Guides (PAG) to help responders determine when evacuation is necessary:

  – Shelter & Evacuation PAGs are based on 1 & 5 rem exposures to the public.

  – Emergency phase PAGs are based on a 4 day exposure to “re-suspended” material and dependant on weather.

  – Developed for acute exposures (such as at a power plant accident), these guidelines are conservative for chronic internal exposures.
Example: Brazil’s 1.37 kCi (1,370 Ci) Cs-137 Source Made Into a “Dirty Bomb”

• Despite the accident in Brazil, sources of this strength are very difficult to obtain.

• This model assumes “worse case” in that:
  – The source was 100% aerosolized
  – Lots of explosive (~ 10 sticks of dynamite)
  – Presumes exposed populations “stood outside” during the exposure period.
  – Effects dependant on weather
Detectable Ground Contamination Can be Found ≥ 0.2 uCi/m² Can be detected with thin window G-M meter

≥ 2 uCi/m² Can be detected with dose rate meter
San Francisco Example: Ground Contamination Can be Detected East of Berkeley Hills

Release: 1.3 KCi CS-137 RDD with 5 lbs HE
Deposited Contamination

<table>
<thead>
<tr>
<th>Color</th>
<th>Level (uCi/m²)</th>
<th>Area (km²)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>5.4</td>
<td>Take measures to prevent cross contamination.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>59.04</td>
<td>Detectable with “hot dog” GM</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>409.34</td>
<td>Detectable with “Pancake” GM</td>
</tr>
</tbody>
</table>

Release location: San Francisco Police Department, 850 Bryant
37° 46’ 31” N  122° 24’ 15” W

100% Aerosolized release fraction

Strong afternoon west winds 18-25 mph.

Map size: 25 x 25 km
Despite Widespread Contamination, There Are Relatively Small Exposures

≥1 REM
EPA Shelter Area Less than 0.1 Miles Downwind

0.01 – 0.1 REM out to 2 miles [Dose Similar To a Chest X ray or 10% of natural background]
Los Angeles Example: EPA PAG Would Recommend Shelter/Evacuation of a Few Residential Blocks

Release: 1.3 KCi CS-137 RDD with 5 lbs HE
4-Day Dose (Internal + External)
Evacuation/Relocation PAG

<table>
<thead>
<tr>
<th>Color</th>
<th>Level (Rem)</th>
<th>Area (km²)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.026</td>
<td>0.01</td>
<td>Consider evacuation. Shelter in place if no evacuation.</td>
</tr>
<tr>
<td>0.1</td>
<td>0.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>3.84</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Release location: Burbank Police Department 34 10' 60"N, 118 18' 31"W

100% Aerosolized release fraction

Normal summertime west-northwest winds, 10-12 mph.

Map size: 6 x 6 km
Conclusion: First Responder Considerations

• Acute health effects from radiation dose are unlikely without prolonged, high concentration exposure.

• Contamination readily detectable at long distances.

• Medical emergencies take precedent over radiological monitoring.

• Wear respiratory protection, isolate area.

• Use decontamination techniques (removing outer clothing most effective)

• Call for assistance
CDV-777M Guide Booklet

➢ 1 Copy Per Set.
➢ Developed by FEMA in cooperation with DOT and Federal/State authorities.
➢ Revised 3/2000
➢ Provides answers to the most frequently asked questions by Fire Fighters, Police and EMS regarding Radiological Transportation Accidents.
Use a Standard CD V-700 to Establish Hot and Warm Zones in mR/Hr.

Prefer use of a Pancake equipped CD V-700 at the Checkpoint for Contamination Monitoring in CPM.
CDV-777M Forms Packet

Emergency Information Insert (MP-72)

- FEMA issued during the “Cold War” to assist personnel in the use of instruments and taking protective actions to reduce exposures.

- Information remains applicable in the event of a WMD emergency.

A copy is included in all CD V-777 Instrument Set.
Emergency Worker Monitoring & Decontamination Form

2 Copies supplied per set.

- **Purpose**: ID Workers, Document Contamination.
- Make initial survey.
- ID Contaminated areas.
- Attempt Field Decon if personnel are not injured.

- **DO NOT DELAY MEDICAL ATTENTION DUE TO RADIATION HAZARD!!**
CDV-777M Forms Packet

Vehicle Monitoring and Decontamination Form

- **2 Copies** supplied per set.
- Provides a means of documenting the presence of vehicle contamination.
- Decontamination is based on the need for use. If no priority, isolate vehicle for decon at a later time.
- Make effort to leave critical emergency response vehicles outside of the “hot zone” to prevent contamination.
CDV-777M Forms Packet

FEMA’s “Good, Some, None” Tables

- Provides computer generated estimates of the relative response of CD V-700 and CD V-715 meters to 350 Radionuclides found in DOT shipping regulations.

- Tables provide type of radiations emitted, half lives and permissible shipping quantities for type “A” packages of RAM’s.

- Valuable information for responders when the RAM can be identified.

Appendix E:
Response of Radiation Monitoring Instruments to Normalized Risk Quantities of Radionuclides

Table A-1 Response of Civil Defense Instruments to 0.1% A; Quantity given in the IAEA Regulations

K. F. Eckerman
Health and Safety Research Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

A. W. Carriker
Research and Special Programs Administration
U. S. Department of Transportation
Washington, DC

March 1992
(Revised September 1995)

Prepared for the Sandia National Laboratories
**FEMA Table**

- Provides permissible Stay-Time needed to obtain Dose based on readings for the CDV-700 (mR/h) and CDV-715 (R/h).

**Dose Limits Are:**

- .5 Rem or 500 mRem
- 5.0 Rem or 5000 mRem
- 25 Rem or 25000 mRem
Prompt Effects of Nuclear Weapons
Learning Objectives:

• Understand the immediate effects of a nuclear explosion
• Understand the health hazards of these effects
• Know immediate actions that can be taken to minimize injury and death.
The yield of a nuclear weapon is measured in *kilotons*.

Kiloton: the energy released by the detonation of 1,000 tons of TNT
Ways of measuring radiation

- Atoms disintegrating per unit time: curie, bequerel
- Energy absorbed: rad, gray
- Risk of cancer: rem, sievert
Putting doses into perspective...

- Dose from one hour of high altitude airplane flight = 0.003 rads
- 1 chest X-ray = 0.02 rads
- Annual dose from natural background = 0.3 rads
- Annual regulatory limit to a radiation worker = 5 rads
- Threshold for acute radiation syndrome = 50 rads
- 50% fatality dose = 500 rads
- 100% fatality dose = 1,000 rads
A nuclear weapon releases energy in 3 ways:

- Radiation: 15%
- Blast: 35%
- Heat: 50%
Thermal energy is released in a double pulse
1st pulse – 1% of thermal energy

- Ultraviolet, X-rays
- Blindness

2nd pulse – 99% of thermal energy

- Full spectrum of electromagnetic energy
- Lethal range from burns = 50%
  Fatality range from radiation
Blast – 50% of total yield

- Shock wave
- High winds
- Afterwind
Radiation – 15% of total yield

• Prompt radiation from the explosion
• Residual radiation at Ground Zero
• Fallout
Prompt effects of a 1 kiloton surface burst:

<table>
<thead>
<tr>
<th>Blast</th>
<th>Thermal</th>
<th>Radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths to .1 miles</td>
<td>3\textsuperscript{rd} degree burns to .8 miles</td>
<td>50% deaths to .5 miles (500 rad)</td>
</tr>
<tr>
<td>Lung damage, ruptured eardrums to 1/3 mile</td>
<td>1\textsuperscript{st} degree burns to .8 miles</td>
<td>Sickness to ¾ mile (100 rad)</td>
</tr>
<tr>
<td>Blindness to 2.5 miles (Further at night)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retinal burns to 7 miles (Further at night)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Weather has an effect:

- Temperature inversions focus blast effects.
- Visibility increases or decreases thermal effects.
- Snow or clouds increase thermal effects.
- Precipitation reduces all effects.
Flash and prompt radiation travel in straight lines.

Shock waves bend around corners.

Implications for public safety…?
Implications for public safety

- People without burns did not get enough radiation to cause Acute Radiation Syndrome.
- People may suffer burns without blast injuries.
- People may suffer blast injuries without burns.
What about a neutron bomb?

- Radiation sickness or death possible without other injuries
- Very unlikely --
  ✓ Requires very high degree of sophistication in manufacture
  ✓ Design doesn’t enhance the radiation; it retards the other destructive effects.
Radiation Hazards After the Explosion

Lesson 2
Learning Objectives:

- Know the sources of radiation from a nuclear weapon
- Understand the hazards from these sources
- Know what actions may be taken to protect people from these hazards
Sources of radiation from a nuclear weapon

- Unfissioned plutonium or uranium
- Fission products
- Activation products
A nuclear weapon splits atoms of uranium or plutonium

Most of the available uranium or plutonium does not fission

- Complete fission not physically possible
- Energy released tends to blow the material apart before theoretical physical limit is reached
Fissionable material

- U-235 or Pu-235
- Emits alpha radiation
- Internal hazard only
- No implications for first responders after a detonation
Activation products: The neutrons released by the fission reaction are absorbed by other atoms, making them radioactive

- Structural materials in the bomb
- The atmosphere
- The soil or water
Fission products: Each fission produces 2 fission product atoms.

- 900 different possible fission product atoms
- 77 are stable
- 165 have half-lives longer than one hour
Ground Zero is highly radioactive

• Do not approach the crater; no one is alive there
• Enter peripheral areas…
  - Only to save lives
  - Only with a Geiger counter or dosimeters
  - Only after determining maximum stay time
• Minimize people entering and keep track of their exposures
Fallout production:

- Everything inside the fireball vaporizes.
- The fireball rises and cools.
- Vaporized material condenses, trapping all 3 kinds of radioactive material.
  - Fission products
  - Activation products
  - Unfissioned plutonium or uranium
There is no fallout danger after an air burst.

Definition: The fireball radius is less than the altitude of the burst.

A terrorist attack will be a surface burst.
Fallout Transport

• The fallout will travel in the direction and at the speed of the prevailing wind.
• Larger and more radioactive particles fall to earth faster.
• Falling rain or snow washes the particles out faster.
• Radioactivity drops off rapidly with distance because of settling and decay.
Downwind effects of a 1 kiloton surface burst with a 15 mph wind

<table>
<thead>
<tr>
<th>Radiation Level</th>
<th>1 Hour</th>
<th>6 Hours</th>
<th>24 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 Rads</td>
<td>3 Miles</td>
<td>4 ½ Miles</td>
<td>4 ½ Miles</td>
</tr>
<tr>
<td>500 Rads</td>
<td>4 ½ Miles</td>
<td>6 ¼ Miles</td>
<td>6 ½ Miles</td>
</tr>
<tr>
<td>100 Rads</td>
<td>7 ½ Miles</td>
<td>12 ½ Miles</td>
<td>14 Miles</td>
</tr>
</tbody>
</table>
Initial actions to protect the public

- Determine wind direction.
- Evacuate downwind.
- Use respiratory protection until clear of the fallout path.
If unable to evacuate, seek shelter.

- Put as much shielding between the person and the fallout as possible.
- Seal the shelter. Admit no outside air.
- Do not exit the shelter until advised to do so by public officials. (Probably at least 2 days.)
Dirty Bombs and Silent Sources

Lesson 3
Learning Objectives:

• Be able to describe a radiological dispersal device (RDD)
• Understand the possible hazards associated with a radiological dispersal device
• Be able to describe a silent source
• Understand the possible hazards associated with a hidden source in a public area
Radioactive Dispersal Device (RDD): A device which scatters radioactive material over a wide area by mechanical means.

- May be scattered by conventional explosive
- May be scattered by water spray
- May be scattered by compressed air
- Probably a single radioisotope
- May be combined with chemical or biological agent
Mechanisms for scatter after an explosion

- Material is propelled up and out by the shock wave.
- Large particles tend to lag behind smaller ones, creating non uniform distribution.
- Further distribution is driven by settling velocities and local meteorology.
Settling velocities

• Large particles settle out faster.
• If agent was in the form of pellets or needles, may be deposited as one or more hot spots instead of uniform cover
Local meteorology

• Prevailing wind speed and direction are most important factors.
• Rain or snow causes faster, more local deposition.
• Building wakes and local topology are important factors.
Sample calculation

- 2500 pounds of high explosive
- 1370 curies of Cs-137
- 15 mph winds
How big is 1370 curies?

• Typical medical source
• Lethal dose in 15 – 20 minutes standing close to it
• Shielding too heavy to lift
Hazards

• .003 Rem in 1 year from direct exposure out to 1 mile (7 years to get 1 chest X-ray)
• Inhalation dose depends on concentration and could be hazardous
• Could find dangerous hot spots if material not evenly dispersed
Actions to protect the public

• Immediately use whatever respiratory protection is available
• Clear the area
• Decontaminate by removing clothing and washing as soon as possible
• Do not defer treatment of physical injuries because of contamination considerations
What is a silent source?

• Leave a radioactive source in a public place
  - Post office box
  - File cabinet in an office
  - Under a seat in a theatre
How much radiation would people get?

• Determined by source strength +
  - Time
  - Distance
  - Shielding
What kind of sources might be used?

- Many industrial and medical sources
- Must be a gamma emitter
  - Alpha and beta emitters internal hazards only
  - Neutron sources require machinery or mix of isotopes; won’t work once scattered
How long would it remain undetected?

• Possibly for many years
  - Many industrial and medical sources have half lives measured in years
  - Symptoms of Acute Radiation Syndrome are not unique
What should you do if you find out a silent source is planted somewhere?

• Clear people away from the area
• Find it with a Geiger counter
• Check for possibility of area contamination
  - Check source for visible damage if dose rates permit
  - Check the area again with counter after removing the source
Packaging

• Types of radioactive material packaging:
  – Industrial packaging
  – Type A
  – Type B
Normal and Special Forms

Normal Form

Special Form
Radiopharmaceuticals

Source:

123 I  100 µCi  72 Ga  3 mCi
Radiopharmaceuticals

Source:
99 Mo
99m Tc
1800 mCi
TYPE B PACKAGING

Designed to withstand a serious accident and remain intact
Pig tail

Figure 9. The radiation dose on the surface of a gamma radiography source is so enormous that, if held in the hand like this, radiation burns would be caused in seconds. (A dummy source, shown between the thumb and forefinger, was used in this photo.)
Figure 5. A skin flap has been sewn over the wound to close it (50 days after the accident).
Soil Moisture Density Gage
Placards, Labels

- White – 1
- Yellow – II
- Yellow – III
- Transport Index T.I.
Radioactive White – I
Surface Reading .5 mr/hr
Transport Index

- Measured at one meter from the surface of a package (this is a unit-less number)
Radioactive Yellow II
Surface 50mr/hr
At 1 meter 1mr/hr
Radioactive Yellow III

Surface 200mr/hr
At 1 meter 10mr/hr
Exclusive use 1000mr/hr surface – 200mr/hr vehicle surface – 10mr/hr two meters away
Information Sources

- Package markings present the item’s shipping name and U.N. identification number.
- Emergency Response Guide.
Information Sources

- Shipping papers provide:
  - The same information as the package label and markings
  - Physical and chemical form
  - Hazard class
  - Identification number
Common Sources

Radiopharmaceuticals
Used for therapeutic or diagnostic use in humans
Most are shipped in single doses
Generally considered a contamination hazard as opposed to a exposure risk
Common Sources, continued

Examples of radiopharmaceuticals
Common Sources, continued

• Industrial Gauges

Soil moisture/density gauges-used to determine suitability of roadbeds. Small sources.

Radiography cameras-used to identify flaws in welds, castings, pipe, etc. Large, dangerous sources.
Common Sources, continued

Examples of industrial gauges
Common Sources, continued

- Waste Shipments from hospitals, universities, laboratories, research facilities, and nuclear power plants. Generally shipped as Radioactive LSA (Low Specific Activity).
Common Sources, continued

• Nuclear power plant waste shipment
Forms of RAM

- Normal Form
- Special Form
Packaging

• Generally there are three types of packages

  Strong, tight packages—Low concentrations of RAM uniformly distributed.
Packaging, continued

• Type A packages - Most common package used. This package, with its radioactive contents, meets general DOT requirements and will retain its shielding and integrity during normal transportation.
Packaging, continued

Type A containers
Packaging, continued

• Type B Packaging—Very strong packages used to ship amounts of RAM that could be hazardous to people and the environment. Must meet stringent tests for fire, physical damage and water immersion.
Packaging, continued
Package Labels
Package Labels, continued

CONTENTS
The name of the radionuclide
* ACTIVITY
The number of curies
* TRANSPORT INDEX
The radiation exposure rate in mR/hr at 3 feet from package
Package Markings

USA DOT 7A
TYPE “A”
RQ RADIOACTIVE
MATERIAL
SPECIAL FORM
NOS, 7, UN 2974

Troxler Electronic Laboratories, Inc., Research Triangle Park, NC 27709 USA

RADIOACTIVE
MATERIAL
N.O.S.
UN 2982
Vehicle Placards

- Highway Route Controlled Quantity
Shipping Documents

- Shipping Papers—Required for all HM in transportation; must accompany the HM. Provides a description of the material. Must include a “shipper’s declaration” that the package has been properly prepared. Called “Bill of Lading”, “Shipper’s Certificate”, or “Declaration of Dangerous Goods”
Shipping Papers, continued

• Emergency Response Information-Required for all HM. Must accompany shipping papers. Provides first responders with information on how to handle an accident involving the package. Must be immediately accessible and must include an emergency response phone number.
Objectives

• Determine if material is Hazardous Material (HAZMAT).
• Understand HAZMAT employee training requirements.
• Identify different regulatory agencies.
• Understand the relationship between regulatory agencies.
History

• Approximately 50 years of safely shipping RAM.
• 5 million packages annually.
• No deaths or serious illness.
• 1st regulations by US Postal Services to protect film.
Transportation of Radioactive Material
Objectives

• Identify the seven steps for shipping radioactive material:
  – Classification.
  – Packaging.
  – Marking.
  – Labeling.
  – Shipping papers.
  – Placarding.
  – Carriage.
Objectives

• Understand the procedure for completing steps one and two of the seven steps.
Step One - Classification

• Is the material regulated? (173.403).
  – Specific activity $> 0.002 \mu$Ci/g.
  – All RAM is listed on table 173.435.

• Is the shipment outside of a restricted access installation?

• If YES then 49 CFR applies.
Containment

- Containment type:
  - Is the item special form or normal form?
- Look at 173.403.
Special Form (173.403)

• Class 7 material which:
  ų Is a single solid piece or contained in a sealed capsule, must be destroyed to open.
  ų Is at least one dimension not less than 5 millimeters (0.2 inches).
  ų Meets test requirements of 173.469.
Test Requirements (173.469)

- Pass a impact, percussion and bend test.
- Withstand a heat test (1475° F) for ten minutes.
- Must not leak when subjected to a leach test.
Normal Form

Any class 7 material not classified as special form is normal form!
Quantity (Type A)

- Type A packaging is the weaker packaging (cheaper too).
  - To be able to use type A packaging for special form, the quantity may not exceed the $A_1$ value.
  - To be able to use type A packaging for normal form, the quantity may not exceed the $A_2$ value.
Quantity (Type B)

• Type B packaging is the stronger packaging (more expensive).
  ⇒ Type B packaging is required if the special form quantity exceeds the $A_1$ value.
  ⇒ Type B packaging is required if the normal form quantity exceeds the $A_2$ value.
Example 1

- A plastic check source 1079 Ci of cadmium-109 (CD-109).
  - Is it special form?
    - ❌ No, will not pass heat test.
Example 1 (Con’t)

• A plastic check source 1079 Ci of cadmium-109 (CD-109).
  - Does it exceed $A_2$ value? (173.435)
    - Yes
Example 1 (Con’t)

• A plastic check source 1079 Ci of cadmium-109 (CD-109).

★ The material is normal form and exceeds the $A_2$ quantity therefore it requires type B packaging.
Multiple Sources
(Sum of Fractions (173.433(d)))

• Now suppose we have two or more sources (different isotopes) in the same package?
• What do we do?????
  4 Take the early retirement option?

Or:
Multiple Sources
(Sum of Fractions (173.433(d)))

- For each source take the activity divided by the $A_1$ (or $A_2$) value of that source.
- Then add your answers.
- If the SUM exceeds 1 (one) you must use type “B” packaging.
Example 2

- Normal form commodity sources.
- Look up the $A_2$ value in 49 CFR 173.435.

<table>
<thead>
<tr>
<th>Source</th>
<th>Activity (Ci)</th>
<th>$A_2$ Value (Ci)</th>
<th>Activity / $A_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am-241</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-3</td>
<td>250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-40</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example 2

- Enter the $A_2$ value and divide the activity by the $A_2$ value.

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<tbody>
<tr>
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<td></td>
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<tr>
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<td>250</td>
<td></td>
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<td></td>
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</table>
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<th>Activity / $A_2$</th>
</tr>
</thead>
<tbody>
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<td>0.004</td>
<td>0.00541</td>
<td>$0.004 / 0.00541 = ???$</td>
</tr>
<tr>
<td>H-3</td>
<td>250</td>
<td>1080</td>
<td>$250 / 1080 = ???$</td>
</tr>
<tr>
<td>K-40</td>
<td>0.9</td>
<td>16.2</td>
<td>$0.9 / 16.2 = ???$</td>
</tr>
</tbody>
</table>
Example 2

- Using the sum of fractions method as shown in 49 CFR 173.433 we see the combined limit exceeds “1.”
- Therefore a type B package is required.

<table>
<thead>
<tr>
<th>Source</th>
<th>Activity (Ci)</th>
<th>$A_2$ Value (Ci)</th>
<th>Activity / $A_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am-241</td>
<td>0.004</td>
<td>0.00541</td>
<td>0.004 / 0.00541 = 0.739</td>
</tr>
<tr>
<td>H-3</td>
<td>250</td>
<td>1080</td>
<td>250 / 1080 = 0.231</td>
</tr>
<tr>
<td>K-40</td>
<td>0.9</td>
<td>16.2</td>
<td>0.9 / 16.2 = 0.055</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.025</td>
</tr>
</tbody>
</table>
Highway Controlled Route (HRC)

• The amount of radioactive material is great enough that you are required to obtain a route from the appropriate state DOT.

• How much is that?
HRC Limits

- 3000 times $A_1$ or $A_2$

Or

- 1000 TBq (27,000 Ci)

Whichever is smaller.
HRC Quantity

- Always requires a radioactive yellow III.
- Always an exclusive use shipment.
HRC Quantity Example

• A type B package with 105 Ci of iridium-192, is this an HRC quantity?
  1st - what is the $A_1$ value from 49 CFR 173.435 (pg. 578).

  $A_1 = 27$
HRC Quantity Example

• 2nd - multiply $27 \text{ Ci} \times 3000 = 81000 \text{ Ci}$

Does $105 \text{ Ci}$ exceed $81,000 \text{ OR } 27,000$?

No

☆ Then this package IS NOT an HRC quantity.
Limited Quantities

• Exception for limited quantities of RAM (173.421).
  ➔ Does not have to follow all the packaging, labeling, etc.
  ➔ Can not be a hazardous substance or hazardous waste.
  ➔ Determined by the activity not the physical size (not more than allowed by 173.425).
Limited Quantities (Example)

- An IM-231A, RSO-5 RADIAC box contains 8 μCi of Cs-137 in normal form.
- Table 7 says you must not exceed $10^{-3} A_2$ value to be limited quantity.
- The $A_2$ value is 13.5 Ci.
- Then $13.5 \text{ Ci} \times 10^{-3} = 0.0135 \text{ Ci}$.
- Our source in the units of μCi: $8 \mu\text{Ci} = 0.000008 \text{ Ci}$. 
Instruments and Articles

• Manufactured item containing a radioactive source as a component part. (Could include RADIA\-C\-s, XRFs, etc).
  ➔ Rad level at 4 inch. ≤ 10 mR/hr for each article.
  ➔ ≤ Table VII limits, 49 CFR 173.425.
Instruments or Articles (Example)

• An IM-125D, (AN/PDR-43) RADIAC contains 80 $\mu$Ci of Kr-85 in normal form.

• Table 7 says you must not exceed $10^{-2} A_2$ value to be limited quantity.

• The $A_2$ value is 270 Ci.

• Then $270 \text{ Ci} \times 10^{-2} = 2.70 \text{ Ci}$.

• Our source in the units of $\mu$Ci: $80 \mu\text{Ci} = 0.00008 \text{ Ci}$. 
Low Specific Activity (LSA)

- LSA-I
  - Solid material only.
  - Naturally occurring LSA materials.
  - Unirradiated or depleted uranium.
  - Non fissile material with unlimited $A_2$ values.
  - Mill tailings, etc. Uniformly distributed with avg. spec. activity $\leq 10^{-6} A_2/g$. 
• LSA-II

• Includes liquids, solids may be up to 100 times the activity of LSA-I.

→ Water with tritium concentrations up to 0.8 TBq/l (20 Ci/l).

→ Material that is uniformly distributed with avg. spec. activity $\leq 10^{-4} \text{A}_2/\text{g}$ for solids and gases, and $10^{-5} \text{A}_2/\text{g}$ for liquids.
LSA (Cont.)

• LSA-III
  ➔ Liquid must be solidified and solids may be up to 10 times the activity of LSA-II.
  ➔ RAM distributed uniformly in a solid or collection of solids; And
  ➔ Is relatively insoluble so that if submerged for seven days it would not leach in excess of 0.1 A$_2$; And
LSA (Cont.)

- LSA-III (cont.)
  - Average spec. activity $\leq 2 \times 10^{-3} \text{A}_2/\text{g}$.
  - REQUIRES TESTING FOR PROOF OF LEACHING.
Surface Contaminated Object

- An item that is not radioactive but has RAM contamination on any of its surfaces.
- Divided into two groups:
  - SCO-I
  - SCO-II
• Limits may not exceed (averaged over 300 cm$^2$ of accessible area):

σ Non fixed contamination limits:

① 4 Bq/cm$^2$ (10$^{-4}$ μCi/cm$^2$) beta and gamma and low toxicity alpha emitters.

② 0.4 Bq/cm$^2$ (10$^{-5}$ μCi/cm$^2$) alpha emitters.
SCO-I (Cont.)

• Fixed contamination limits:
  - 4 x 10^4 Bq/cm^2 (1.0 μCi/cm^2) beta and gamma and low toxicity alpha emitters.
  - 4 x 10^3 Bq/cm^2 (0.1 μCi/cm^2) alpha emitters.
SCO-I (Cont.)

• Non-fixed plus the fixed contamination limits on inaccessible surfaces:
  - $4 \times 10^4 \text{ Bq/cm}^2 (1.0 \mu\text{Ci/cm}^2)$ beta and gamma and low toxicity alpha emitters.
  - $4 \times 10^3 \text{ Bq/cm}^2 (0.1 \mu\text{Ci/cm}^2)$ alpha emitters.
SCO-II

- Limits are greater than SCO-I but may not exceed (averaged over 300 cm² of accessible area):

- Non fixed contamination limits:
  - 400 Bq/cm² ($10^{-2} \mu\text{Ci/cm}^2$) beta and gamma and low toxicity alpha emitters.
  - 40 Bq/cm² ($10^{-3} \mu\text{Ci/cm}^2$) alpha emitters.
SCO-II (Cont.)

- Fixed contamination limits:
  - $4 \times 10^4$ Bq/cm$^2$ (1.0 $\mu$Ci/cm$^2$) beta and gamma and low toxicity alpha emitters.
  - $4 \times 10^3$ Bq/cm$^2$ (0.1 $\mu$Ci/cm$^2$) alpha emitters.
SCO-II (Cont.)

- Non-fixed plus the fixed contamination limits on inaccessible surfaces:
  - $8 \times 10^5$ Bq/cm$^2$ (20 µCi/cm$^2$) beta and gamma and low toxicity alpha emitters.
  - $8 \times 10^4$ Bq/cm$^2$ (2 µCi/cm$^2$) alpha emitters.
Step Two - Packaging

- Package or packaging:
  - Packaging - ALL packaging without RAM.
  - Package - packaging plus RAM.

Packaging + Radioactive Material = Package
Packaging Specifications

• Type A or type B package:
  ➔ Type A packaging is designed to maintain integrity during normal transport.
  ➔ Type B packaging is designed to maintain integrity during normal transport and hypothetical accidents.
The Transport Activity Spectrum

Not Regulated in Transport

Limited Quantities & Accepted Articles

Excluded Packaging

Type A Packaging

Type B Packaging

Highway Route Controlled Quantity

0.002 μCi/g

Limited Quantities & Accepted Articles

Type A Quantities

Type B Quantities

Type A Packaging

Type B Packaging

3,000 A₁ or 3,000 A₂ or 27,000 Ci (Whichever is Least)

10^{-3} A₁ – Solids

10^{-3} A₂ – Solids

10^{-4} A₂ – Solids

A₁

A₂

ARSCE 2002; WPM-A.4
General Requirements

• Easily handled;
  ➔ 22-50 kilograms require means for manual handling.
  ➔ Greater than 50 kilograms needs mechanical means.
  ➔ Easily decontaminated, no protrusions, pockets, etc.
General Req. (Cont.)

- Good strength, compatible material.
- Means to prevent escape of RAM through valves, etc.
- For air travel the following restrictions apply;
  - Not more than 122 deg. F external temp at 100 deg. F ambient.
  - Maintains integrity from -40 - 131 deg. F.
  - Pressure tested to at least 13.8 lb./in².
Type A Specific Requirements

• Listed in 49 CFR 173.410, includes;
  ➔ Minimum dimension 10 cm (4 in).
  ➔ Need for tamper seals.
  ➔ Contain absorbents or leak proof for liquids.
Type A Test Requirements

• Water spray test.
  – Similar to 2 inches per hour for one hour.

• Free drop test; On an unyielding surface.
  – Height dependant on weight.
  – Boxes and drums require additional test on corners/seams.
Type A Test Req. (Cont.)

• Compression test.
  – 5x weight of actual package or 265 lb./in$^2$ on two opposite sides. One side may be the bottom.

• Penetration test.
  – Drop a 1-1/4 inch, 13.2 lb., bar 1 meter.
Radiation Level Limits

- Normal shipments;
  - > 200 mrem/hr on surface.
  - < 10 mrem/hr at 1 meter (max TI=10)

- Exclusive use;
  - > 200 mrem/hr on surface.
  - ≤ 1000 mrem/hr on surface with restrictions.
  - No air transport.
Contamination Limits

- $\leq 2.2$ dpm/cm$^2$ alpha.
- $\leq 22$ dpm/cm$^2$ beta-gamma.
- Swipe area is to be representative of a 300 cm$^2$. This may be 3, 100 cm$^2$ areas. 100 cm$^2$ is roughly 4 inch by 4 inch.
Summary

• Seven steps for shipping RAM

• *Step one - classification;*
  - Containment
  - Quantity
  - $A_1$ and $A_2$ quantity
  - Type B quantity
Summary (Cont.)

• *Step one - classification (cont)*;
  ➡️ Highway controlled route
  ➡️ Limited quantity
  ➡️ Instruments and articles
  ➡️ Low specific activity
  ➡️ Surface contaminated object
Summary (Cont.)

• *Step two - packaging;*
  - Package design
  - Test requirements
  - Radiation levels
  - Contamination limits
Any Questions?