RADIATION UNITS OF MEASUREMENT

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2013 Training Session
Activity Units
Disintegrations Per Unit Time

■ Traditional (US) unit is Curie

- $1 \text{ Ci} = 3.7 \times 10^{10} \text{ dps (dis/sec)}$
- $1 \text{ Ci} = 2.22 \times 10^{12} \text{ dpm (dis/min)}$
- $1 \text{ Ci} = 1 \times 10^{12} \text{ pCi}$
- $1 \text{ Ci} = 37 \text{ GBq} \ (G=10^9)$
- International unit is Becquerel
  - $1 \text{ Bq} = 1 \text{ dps} = 2.70 \times 10^{-11} \text{ Ci}$
  - $1 \text{ GBq} = 0.0270 \text{ Ci}$
Occupational Dose Equivalent Limits

- General Public
  100 mrem/yr

- Any Occupational Worker (unmonitored)
  100 mrem/yr

- Radiation Worker (monitored)
  5,000 mrem/yr = 5 rem/yr
## DOE & USNRC Occupational Dose Limits

<table>
<thead>
<tr>
<th>Part of Body</th>
<th>Limit</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Body</td>
<td>5</td>
<td>rem per yr</td>
</tr>
<tr>
<td>Lens of Eyes</td>
<td>15</td>
<td>rem per yr</td>
</tr>
<tr>
<td>Extremities</td>
<td>50</td>
<td>rem per yr</td>
</tr>
<tr>
<td>Skin</td>
<td>50</td>
<td>rem per yr</td>
</tr>
<tr>
<td>Organ or Tissue</td>
<td>50</td>
<td>rem per yr</td>
</tr>
<tr>
<td>Unborn Child</td>
<td>0.5</td>
<td>rem per pregnancy</td>
</tr>
<tr>
<td>US Background</td>
<td>0.62</td>
<td>rem per yr</td>
</tr>
<tr>
<td></td>
<td>~ 2 mrem per day</td>
<td></td>
</tr>
</tbody>
</table>
Emergency Dose Limits

- Protecting property if 5 rem not practical
  - 10 rem
- Lifesaving or protection of small population if dose limit not practical:
  - 25 rem
- Lifesaving or protection of large population (volunteer basis for person aware of risk)
  - > 25 rem
Absorbed Dose

- Energy deposited by any form of ionizing radiation in a unit mass of material
- Roentgen Absorbed Dose (rad)
- Gray (Gy)
- 1 Gy = 100 rad
US Radiation Symbol - Radioactivity
IAEA Radiation Symbol - Radioactivity
### TABLE: DOSE-LIMITING RECOMMENDATIONS OF STANDARDS-SETTING BODIES; DOSES IN REMS*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occupational Exposure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole body prospective</td>
<td>5/yr</td>
<td>5/yr</td>
<td>5/yr</td>
<td>2/yr averaged over 5 yrs Max. 2/yr</td>
</tr>
<tr>
<td>retrospective</td>
<td>—</td>
<td>10–15 any year</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>to N years of age</td>
<td>100 total career</td>
<td>5(N–18)</td>
<td>(see text)</td>
<td>50</td>
</tr>
<tr>
<td>Skin</td>
<td></td>
<td>15/yr</td>
<td>(see text)</td>
<td>50</td>
</tr>
<tr>
<td>Hands</td>
<td>50/yr</td>
<td>75/yr; 25/qtr</td>
<td>(see text)</td>
<td>50</td>
</tr>
<tr>
<td>Forearms</td>
<td>—</td>
<td>30/yr; 10/qtr</td>
<td>(see text)</td>
<td></td>
</tr>
<tr>
<td>Gonads</td>
<td>5/yr</td>
<td>5/yr</td>
<td>(see text)</td>
<td>15</td>
</tr>
<tr>
<td>Lens of eye</td>
<td>15/yr</td>
<td>5/yr</td>
<td>(see text)</td>
<td></td>
</tr>
<tr>
<td>Thyroid</td>
<td>—</td>
<td>15/yr</td>
<td>(see text)</td>
<td></td>
</tr>
<tr>
<td>Any other organ</td>
<td>50/yr</td>
<td>15/yr; 5/qtr</td>
<td>(see text)</td>
<td>†</td>
</tr>
<tr>
<td>Pregnant women</td>
<td>0.5 gestation</td>
<td>0.5 gestation</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td><strong>General population</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual</td>
<td>0.1/yr</td>
<td>0.5/yr</td>
<td>0.5/yr</td>
<td>0.1/yr</td>
</tr>
<tr>
<td>Average</td>
<td>—</td>
<td>5/30 yrs</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

†Several alternative standards proposed.
‡Less than 0.3 times normal occupational dose from discovery of pregnancy through gestation.
Personal Dosimeter Alarming
Gamma Dose & Dose Rate
100 nSv/hr-10 Sv/hr

Ludlam Model 25 Series small-sized personal dosimeter automatically alarms if dose rate or accumulated dose (0-19.9Sv) setpoint exceeded

Audible signal & bright, blinking red light. Displays time remaining before dose limit exceeded at current dose rate

Worn on belt, lanyard, or armband

With R or Sv units and USA certification

Model Display Range Intrinsic Safety Part

Typical Ranges
0.01 mR/hr - 1,000 R/hr
100 nSv/hr - 10 Sv/hr
Gamma Field Measurements
(0-50 $\mu$Sv/hr or 0-5000 $\mu$R/hr)

Ludlam Model 19 gamma $\mu$R meter
Internal 2.5cm-Dx2.5cm (1x1 in) NaI
Range of 0-50 $\mu$Sv/hr (0-5000 $\mu$R/hr)
Aluminum cast instrument housing with separate battery compartment
Front panel controls include
- rotary switch for 5-decade range
- instrument shut-off,
- audio on/off switch
- fast/slow response switch
- push buttons activates meter lamp
- count reset
- highvoltage display
- battery test

Alarm light on front panel with audio signal
Alpha/Beta Contamination Surveying
Model 2360 survey meter & Model 43-93, 100 cm² alpha/beta detector

Measure alpha and beta as separate counts and data log results

2360 meter analog/digital unit with ratemeter, scaler, data logging

Detector ZnS(Ag) - 0.254 mm (0.01 in) thick plastic scintillator

Background typically < 3 cpm alpha < 300 cpm beta

Efficiencies (4π)
20% - 239Pu
15% - 99Tc
20% - 90Sr/Y
Alpha Sample Counter

Model 2000 Scaler Counter with Model 43-10 Detector Alpha counting system

Scaler reading on digital, 6-digit LED readout
Count 0.1 - 999 mins (or secs)

RS-232 port connects to PC for recording, control or printer

Model 43-10 sample head holds 5.1 cm (2 in) diameter samples

ZnS(Ag) detector background < 3 cpm
4π efficiency 37% for Pu-239
Alpha/Beta/Gamma Measurement
(0-500 kcpm) Model 3 analog ratemeter
with Model 44-9 GM pancake detector

Front panel controls has rotary switch
- four-decade range
- instrument shut-off
- battery test
- audio on/off switch
- fast/slow response switch
- count reset button

GM pancake halogen quenched with
5 sqcm window & protective screen

Typical efficiencies
5% - 14C  (beta)
22% - 90Sr/90Y (beta – gamma)
19% - 99Tc  (beta – gamma)
< 1% - 99mTc (beta – gamma)
32% - 32P  (beta)
15% - 239Pu (alpha)
Hand & Feet Contamination Monitoring

Model 4906AB industrial duty alpha/beta monitoring system for hands & feet

Color, touch-screen LCD system

Displays status & points of potential contamination.

6 gas-flow proportional detectors activated by optical switches

Alarms annunciate locally

Built-in ethernet interface to connect to network
Neutron Measurements
(0-100 mSv/hr)

Model 12-4 Neutron Dose Rate Instrument
Range 0-100 mSv/hr (0-10 rem/hr) for neutrons - thermal to 12 MeV

Detector 22.9 cm (9.0 in) 3He tube
gamma background reject
<10 cpm to 100 mSv/hr (10 R/hr)

Four-decade analog meter with separate battery compartment

Front panel controls
- four decade range
- instrument shut-off and battery test
- audio on/off switch fast/slow count
- switch count reset
- high-voltage test push-button