Nuclear Medicine Physics

Lecture 5
Other equipment and Hotlab

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References :

- https://www.nrc.gov/materials/miau/miau-reg-initiatives/guide_2002.pdf
- https://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1993/in93010.html
- https://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1993/in93030.html

Dose Calibrator

- According to NRC, for direct measurements, a licensee shall possess and use **instrumentation to measure the activity** before it is administered to each patient.
- Administered dose must be within 20% of the prescribed dose

- For unit dose, dose calibrator is no longer required.
- A decay correction method, based on the activity or activity concentration determined by radiopharmacy

  - Gas-filled detector
  - Use pressurized gas, e.g., Argon
  - Ionization chamber
  - measure the number of ions created by radiation

Dose Calibrator – ionization chamber

dipper

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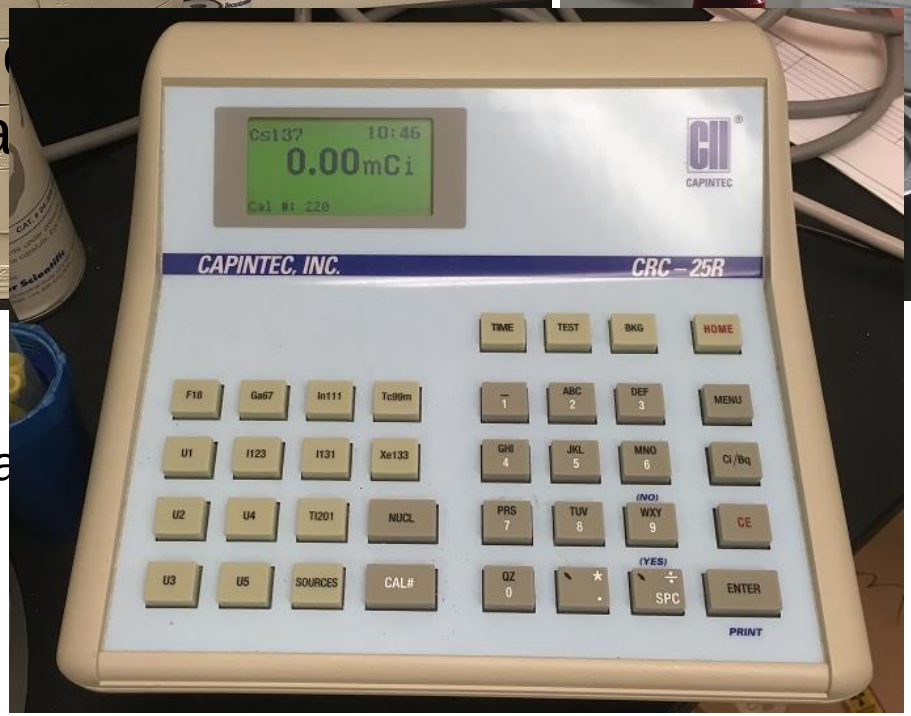
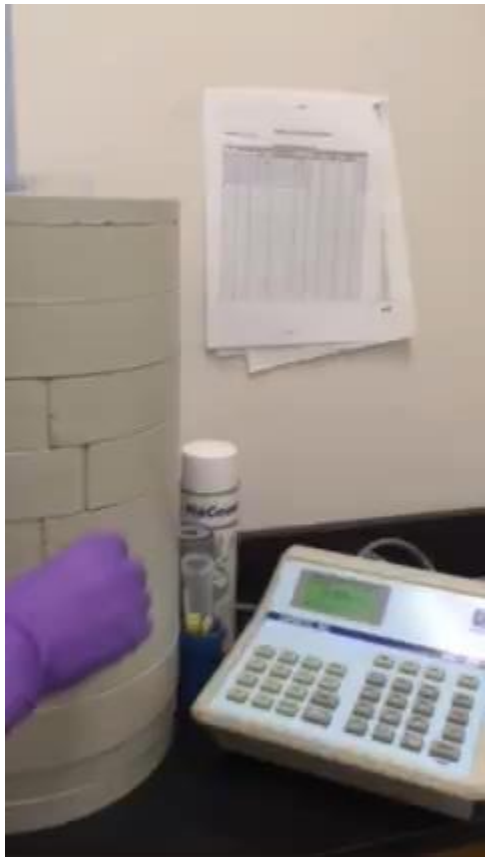
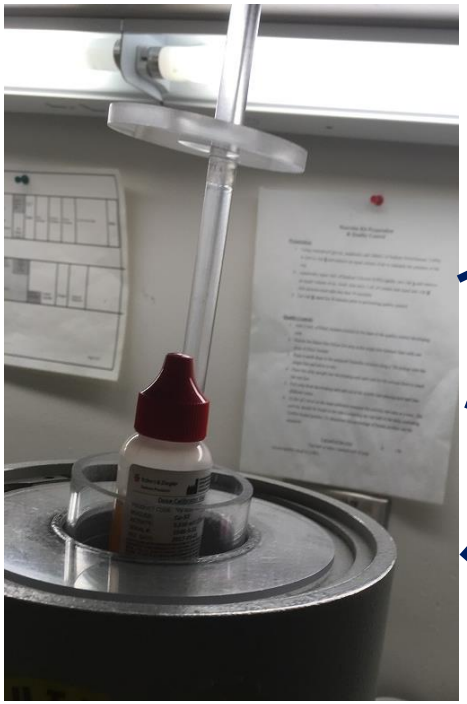
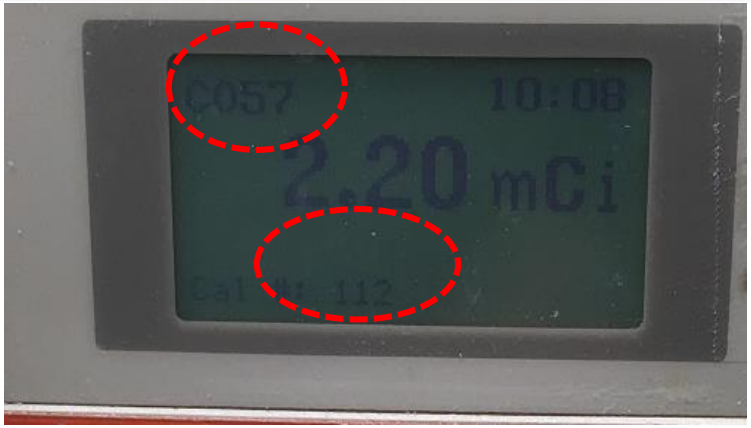




Dose Calibrator

Co-57 source was measured





Dose Calibrator

(a) A licensee shall **calibrate the instrumentation** in accordance with nationally recognized standards or the manufacturer's instructions.

(b) A licensee shall **retain a record of each instrument calibration for 3 years**

Quality Assurance

- Daily constancy
- Quarterly Linearity
- Annual Accuracy
- Geometry test

- Trigger level (5%) : may indicate a need for repair or adjustment
- Regulatory level (10%) : requires repair or replacement

NRC's regulation on Dose Calibrator

Daily Constancy

- 10 CFR 35.50(b)(1)) to be checked for constancy with a dedicated check source at the beginning of each day of use.
- Constancy means **reproducibility in measuring the activity** of a known source
  - Licensees must plot or log (10 CFR 35.50(e)(1)) the measured activity of each source
  - and compare it to the calculated activity, based on decay of the dedicated **check source.**
  - If the error > **10 percent**, the dose calibrator must be repaired or replaced (10 CFR 35.50(d)).

Check sources

- Co-57 (122keV, $T_{1/2}$=271 days, 1-5mCi)
- Cs-137 (661keV, $T_{1/2}$ = 30 yrs, ~200 µCi)

NRC's regulation on Dose Calibrator

Annual Accuracy

- The accuracy test ensures that the activity is within 10 percent of a given calibrated reference source.
- if the error exceeds **10 percent** then the dose calibrator must be repaired or replaced.

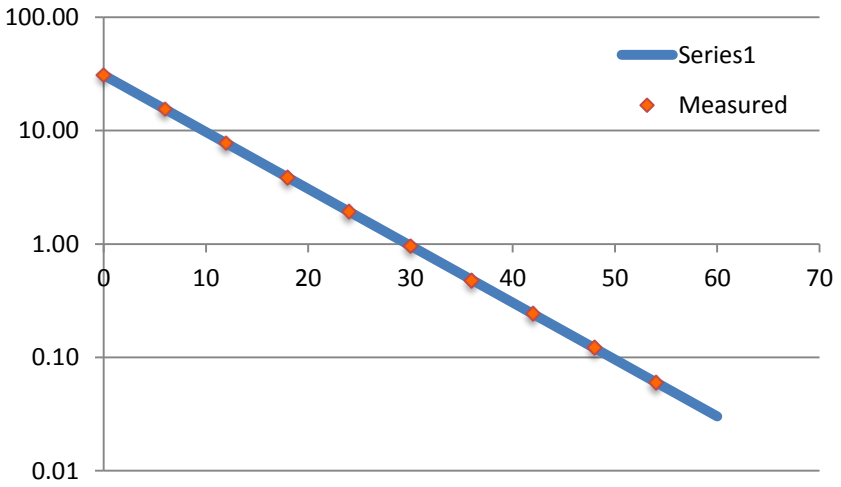
Average (measured activity) vs decay corrected reference activity

NRC's regulation on Dose Calibrator

Quarterly Linearity

- ensures that the dose calibrator can **indicate the correct activity over the range of use** between the highest dose that will be administered to a patient and 10 microcuries (e.g., 50mCi - 10μCi)
- If the percent deviation exceeds 10 percent, dosage readings must be mathematically corrected. .

time delay (hr)	Measured activity (mCi)	calculated (mCi)	Error (%)
0	30.9	30.90	0.00
6	15.46	15.45	-0.06
12	7.74	7.73	-0.19
18	3.87	3.86	-0.19
24	1.93	1.93	0.06
30	0.96	0.97	0.59
36	0.477	0.48	1.22
42	0.243	0.24	-0.66
48	0.122	0.12	-1.06
54	0.06	0.06	0.59
60	0.031	0.03	-2.66



Takes ~ 3 days using Tc-99m

Linearity using attenuators (or shielding method)

attenuation factor	
Black	1
Red	3.39
Orange	10.14
Yellow	29.5
Green	122.97
Blue	333.2
Purple	825.54

Take ~ 10min to perform the linearity test

Dose Calibrator – Geometry dependence

- ensures that the indicated **activity does not change with volume or configuration.**
- This test must be performed, **upon installation**, over the range of volumes using a syringe that is normally used for injections
- Licensees who use generators and radiopharmaceutical kits should also do the test using a vial similar **in size, shape, and construction** to the radiopharmaceutical kit vials normally used.
- It is appropriate to conduct linearity and accuracy tests following any repairs to the dose calibrator.

- Volume dependency
- Glass/plastic vials for beta emitters

Radiation Surveys and survey instruments

At least one portable survey instrument capable of detecting radiation levels from 0.1–100 mrem/hr must be available at all times

- personnel self-checking for radioactive contamination before leaving the facility
- testing after spills or other radiation incidents
- checking incoming packages containing radioactive materials
- sealed source leak testing
- testing before waste disposal
- Area wipe test
- Shielding check
- …

Radiation Surveys and survey instruments

- **daily area surveys** (in all rooms of the clinic, at specified locations). exposure rate must be < 0.02 mR/h, (or <0.1 mR/h in the hot-lab).

- **weekly area wipe test** to look for removable contamination at specified locations throughout the nuclear medicine clinic. Count all wipe samples in the well-counter. BWH action level: 2,000 dpm/100 sq. cm, for Tc-99m (200 dpm/100 sq. cm I-131)

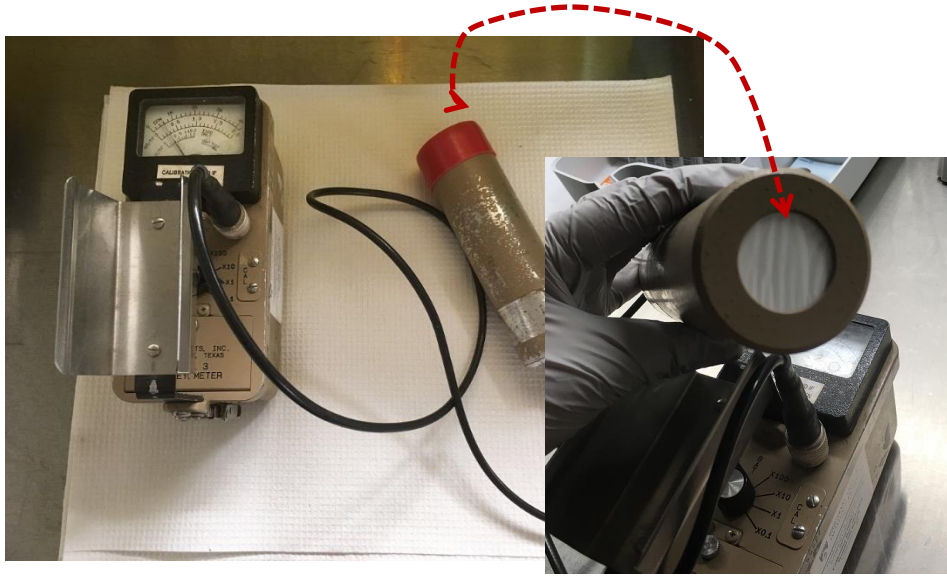
- **radioactive package wipe test.** Same limit (2,000 dpm/100 sq.cm)

Survey meters

Geiger-Muller (G-M) survey meter with a pancake detector

- High energy gamma and beta emitters
- Identify contamination areas
- Low efficient

Survey meter with a scintillation detector



- Portable thin scintillation detector
- High sensitivity
- Efficiently detect low energy γ & x-rays (e.g. I-125)

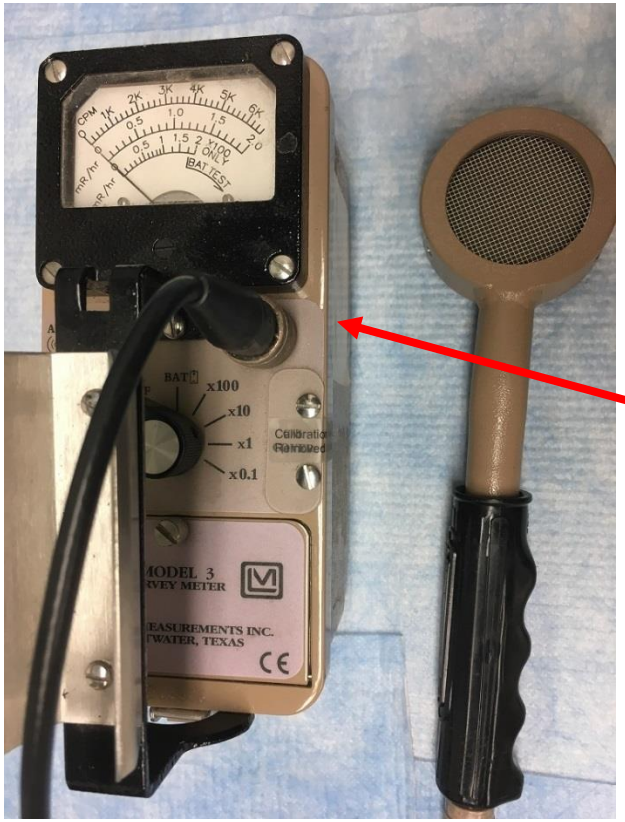
Surveys of ambient radiation exposure rate & Calibration

1. survey with a radiation detection survey instrument at the end of each day of use.
2. A licensee does not need to perform the surveys in an area(s) where patients or human research subjects are confined when they cannot be released
3. A licensee shall retain a **record of each survey** for 3 years

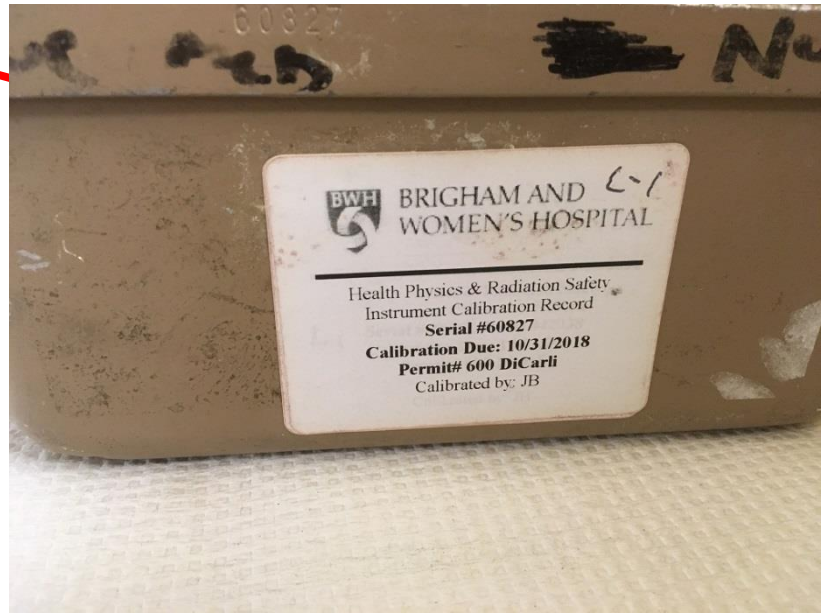
- calibrate the survey instruments before first use, **annually**, and following a repair that affects the calibration.
  - Calibrate all scales with readings up to 1000 mrem /hr
  - **visibly note on the instrument the date of calibration**.
- A licensee may not use survey instruments if the difference between the indicated and the calculated exposure rate > 20 %
- retain a record of each **survey instrument calibration** for 3 years

Survey meter

- **Geiger-Mueller (GM) meter**



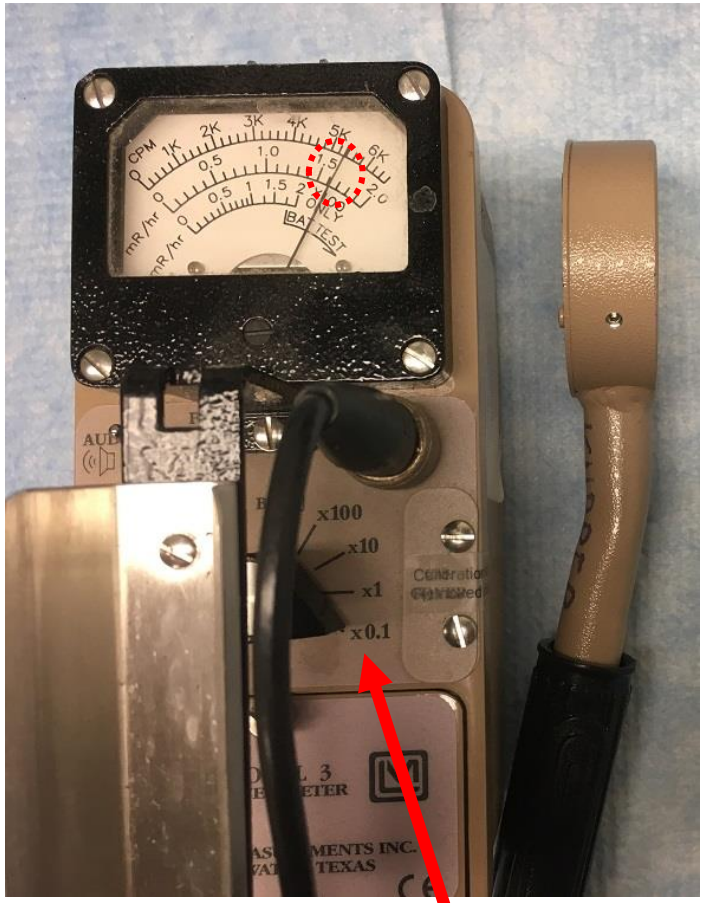
Annual calibration certificate



Survey meter : How to use

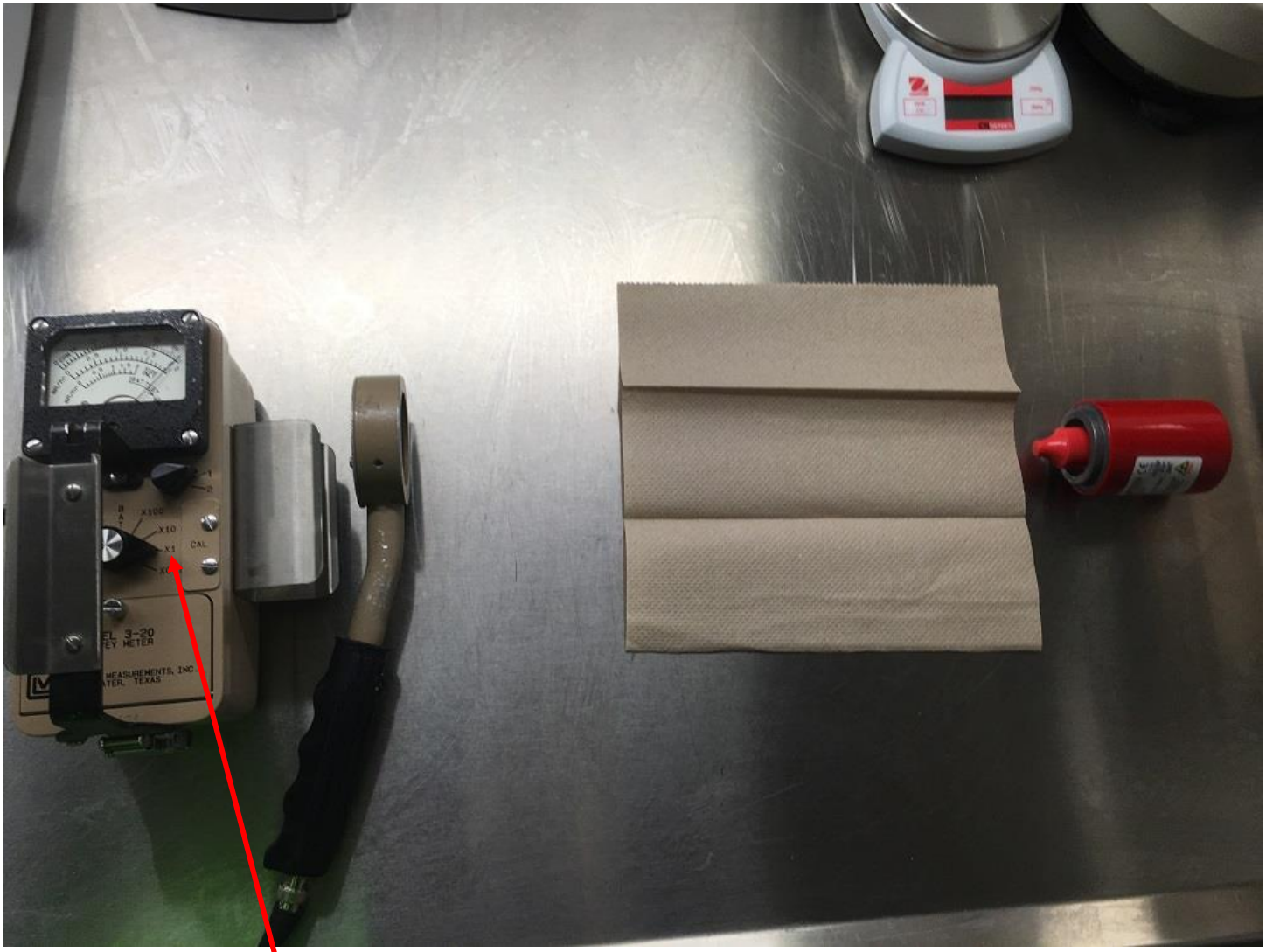
Check battery

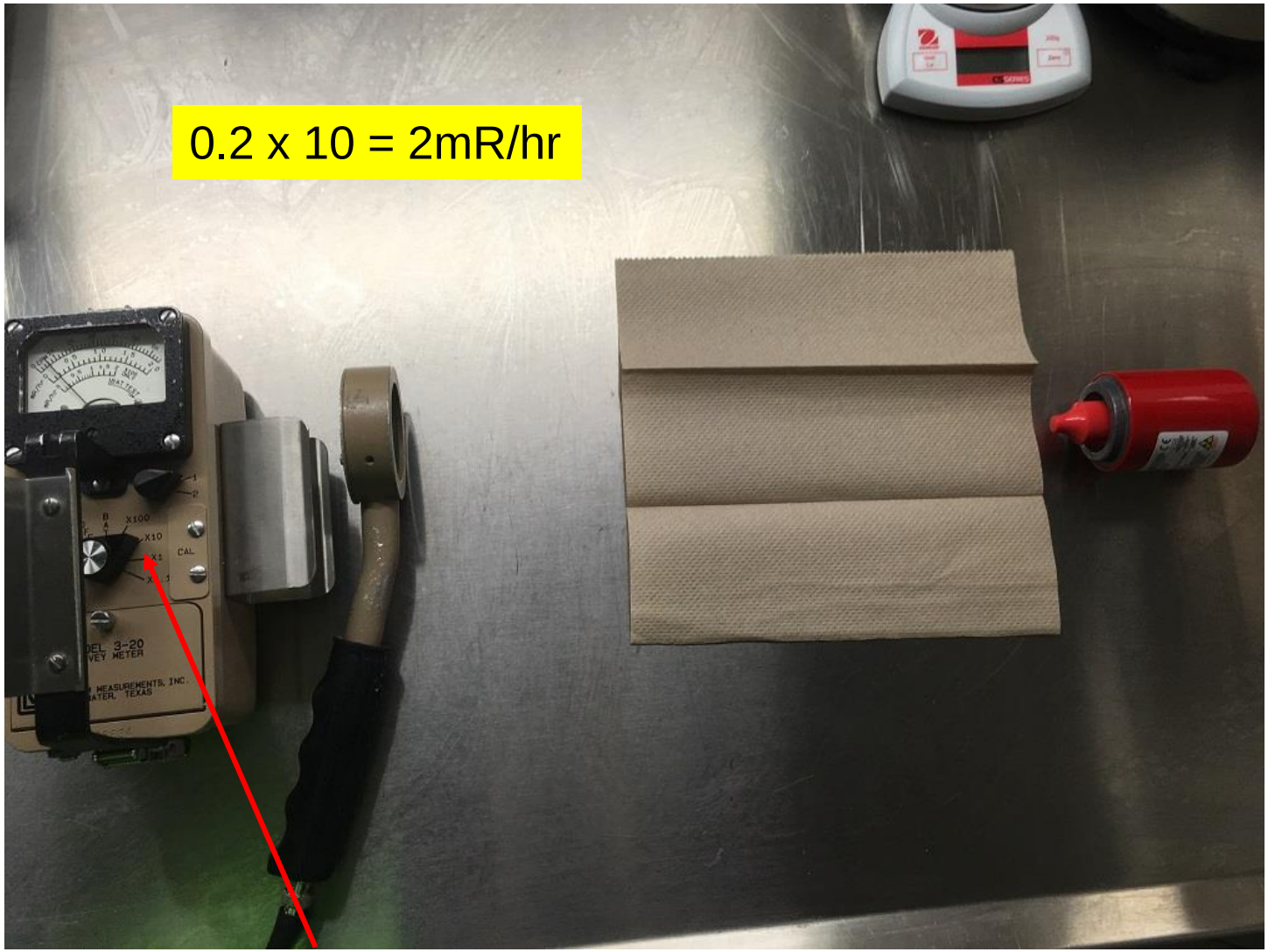
How to read

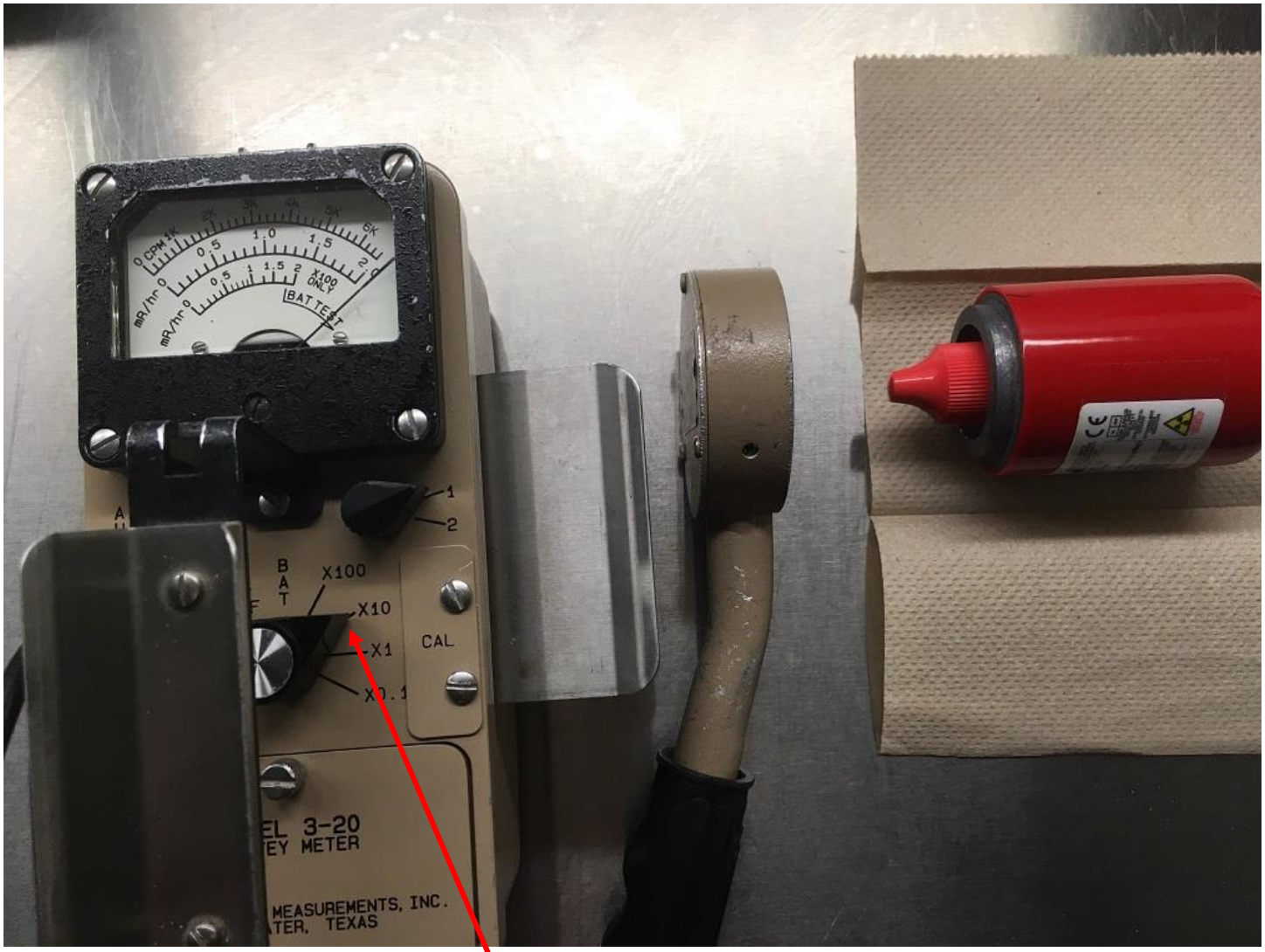


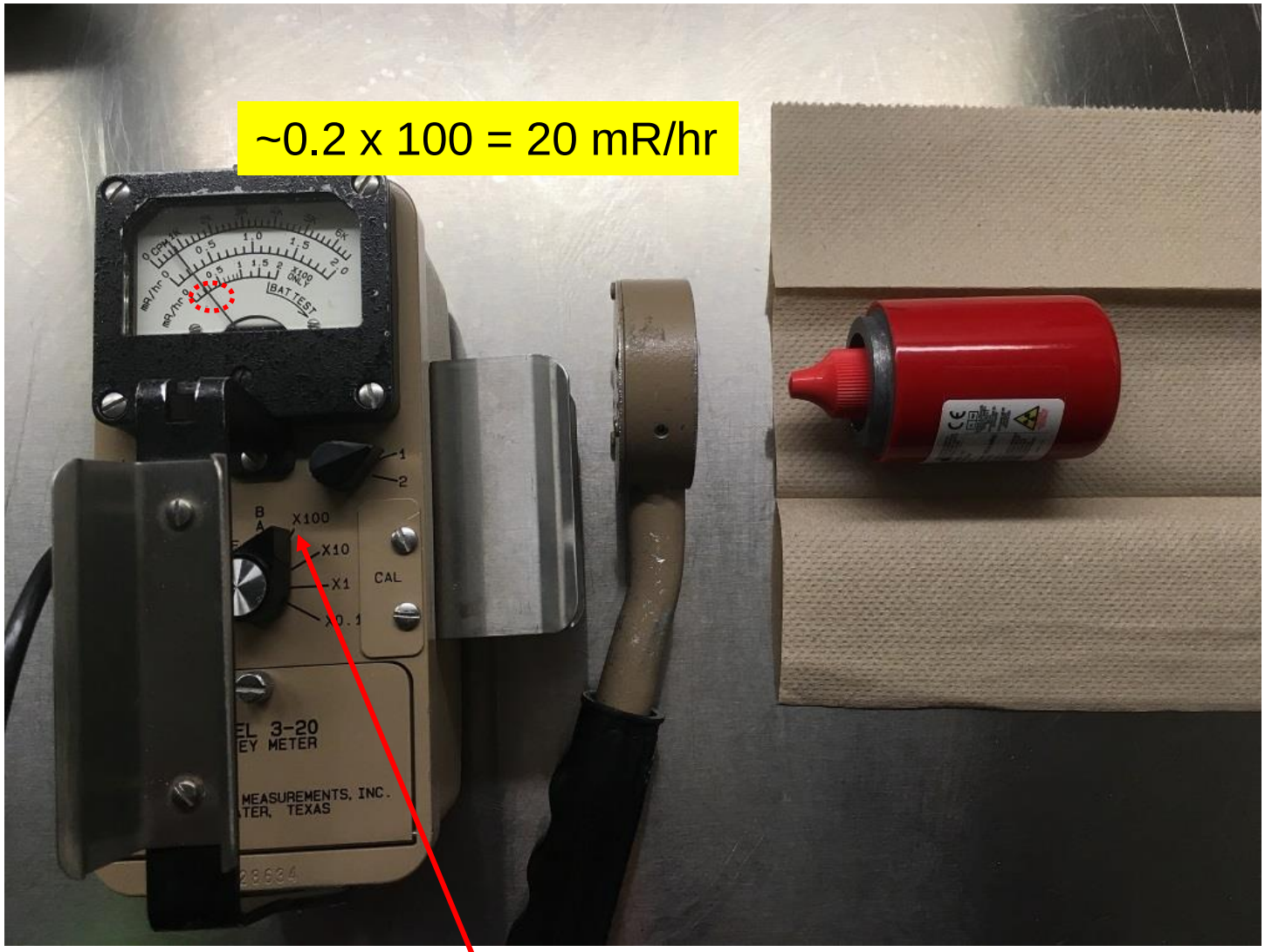
Scaling factor

1.6 x 0.1 = 0.16 mR/hr


x 1


0.2 x 10 = 2mR/hr
x 10

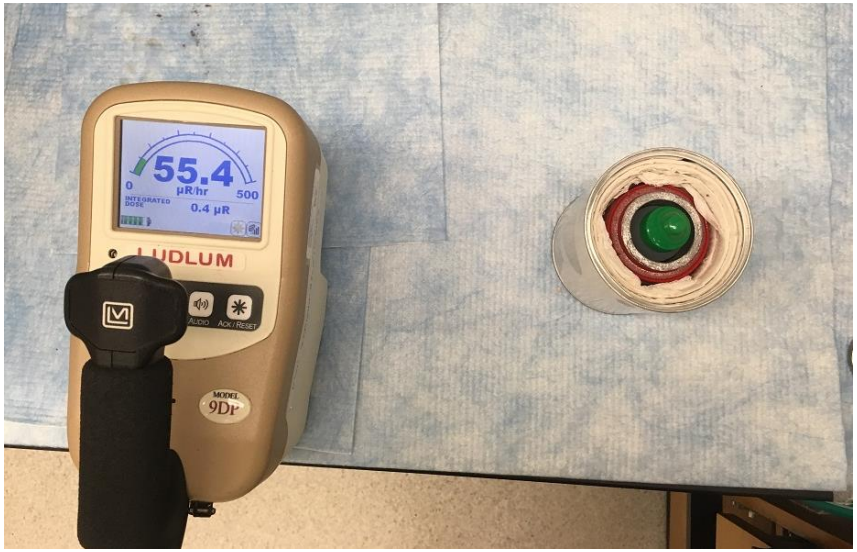

0 CPM 1K
0.5
1.0
1.5
2
5K
mR/hr
0.5
1
1.5
2
X100 ONLY
BAT TEST
1
2
BAT
X100
X10
X1
X0.1
CAL
EL 3-20
EY METER
MEASUREMENTS, INC.
TER, TEXAS
x 10


~0.2 x 100 = 20 mR/hr
X100
X10
X1
X0.1
CAL
BAT TEST
x 100

Survey meter

➢ pressurized ion chamber meter

- High sensitive measurement
- Integrated Exposure (mR, µR) and exposure rate (mR/hr, µR/hr)

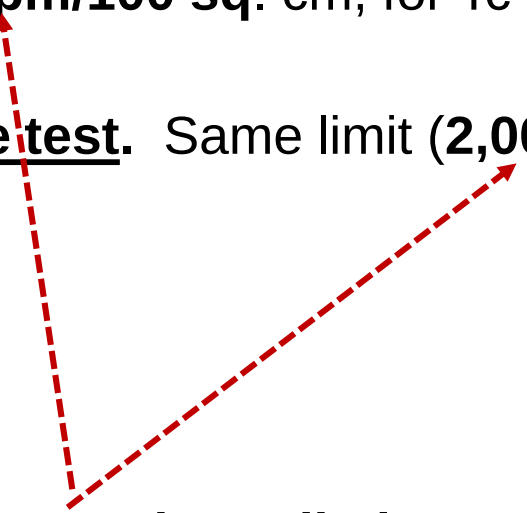


- Shielding survey
- Contamination survey
- Patient survey

Well-counter & wipe tests

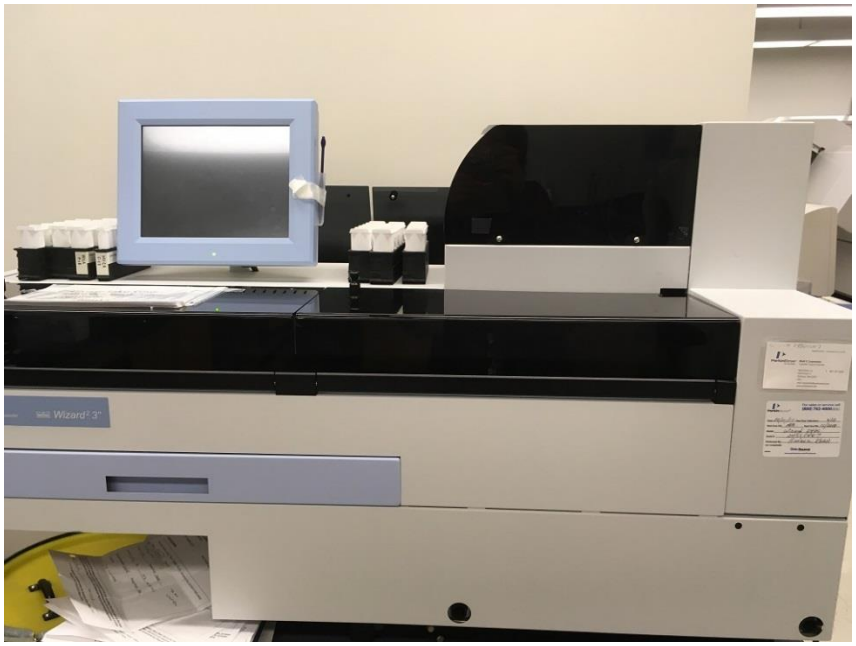
- **daily area surveys** (in all rooms of the clinic, at specified locations). exposure rate with survey meter must be < 0.02 mR/h, (or <0.1 mR/h in the hot-lab).
- **weekly area wipe test** to look for removable contamination at specified locations throughout the nuclear medicine clinic. Count all wipe samples in the well-counter.

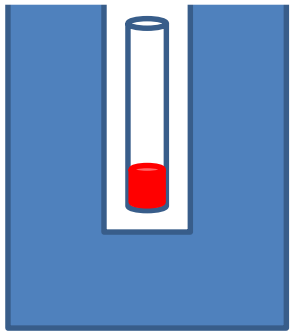
  action level: **2,000 dpm/100 sq**. cm, for Tc-99m (200 dpm/100 sq. cm I-131)
- **radioactive package wipe test.** Same limit (**2,000 dpm/100 sq.cm**)



We need a tool to measure the radiation quantitatively!

Well-counter & wipe tests





well-type geometry

thick scintillation detector

- Usually made of NaI (Tl)
- Very high efficiency > 50%
- Can accurately measure a few nanoCi (1nCi = 37Bq)

Well-counter & wipe tests

Wipe samples

Reference source

Well-counter

- At least **annually,** measure efficiency of 2-3 standard calibration "stick" sources to make sure efficiency has not changed significantly.
- The efficiency is usually expressed as detected counts per minute (cpm), divided by source activity (in decays per minute), i.e., **cpm/dpm**.

Thyroid Probe for Radioactive iodine uptake (RAIU)

- Thick NaI detector(~ 2” thick)
- High efficiency
- portable

Sealed Source

Sources for dose calibrator, well counter, camera calibration in Nuclear Medicine

- dose calibrator reference standards (Cs-137, Co-57 vials),
- well-counter reference sources (Cs-137, Ba-133 tubes)
- For camera QC : Co-57 flood, Co-57 line sources, Ge-68
- Markers : points sources (co-57, Cs-137, Na-22)

Dose calibrator check source

Well-counter check source

Gamma camera flood source

Sealed Source

- Leak test **every six months**
- Sealed source physical inventory checked **at least semi-annually**
- Both inventory and leak test records retain for 3 yrs

- **Leak test**
  - ✓ Using an equipment capable of detecting 0.005 µCi (185 Bq).
  - ✓ If Contamination > 185 Bq, Immediately withdraw the sealed source from use and store, dispose, or repaired
  - ✓ A report must be filed within 5 days.