Quality Management of LDR Sources

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Topic is limited to the sources themselves

- … planning, applicators, surveys …
- Outline
  - Acceptance testing
  - Periodic testing
  - Per-patient testing
- War stories??

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Useful categories

- Temporary *vs* permanent
  - (i.e. >50 keV *vs* <50 keV)
- Long- or short-lived isotopes
  - (e.g. kept in inventory vs ordered per patient)
- Seeds or extended sources
  - (e.g. I-125 seeds *vs* Cs-137 tubes)

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Preparation for calibration

- TG-56:
  - "Every institution practicing brachytherapy shall have a system for measuring source strength with secondary traceability for all source types used in its practice."
- Secondary traceability:
  - use an instrument that has been calibrated at an ADCL (or NIST) for that source type
  - compare with a source of the same type that has been calibrated at an ADCL (or NIST)

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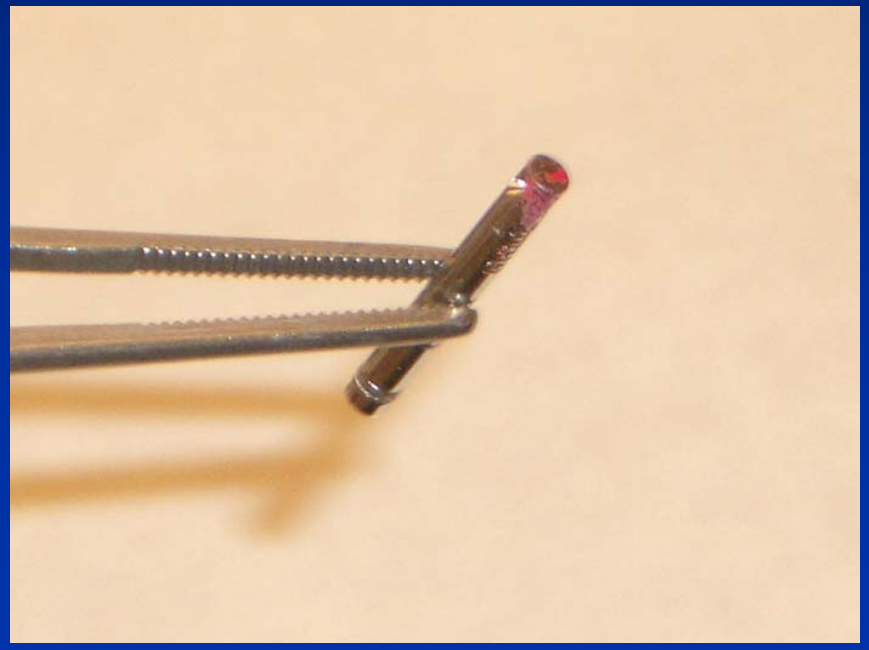
Instrumentation

- So – get yourself a well chamber!

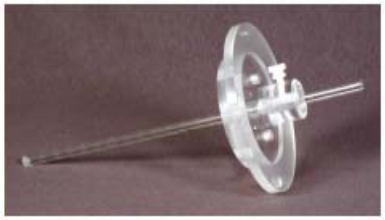
Preparation for calibration

- … and get the chamber or a source calibrated



Well chamber QM

- Constancy check with Cs-137 standard
- Regular calibration cycle with needed source types
- Source holders and geometry factors



44D-1 for ^{137}Cs Tube Sources and HDR ^{192}Ir

44D-1SL for Single Linear Seed Sources

44D-2 for Flexible Ribbon Sources

44D-3 Seed Batch Assay Holder

Acceptance testing of long-lived sources (kept in inventory)

1. Document the physical/chemical form and encapsulation in order to support dosimetry calculations
2. Document the initial leak test based on the manufacturer's certification, and, optionally, repeat with local equipment (see below.)

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Long-lived sources

3. Verify the uniformity of the activity distribution within each source (most likely with an autoradiograph; no tolerance limit is given.)
4. Verify the location of the activity distribution within each source relative to the exterior dimensions to a tolerance of 1 mm (most likely by combining an autoradiograph with a transmission radiograph.)

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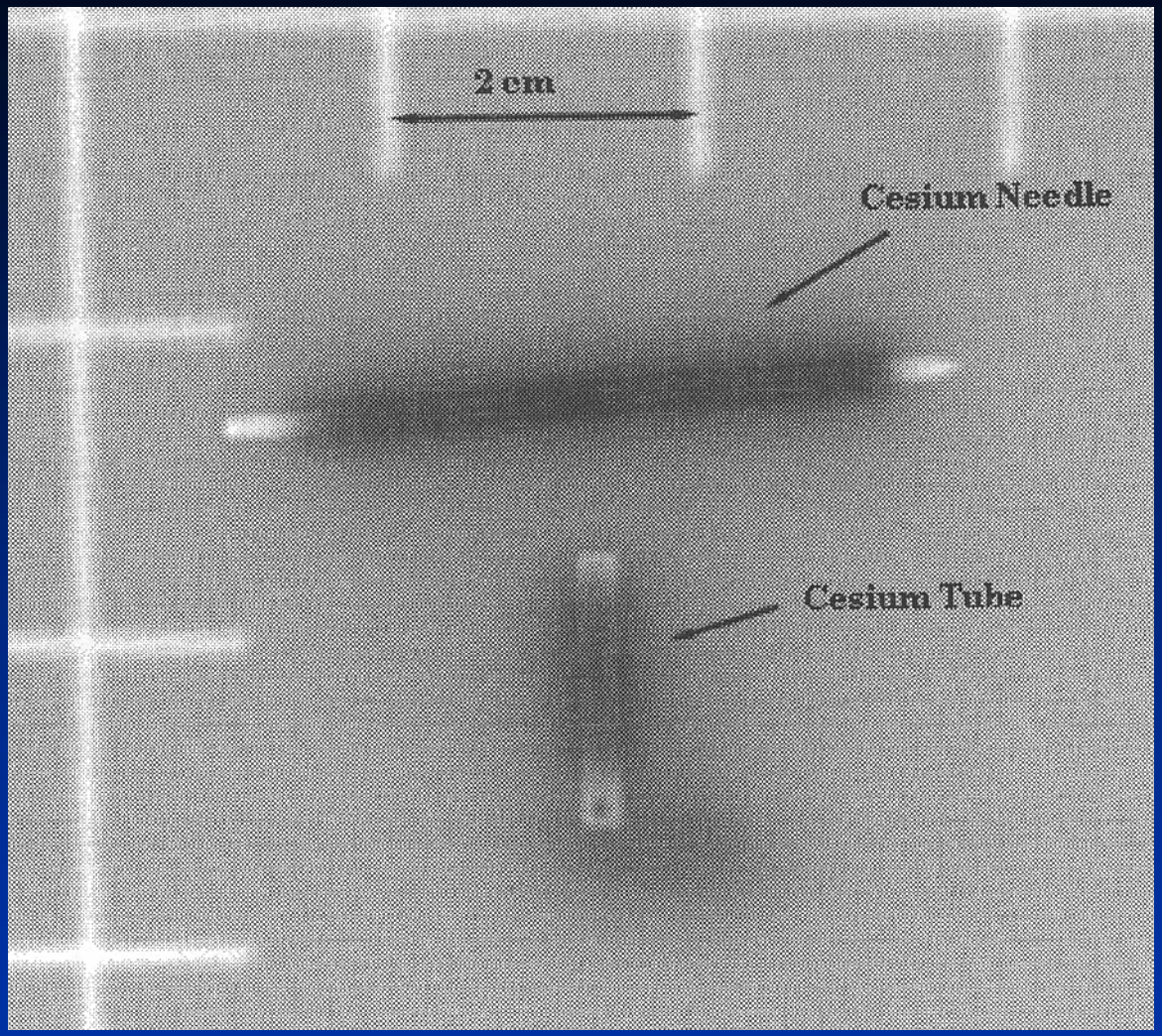
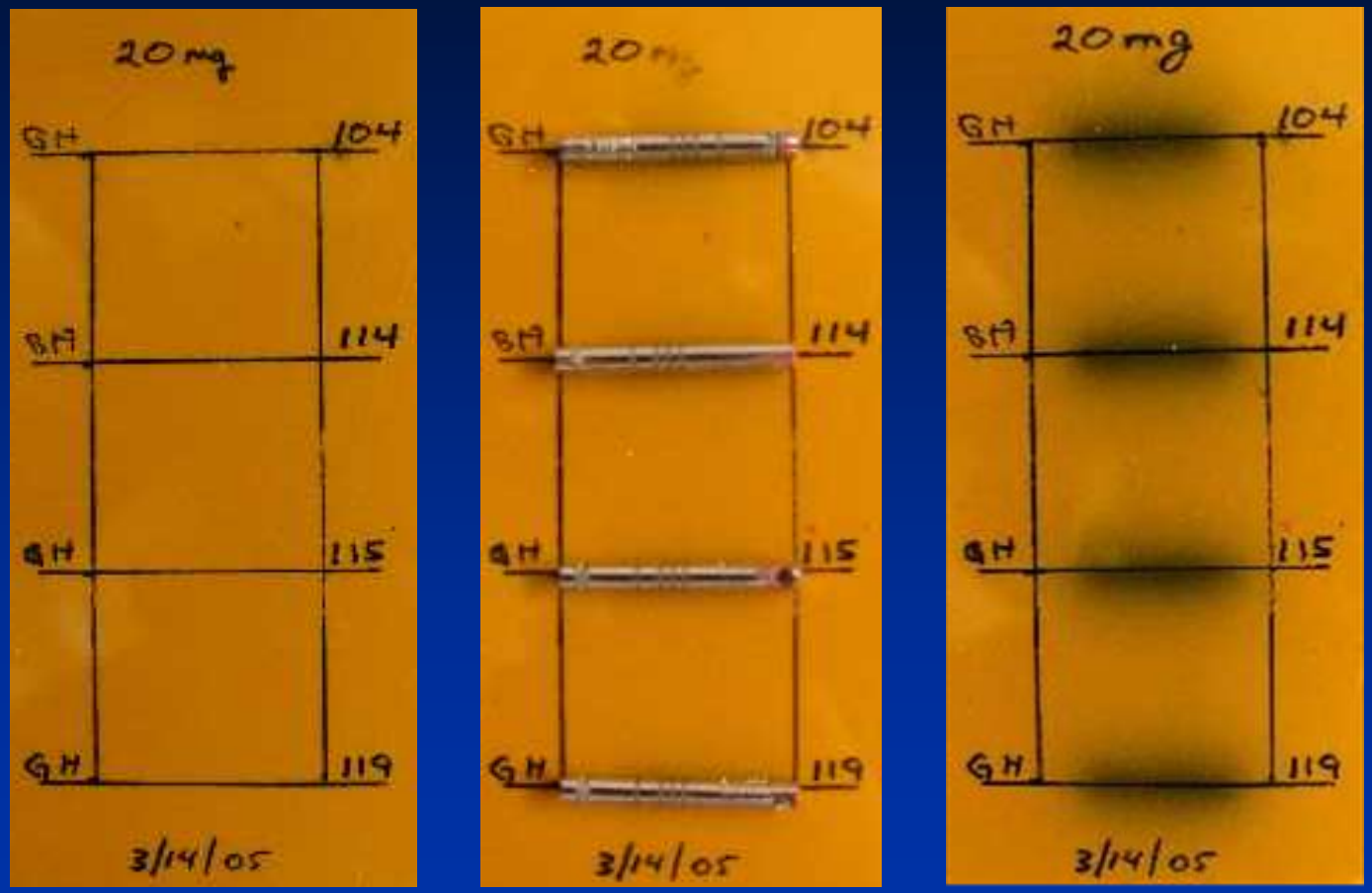


Fig 2.2 from Thomadsen: Achieving Quality in Brachytherapy

Checking sources with radiochromic film



GafChromic RTQA; ~10 minute exposure

Long-lived sources

5. Verify the identification of each source (serial numbers, color coding, etc.)
6. Calibrate each source

Calibration points

- If the measured source strength agrees with the manufacturer's specification to within 3%, then either may be used for dose calculations.
- Differences larger than 3% should be investigated, and differences larger than 5% should be reported to the manufacturer.
- When sources are batched for dosimetry purposes, then the 3% tolerance applies to the mean of the batch, and the range of source strengths within the batch should not exceed 5%.

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Leak testing

- At intervals of 6 months or 3 years, depending on the license conditions
- Need appropriate instrumentation for a minimum detectable activity of 0.005 μCi (185 Bq)
  - e.g. NaI well
  - μCi test source

See Thomadsen Chapter 2 : Achieving Quality in Brachytherapy

Leak testing details

- Basic requirement:
  - Net counts must be reliably above background
  - Be able to measure 0.005 μCi (185 Bq)
- "Leak" testing typically means wiping with an alcohol swab; dry wipe may only be 3% efficient

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$C_T \equiv total\ counts$

$C_B \equiv background\ counts$

$C_T - C_B = C_{wipe} > 1.645 * \left(C_B^{1/2} + \left(C_B + C_T\right)^{1/2}\right)$

$C_{wipe} \cong 4 * C_B^{1/2}$

Net counts > background

- If accept 5% false negatives (wipe has activity, but is called clean):

$$C_T \equiv total\ counts$$

$$C_B \equiv background\ counts$$

$$C_T - C_B = C_{wipe} > 1.645 * \left(C_B^{1/2} + \left(C_B + C_T\right)^{1/2}\right)$$

$$C_{wipe} \cong 4 * C_B^{1/2}$$

e.g. for background = 700 counts, net ≥ 104 counts

Counts to activity

- Use standard source with similar energy and strength, so counting efficiency is similar

- If different source type, account for difference in number of photons emitted per decay

Counts to activity

$$A \equiv activity$$

$$C \equiv counts$$

$$T \equiv count\ time$$

$$P \equiv photons\ per\ decay$$

$$A_{wipe} = A_{stndrd} * \left[C_{wipe} / T_{wipe}\right] / \left[C_{stndrd} / T_{stndrd}\right] * \left[P_{stndrd} / P_{wipe}\right]$$

For compliance …

$$0.005\mu Ci = A_{stndrd} * \left[C_{wipe} / T_{wipe}\right] / \left[C_{stndrd} / T_{stndrd}\right] * \left[P_{stndrd} / P_{wipe}\right]$$

$$0.005\mu Ci = A_{stndrd} * \left[4 * C_B^{1/2} / T_{wipe}\right] / \left[C_{stndrd} / T_{stndrd}\right] * \left[P_{stndrd} / P_{wipe}\right]$$

Can use this to calculate the necessary count time once you know the background count rate and the standard count rate

e.g. for background = 700 counts, net ≥ 104 counts;
So count long enough so 0.005 μCi will give 104 counts

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Acceptance testing of short-lived sources (TG-56)

1. Document the physical/chemical form and encapsulation in order to support dosimetry calculations
2. Verify the uniformity of the activity distribution within each source, where applicable, or the distribution of seeds along an extended ribbon (e.g. autoradiograph each ribbon.)

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Short-lived sources

3. Calibrate the sources, either individually or as a batch. Should agree with manufacturer within 3% with range of 5%

Issues:

Seeds in ribbon (e.g. Ir-192)

Loose seeds

Pre-sterilized seeds

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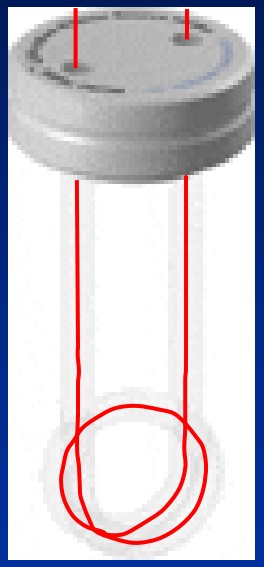
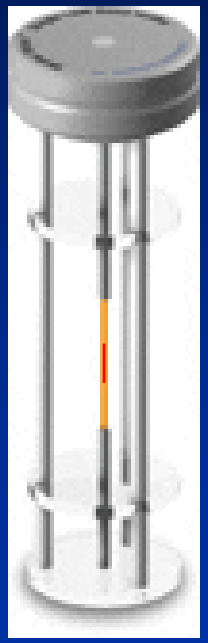
Seeds in ribbon

- Can use source holder for well chamber that holds the ribbon in a coil.
- May need to develop correction factor vs. ribbon length.
- TG-40: For large number of ribbons, measure at least 10% of seeds



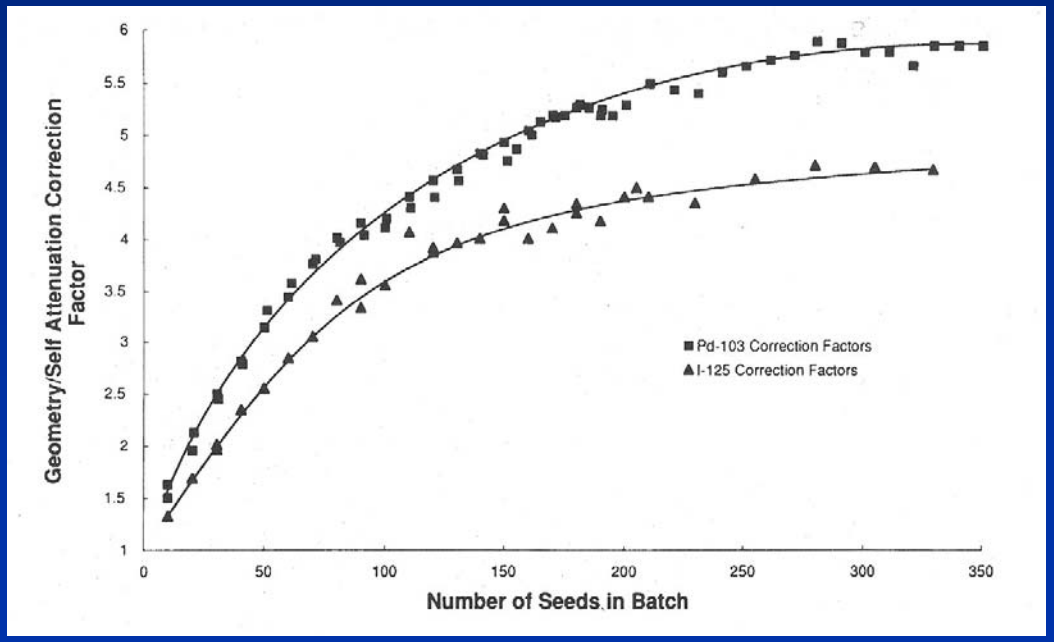
Loose seeds

- TG-56 allows for “secondary traceability by statistical inference” in which a “suitable random sample” is calibrated with secondary traceability.
- TG-40 and TG-56 call for that sample to comprise at least 10% of the total batch.



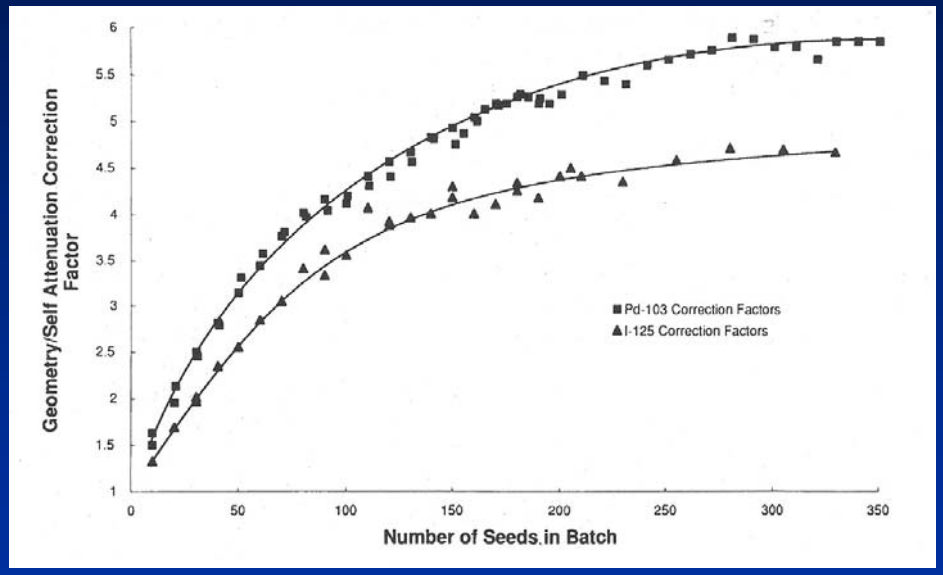
Loose seeds

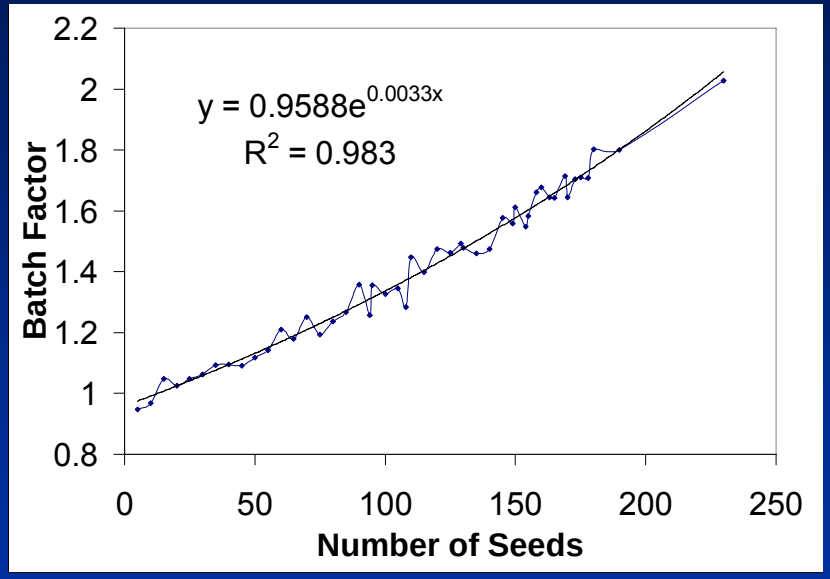
- Can also measure the entire batch, using an empirical correction for geometry and self-absorption



Mellenberg and Kline, MedPhys 22: 1495-7 (1995)

Batch factor depends on system





Pre-sterilized seeds

- TG-56 recommends “purchasing and calibrating a single (non-sterile) seed for each designated-strength grouping.”
  - What is the connection between the seeds?
    - Same lot?
    - Different lot, same process?
  - Only one seed?

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Pre-sterilized seeds: options

- Purchase and calibrate some loose seeds of the same type and activity, which are then discarded.
- Purchase and calibrate some assemblies of the same type and activity, which are then discarded.

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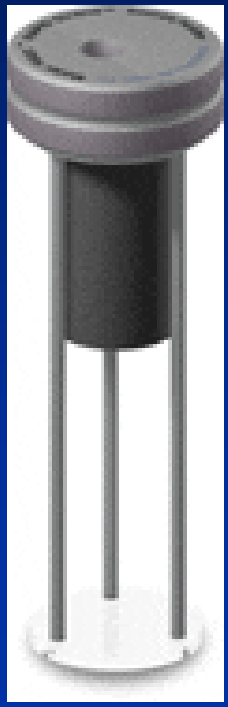
Pre-sterilized seeds: options

- Calibrate some assemblies under sterile conditions in the OR
  - Sterilizable insert that can measure 5 of 10 seeds in one RAPID Strand™
- (calibrating sources actually used!)



Pre-sterilized seeds: options

- Use third-party service to assay (not limited necessarily to pre-sterilized seeds)
- Controversial with respect to end-user responsibilities
  - TG-64: “In whatever form the seeds are procured, the manufacturer’s assay *must* be independently confirmed.”

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AAPM Brachytherapy Subcommittee **draft*** statement on third party calibrations

"…each physicist should continue to follow the recommendations of Task Groups 56 and 64 in their intent to place the patient's needs foremost. For those already using a 3rd party calibration service, a prudent approach would be to perform some relevant in-house check of each order received."

*under discussion within Therapy Physics Committee

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Leak testing for short-lived sources

- Generally not necessary, unless
  - Keep I-125 stock > 6 months?
  - Used for second patient
  - After extensive handling
- Good practice to be prepared to test for potentially ruptured seed (c.f. recent NRC notice)

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Periodic testing of sources kept in inventory

- Formal inventory (typical regulation calls for quarterly inventory)
- Annual calibration
  - Deviation from expected half life would indicate contamination with a different isotope
- Inspect identification, refresh color coding if necessary
- Leak test when required

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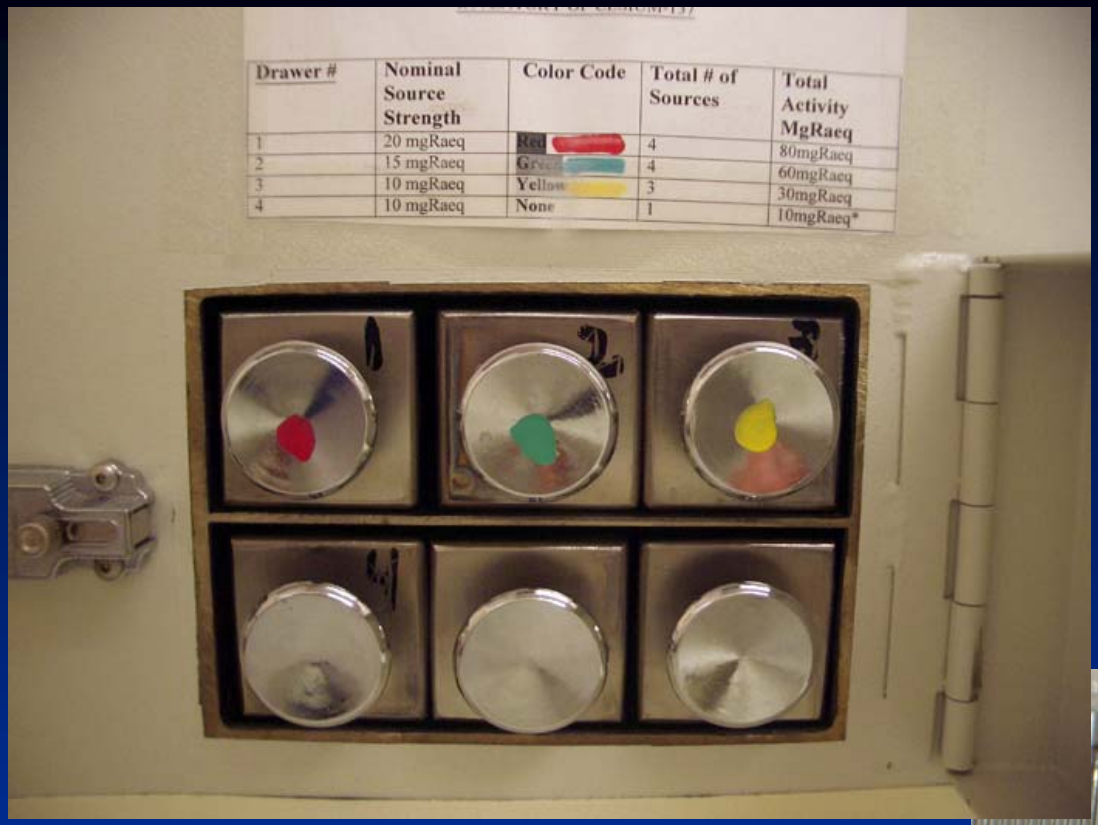
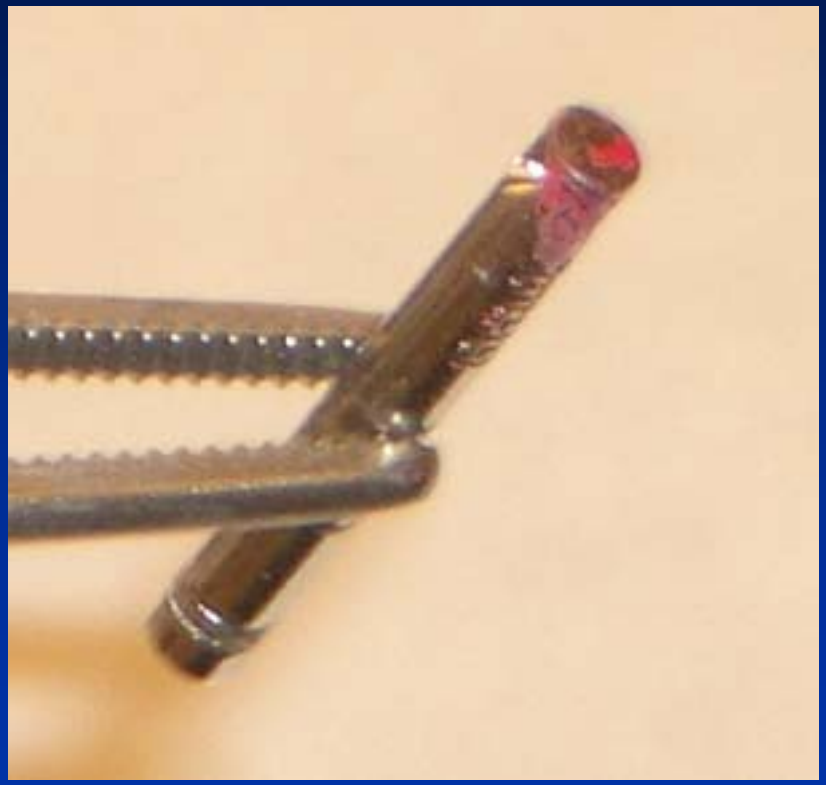
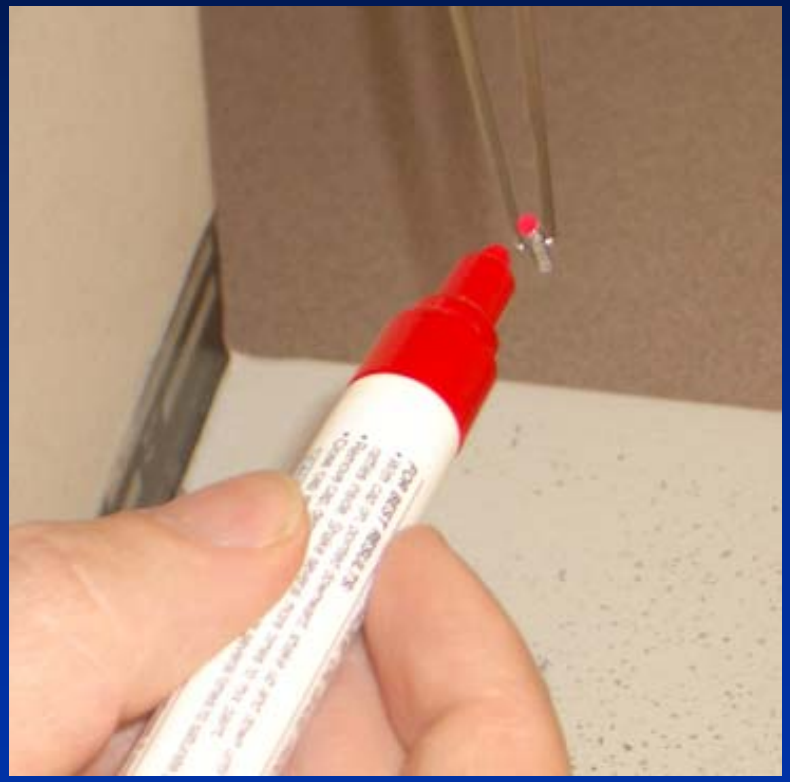


Drawer #	Nominal Source Strength	Color Code	Total # of Sources	Total Activity MgRaeq
1	20 mgRaeq	Red	4	80mgRaeq
2	15 mgRaeq	Green	4	60mgRaeq
3	10 mgRaeq	Yellow	3	30mgRaeq
4	10 mgRaeq	None	1	10mgRaeq*

Time for a paint job





Per-patient testing (… of sources)

- Inventory control, showing which sources are out of storage, where they are, when they were removed, and when they are returned
- Main concerns overlap with the more general quality management of the brachytherapy procedure
  - Right sources into right places …

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Plan Summary and Implant Record

From W. Butler

Patient: _____ Treatment Start Date: _____

Radionuclide: _____ Calibration Date: _____ Half-Life: _____

Date at Midtreatment: _____ Decay Time: _____ Decay Factor: _____

Treatment Diagram

Source No.	Source Ident.	Calibrated Activity	Calculated Activity

Calculated Doses

Calculation Point	Dose Rate (cGy/hr)	Time (hours)	Total Dose (cGy)

Implant applied: Date: _____ Time: _____ Hours: _____

_____ Date: _____ Time: _____ Hours: _____

Implant removed: Date: _____ Time: _____ Hours: _____

Calculated by: _____ Checked by: _____

Date: _____ Date: _____

Cs-137 Requisition

Radioactive Materials Requisition

Patient: _____ Room: _____

( ) Cesium - 137

Tandem Loading *(mg Ra eq.)*	Upper, inner end	_____	Color _____		_____	Spacers
		_____	_____		_____	
10 = green					_____	
		_____	_____			
15 = yellow					_____	
		_____	_____			
20 = orange					_____	
	Outer end	_____	_____			Color
Ovoid Loading *(mg Ra eq.)*	Right	_____	_____	Left	_____	_____

Date and Time needed: _____

Radiation Oncologist: _____ Date: _____

Requisition filled by: _____ Date: _____

Checked by: _____ Date: _____

From W. Butler

Cs-137

In-use inventory

From W. Butler

Patient: _____ Room: _____

Sources removed: _____ Date: _____

_____ Time: _____

Cesium in Hot-Cell Storage Safe

Quantity After Removal	Color Code	Quantity Stocked	Identity	Quantity After Return
	Green	6	10 mg Radium equivalent	
	Yellow	6	15 mg Radium equivalent	
	Orange	4	20 mg Radium equivalent	
	← **Authorized Handler Initials** →			

Sources returned: _____ Date: _____

_____ Time: _____

* *

Authorized Handlers:

Wayne Butler, Ph.D.

Amber Hines, M.S.

Richard Anderson, CMD

Gregory Merrick, M.D.

Tapash Roy, Ph.D.

Brian Kurko, CMD

Brian Murray, CMD

Jondavid Pollock, M.D.

Ir-192 Requisition

From W. Butler

Radioactive Materials Requisition

Iridium - 192 (>4 ribbon types)

Patient: _____ Room: _____

Number of Ribbons	No. of Seeds per Ribbon	Seed Spacing *mm*	Activity per seed *mg Ra eq*	Activity per seed *mCi*	Ribbon Color

Date and Time needed: _____

Radiation Oncologist: _____ Date: _____

Requisition filled by: _____ Date: _____

Checked by: _____ Date: _____

Ir-192 Inventory

From W. Butler

Receipt

Manufacturer: _____ Received by: _____ Date: _____ Time: _____

Ludlum 14C check ❑ lavender | ❑ green	Package Damaged?	Package Wipe Test <6.6kdpm/300cm^2	Transport Index	Exp. Rate @ 1m mR/hr	Max. Surface mR/hr

Seed Calibration

Lot Number / Ribbon color	Calibration Date	Activity per seed (mg Ra eq)	Calculated Activity ($t_{½}$ = 73.83 d) Upon Receipt			At start of treatment:	
			days / D.F.	mg Ra eq	mCi	days / D.F.	mCi

Inventory for Implant

Ribbon Color	Number of Ribbons	No. of Seeds per Ribbon	Act. / Ribbon (mCi)	Dose Calibrator Check (mCi)	Total Number of Seeds	Total Activity (mCi)
Totals						

Storage and Use Inventory

Date	Time	In Storage		Removed		Returned		Patient/Room	Init
		No.	mCi	No.	mCi	No.	mCi		

Seed Return

Shipper: _____ Date: _____ Act./Seed: _____ mCi

Total number of seeds _____ Total Activity: _____ mCi = _____ GBq

Max. Surface Activity: _____ mR/hr Exposure @ 1 meter: _____ mR/hr Transport Index:

* *

Authorized Handlers: Wayne Butler, PhD Amber Hines, MS Tapash Roy, PhD Gregory Merrick, MD Jondavid Pollock, MD

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Room Survey

From W. Butler

Patient: _____ Room: _____ Date:

Survey meter: _____ Check source: _____ Time:

Point	Location	Meter Reading (mR/h)	Notes
A	1 meter to side of patient, unshielded	_____	_____
B	1 meter to side of patient, behind leaded shield	_____	_____
C	"Safety Line" tape for visitors at 4 ft height	_____	_____
D	Outside room in adjacent corridor at 4 ft height	_____	_____
E	Adjacent room (202 or 224) at 4 ft height	_____	_____
F	Electric service room <u>or</u> outside corridor	_____	_____
G	Room above patient (301 or 344) at 1 ft height	_____	_____
H	Room below patient (1504 or 1702) at 6 ft height	_____	_____

Survey by: _____ indicates no misplaced sources.

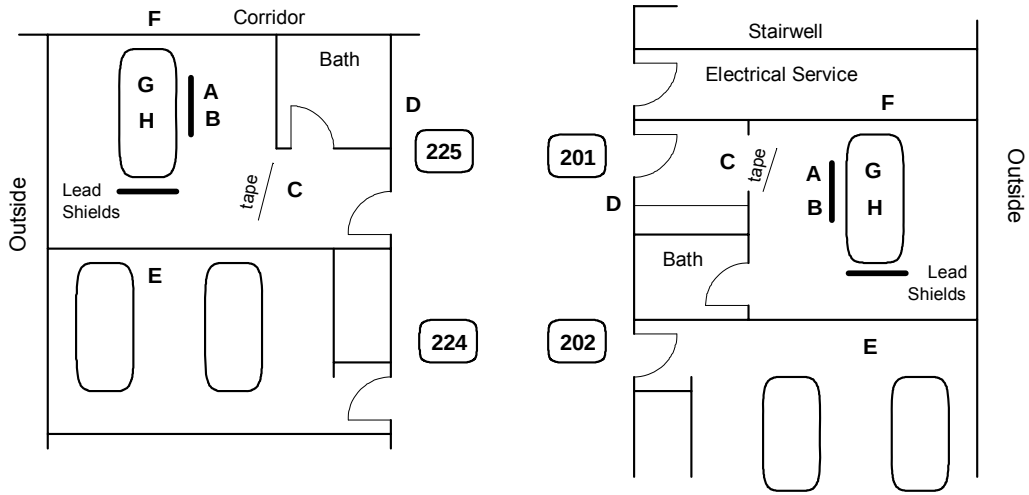
<u>DOSE LIMITS</u>: 10 CFR Part 20 limits the dose from external sources to unrestricted areas (Points **D – H**) to **2 mrem/h** and the dose to any individual member of the public to **50 mrem/yr**.
The Radiation Oncologist and the Radiation Safety Officer must be notified if readings in unrestricted areas exceed **0.5 mR/h** so that patient dose, room occupancy, shielding, or restricted areas be redefined to remain within the 50 mrem/yr limit.

After Removal of Implant

I	Patient body, clothing, and belongings	_____	_____
J	Bed, linens, trash, and afterloading applicators	_____	_____

Survey by: _____ indicates all sources are accounted for. Date:

Survey meter: _____ Check source: _____ Time:



War stories related to source control

"… the doc wouldn't practice with the Mick before the procedure, and we had seeds all over the OR. Stuck in people's shoes … everywhere. It was a mess."

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More stories …

On weekends, the practice was for the resident to unload the sources, do the survey, and take the pig back to the source room; physicist would return the sources to the safe on Monday morning. One Monday, found one source was missing … several days later it was found in the Atlanta landfill.

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Conclusion

- Calibrate the sources
- Keep track of them!
- After that, on to more exciting things…