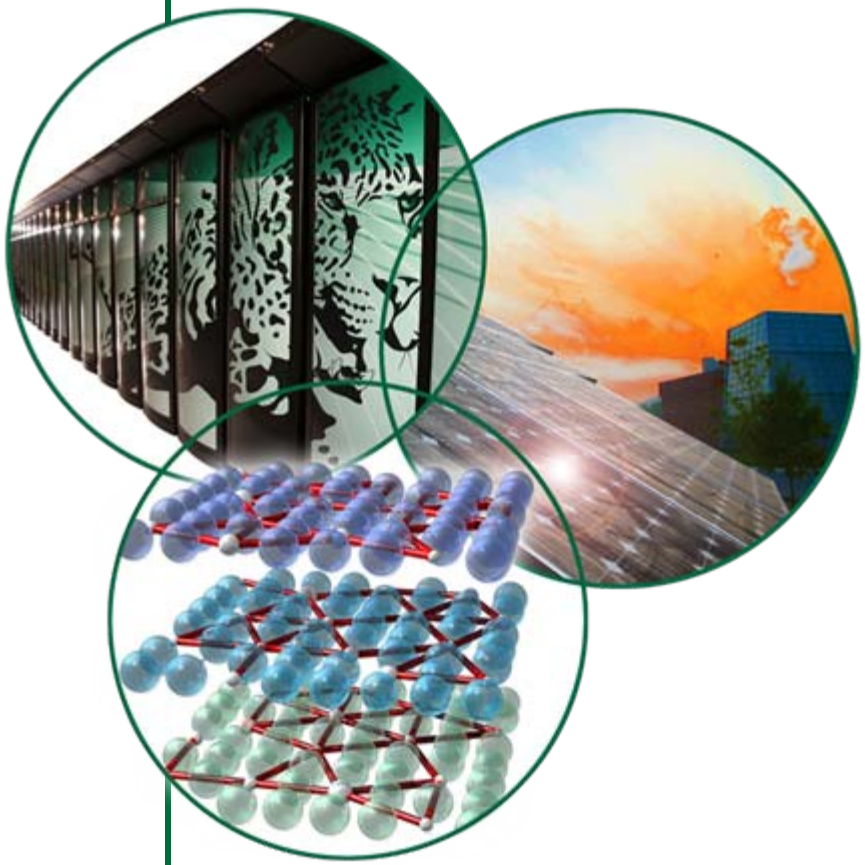
Radioisotopes at the Radiochemical Engineering Development Center



Presented by Julie Ezold

Nuclear Materials Processing Group

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Vision of a Unified Heavy Element Production Program

The field of new transuranium elements is entering an era where the participating scientists in this country cannot go much further without some unified national effort which can only be authorized and coordinated by the Atomic Energy Commission itself.

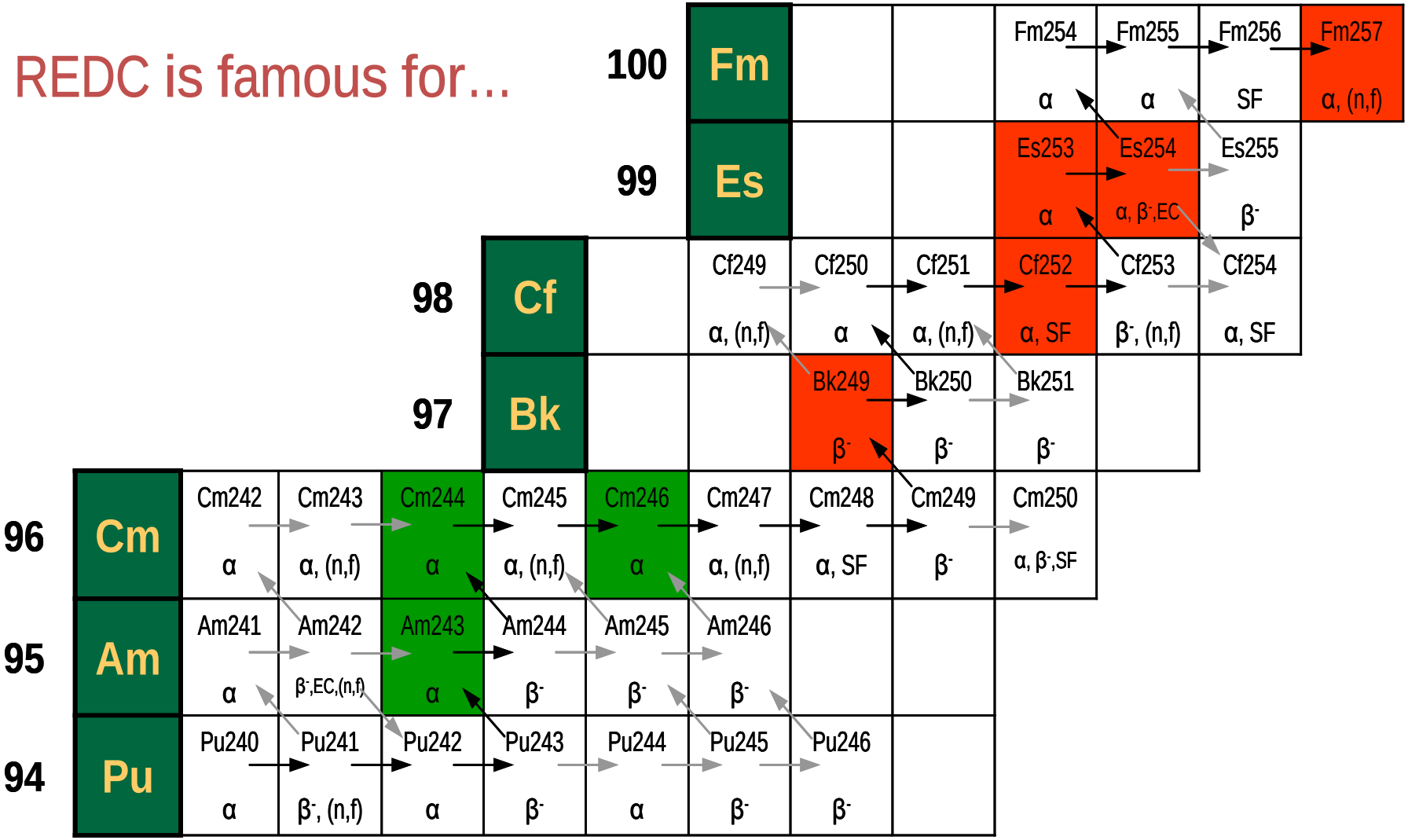
- The future progress in this area depends on substantial weighable quantities (say milligrams) of berkelium, californium, and einsteinium. The acquiring of this depends upon our country's entrance into a two-fold program
- The irradiation of substantial quantities of ^{239}Pu as reactor fuel element, and the reirradiation of the products...to form hundred gram amounts of ^{244}Cm and higher curium isotopes...
- The irradiation of the curium in the suggested "very high flux reactor."

G. T. Seaborg

Berkeley, October 24, 1957

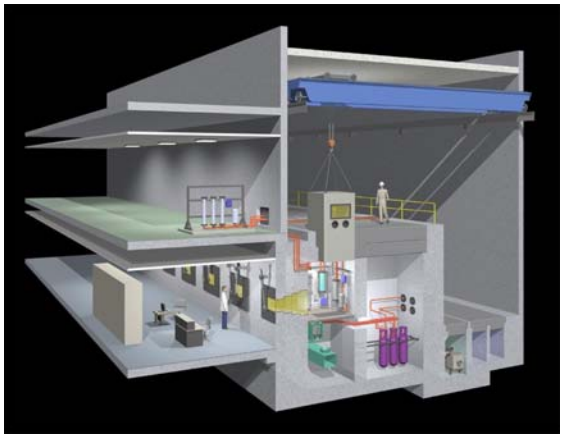
Transmutation Pathway

REDC is famous for…



REDC/HFIR offer Unique Capabilities

- Store the raw material (Curium)
- Fabricate the targets
- Irradiate the targets
- Process the irradiated targets
- Produce the transcurium products



Typical Processing Scheme

Irradiated Targets

HFIR Irradiation

Aluminum Dissolution

Target Fabrication

Caustic Soluble FP

Nitric Acid Dissolution

Microsphere Preparation

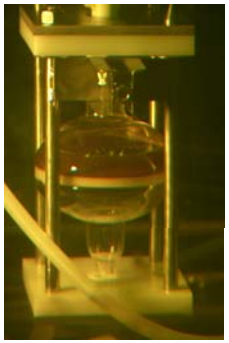
HDEHP Extraction

Waste Organic

Oxalate Purification

LiCl Anion Exchange

Lanthanide FP



Am/Cm

AHIB Cation Exchange

LiCl Anion Exchange

Bk Cf Es Fm

Hydroxide Precipitation

Trans Cm

Transcurium Isotopes

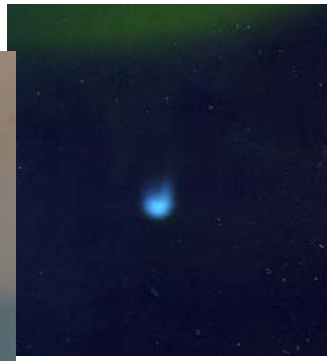
^{249}Bk

- Currently being utilized in a joint US/Russian experiment to discover super-heavy element 117

$^{253}Es/^{254}Es$ & ^{257}Fm

- Predominantly used to determine nuclear physics characteristics

Es-253 (0.17 mg, self-illuminated)

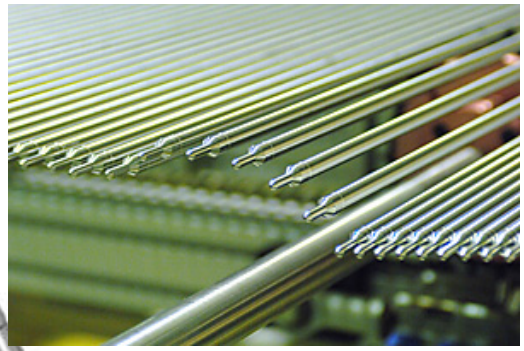


Es-253 (0.30mg)

Californium-252 is versatile because of its unique characteristics

- First isolated in 1952
- 2.3 X 10^6 neutron/s per 1 µg
- 2.645 year half-life
- Portable neutron source
- Utilized in a multitude of applications
- Part of a global market
- Only two producers worldwide

Applications of Cf-252



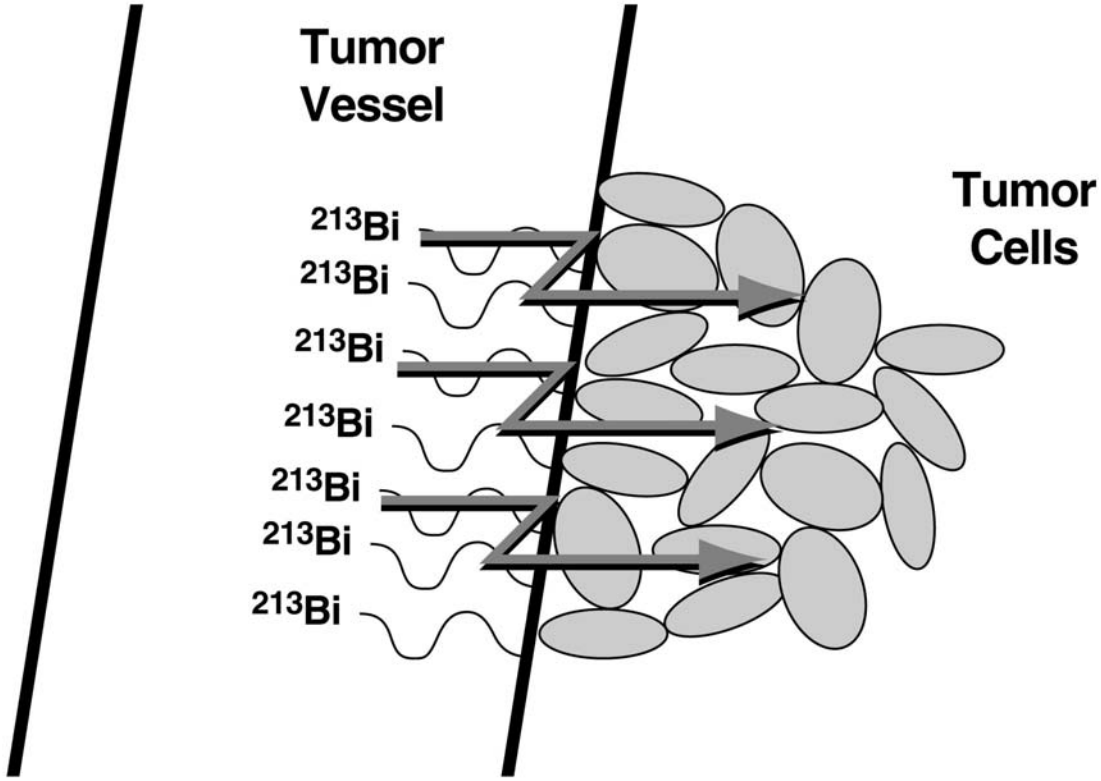
Why Alpha Emmitters?

- Alpha particles have short range but high linear energy transfer (LET) radiation

  – causes double breaks in DNA (It would take ~100β- to do the same damage)
- Alphas kill all cells in short path (~100 µm)
  - 213Bi, 8 MeV, 6-10 cell layer
- Isotope is attached to targeting antibody
  - vascular delivery
- Short half-life alpha emitters
  - immediate effects, external cell
- Longer half-life alpha emitters
  - nanogenerator systems, internal cell, multi-alphas

Vascular targeting of radioisotopes to solid tumors

- DTPA tagged with BI-213
- Selectively seeks out protein only seen with cancer
- Attaches to cell wall and radiates cancer cell
- Penetrates only 6 – 10 cell layers



Courtesy of Saed Mirzadeh

Alpha Medical Isotopes

Candidate Alpha-Emitters for Medical Applications

Source Radioisotope	Generator Radioisotope	Administered Radioisotope
^{228}Th (1.91 y)	^{224}Ra (3.66 d)	^{212}Pb (10.6 h) ^{212}Bi (60.6 m)
^{229}Th (7340 y)	^{225}Ra (14.8 d) ^{225}Ac (10 d)	^{213}Bi (45.6 m) ^{225}Ac (10 d)
^{232}Th (1.4x10^{10} y)	^{232}Th[p, spall]^{211}Rn	^{211}At (7.2 h)
^{209}Bi (stable)	^{209}Bi[✂2n]	^{211}At (7.2 h)
^{232}Th (1.4x10^{10} y)	^{232}Th [p,3n]^{230}Pa(17.4 d) –> ^{230}U(20.8d)	^{226}Th (31 m)

isotope (half-life)

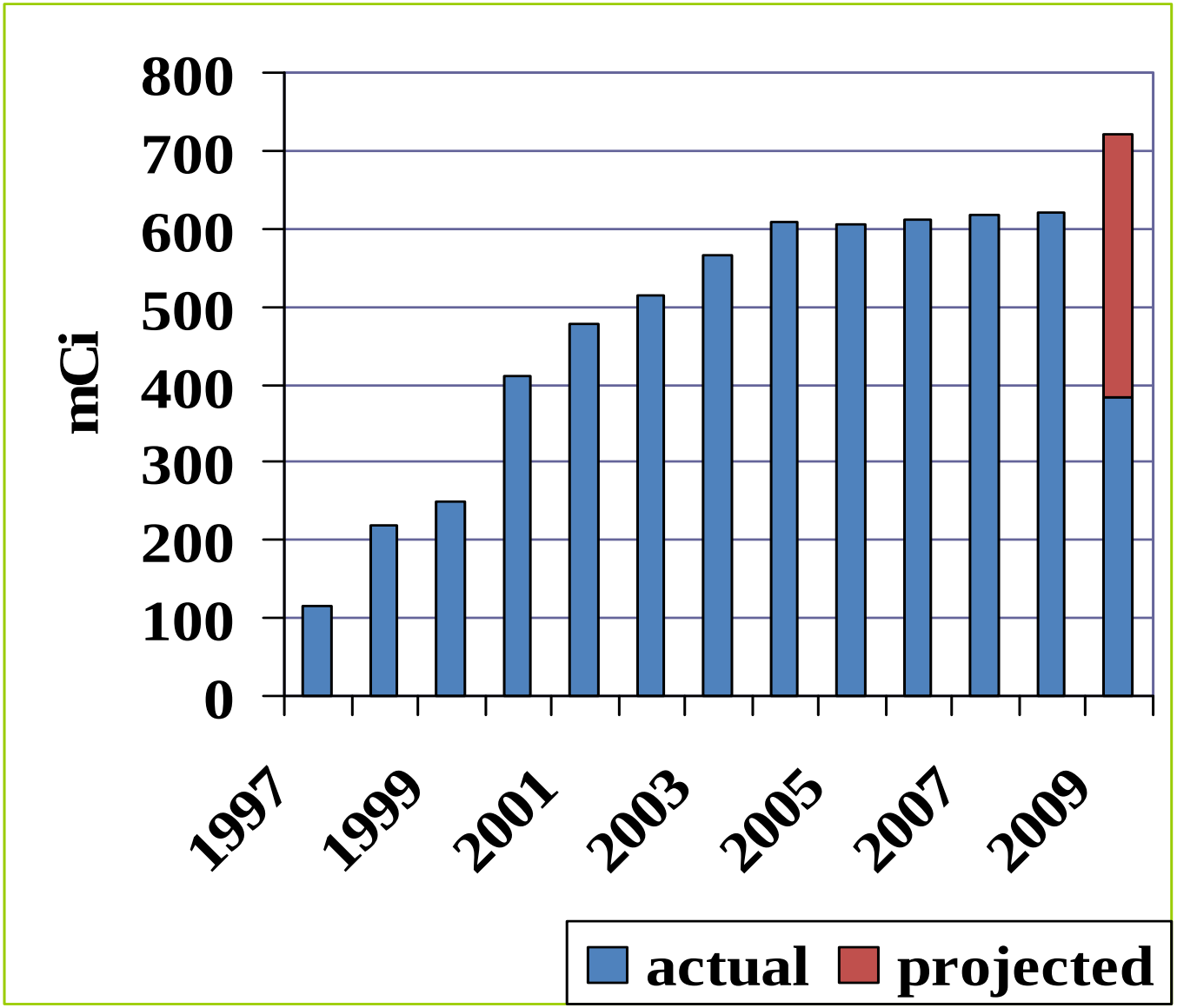
Targeted Alpha Therapy Using Ac225/Bi213

Memorial Sloan-Kettering Cancer Center, New York, (USA)	Acute Myeloid Leukemia (clinical trial), Ovarian Cancer
Technical University Munich, Dept. of Nuclear Medicine (Germany)	Gastric, ovarian and bladder cancer
Univ. Hospital Düsseldorf (Germany)	Non-Hodgkin‘s lymphoma (NHL)
INSERM, Nantes (France)	Multiple myeloma (clinical trial)
University Hospital Basel (Switzerland)	Brain tumors (clinical trial), prostate cancer
St. George Hospital & Centre for Exp. Radiation Oncology, Sydney (Australia)	Malignant melanoma, prostate, pancreatic, breast and ovarian cancer
Johns Hopkins School of Medicine, Baltimore (USA)	Breast Cancer
Albert Einstein College of Medicine, New York (USA)	Fungal, bacterial and viral (HIV) infections

Building Bismuth Generator

- Resin contacted with pure Actinium 225 in solution
- Carefully loaded into generator
- Shipped to customer

ORNL Ac-225 production per year

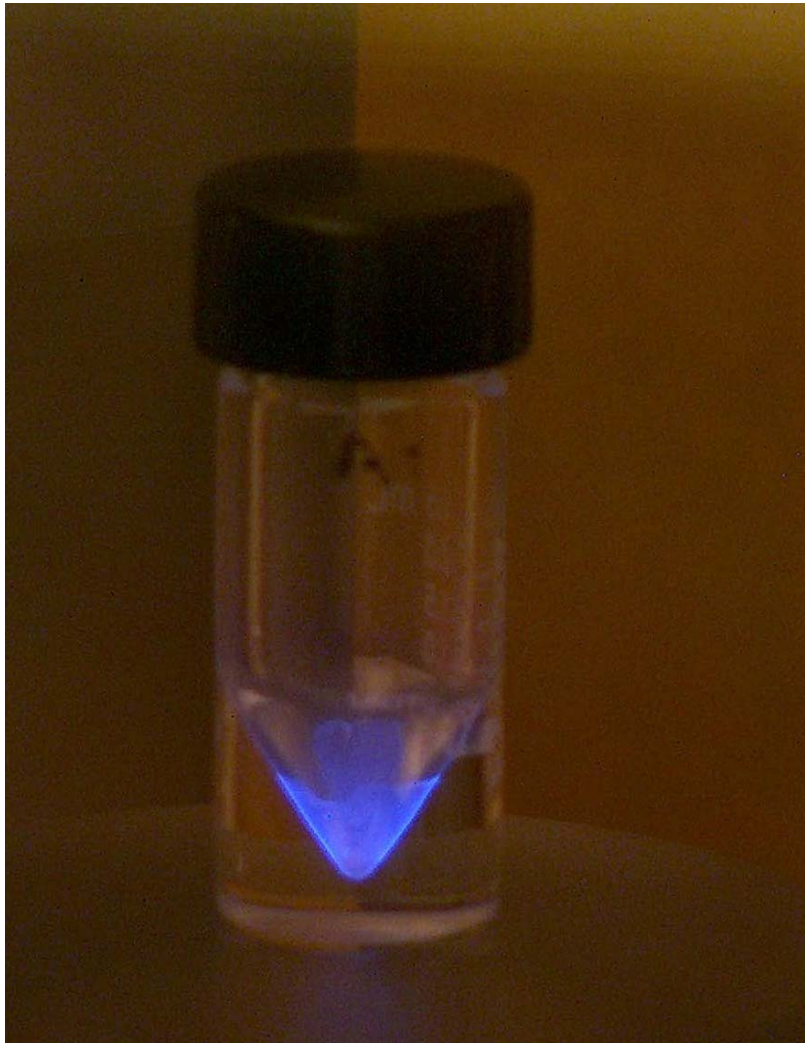


Alpha Scintillation Interaction

50mCi

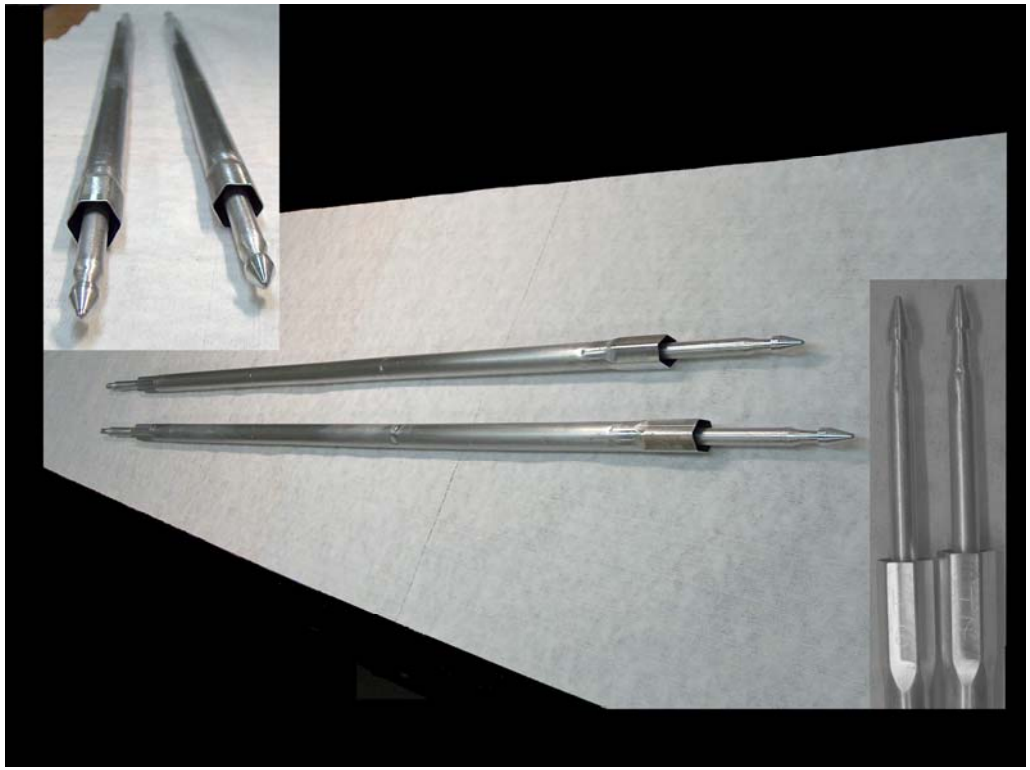
2 X 25mCi

“Lights Out”



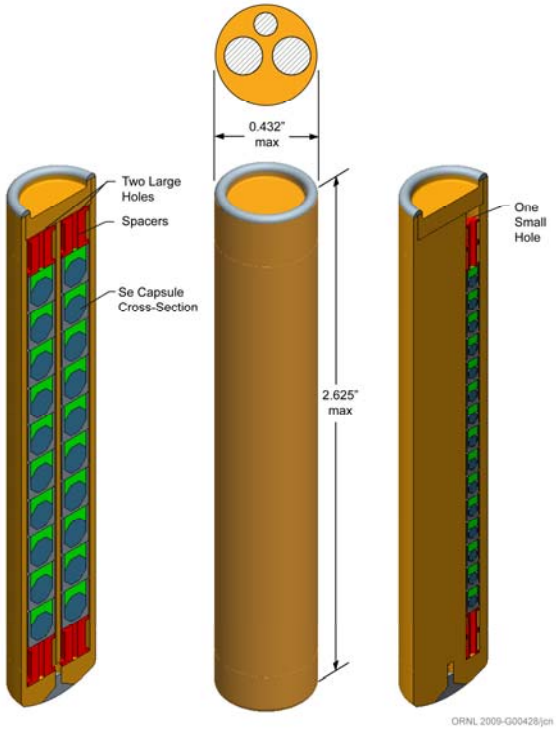
Ni-63

- Activation of Ni-62 utilizing ~13 HFIR Cycles
- Pure β- emitter
- Used in detector systems



Se-75

- Gamma radiography
- Longer half-life than ^{192}Ir



Source	$t^{1/2}$	Useful Working Range in Steel (mm)
^{60}Co	5yr	1.17-1.33MeV
^{192}Ir	74d	206 - 612KeV
^{75}Se	120d	97 - 401KeV
^{169}Yb	32d	63 - 308KeV
^{170}Tm	129d	52 - 84KeV
^{153}Gd	242d	41 - 103KeV

0 20 40 60 80 100 120