Production and Development of Radioisotopes in HANARO

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: The status of the usage and market of Radioisotopes and RT

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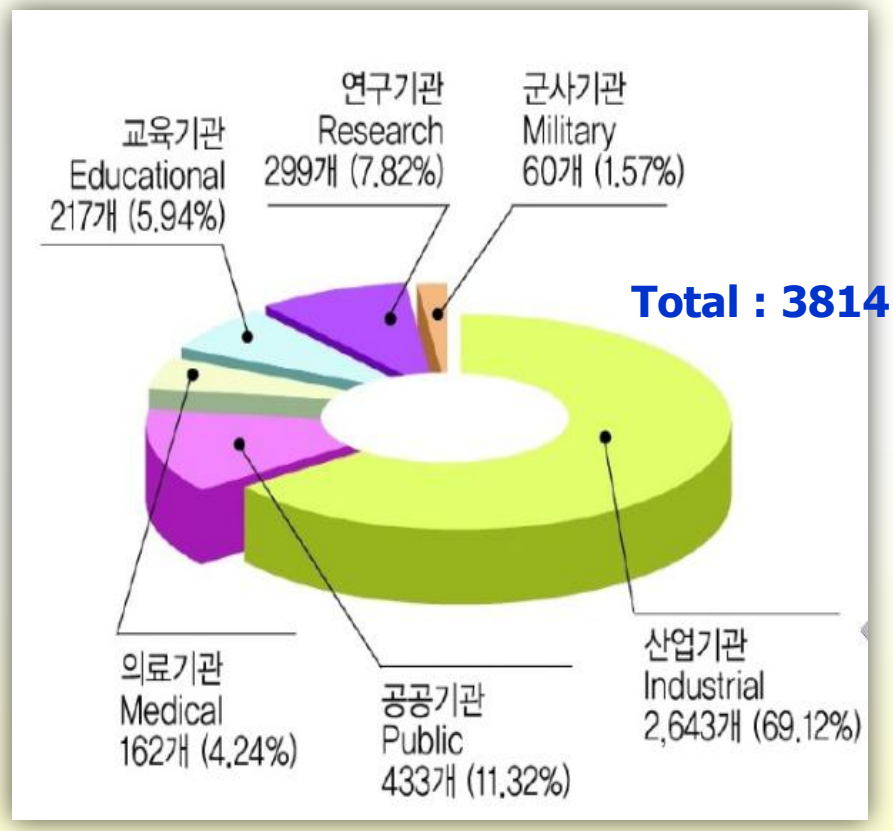
Introduction

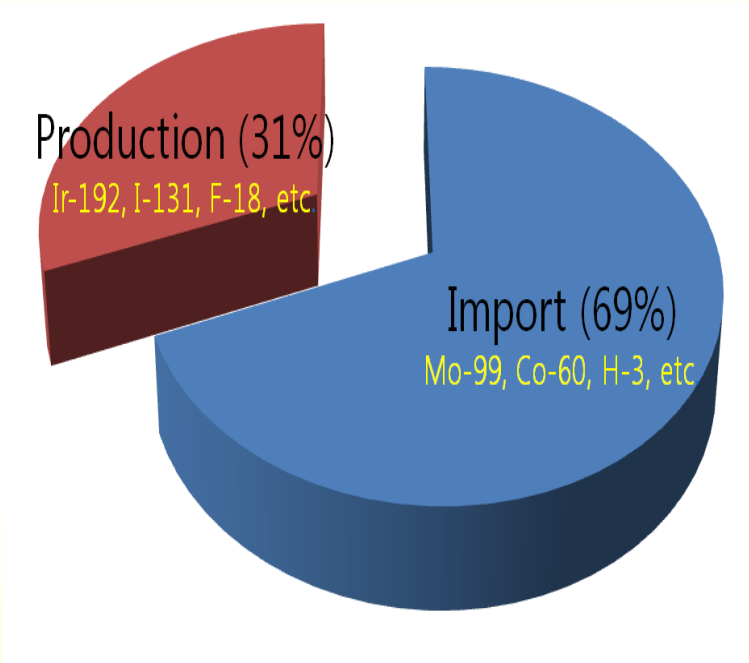
- In Korea, commercial applications of radioisotopes keep increasing with the development of various industries
- More than 395 kCi of RIs were consumed by more than 3,800 organizations in 2008
- Supports by Government have been made to promote RI and RT technologies.
  - "The Mid and Long Term Nuclear R&D Programs" since 1992
  - "A Comprehensive Promotion Plan for Utilization, Research and Development of Radiation and Radioisotopes" in 1995
  - "Act on the Utilization of Radiation and RI" in 2002

RI's Market in Korea

- Number of Licensed Users of RI/Radiation



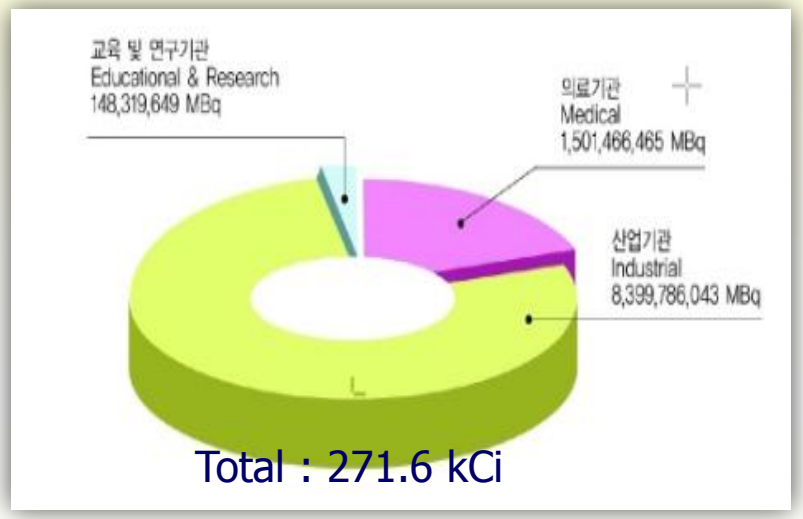
- Status of RI Production /Import



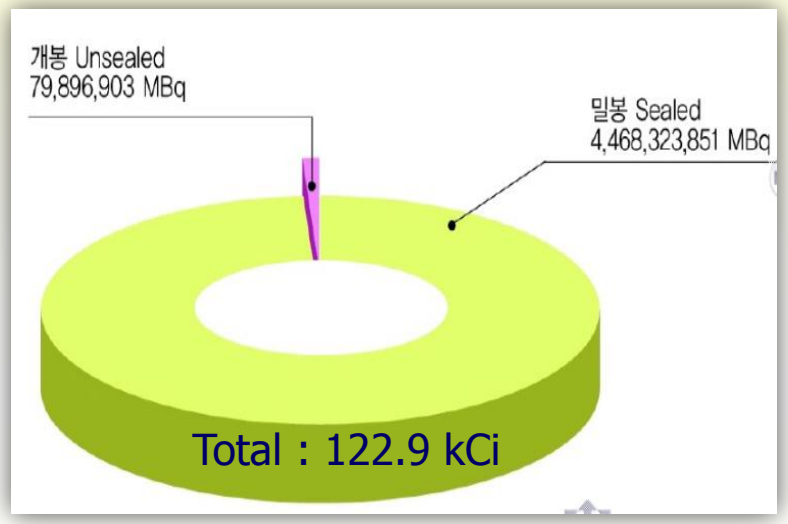
Introduction

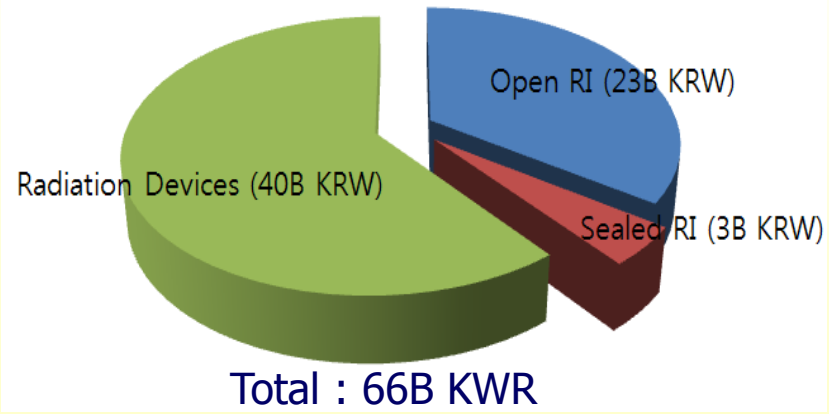
RI's Market in Korea

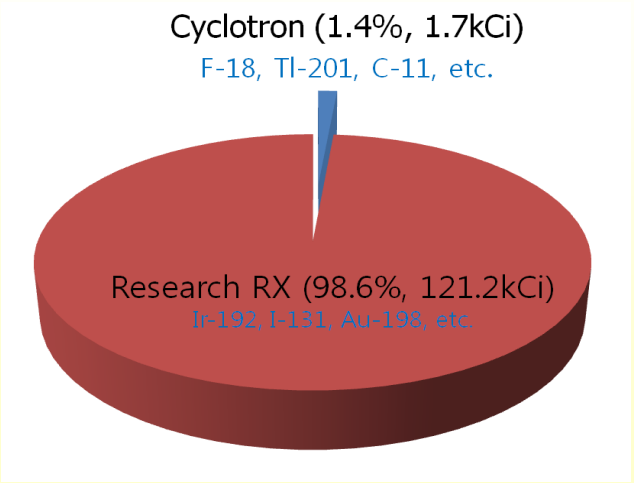
- Import



- Production







Facilities for RI Production

Nuclear Reactors at KAERI

TRIGA Mark-II Reactor

TRIGA Mark-III Reactor

HANARO Reactor

- Reactors for Radioisotope production at KAERI
  - TRIGA Mark-II (250 kW, 1962-1995) in Seoul
  - TRIGA Mark-III (2MW, 1973-1995) in Seoul
  - HANARO (30MW, 1996-) in Daejeon

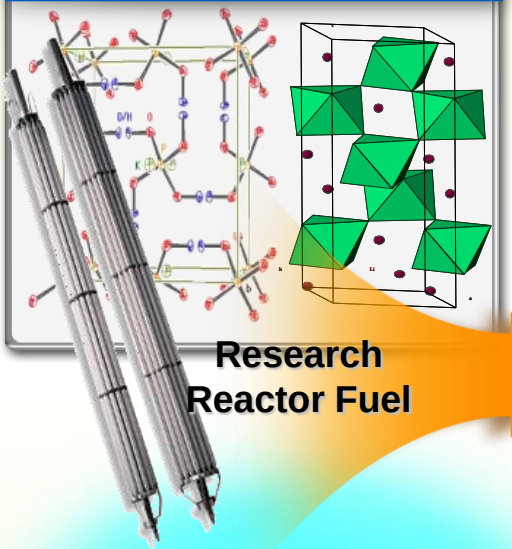
HANARO plays a key role for the Production of Radioisotopes in Korea

HANARO Application Research

HANARO

High-flux Advanced Neutron Application Reactor

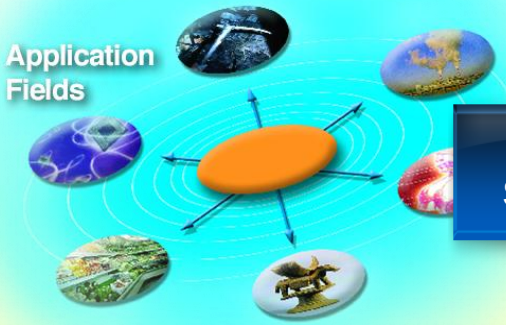
Neutron Beam Application



Research Reactor Fuel

RI Production & Application

^{166}*Ho-Chitosan*

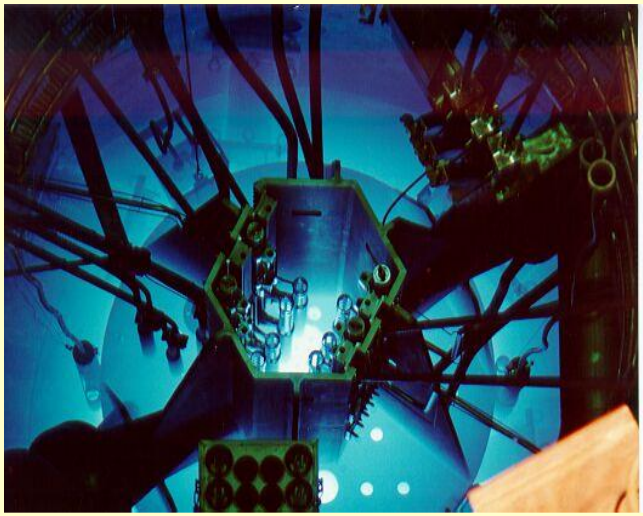


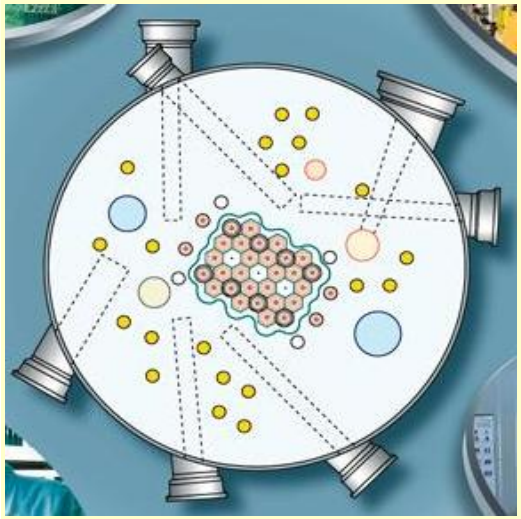
NAA Si-NTD

Post Irradiation Examination

Facilities for RI Production

HANARO Research Reactor





Vertical Irradiation Holes

Region	Symbol	Number	Thermal Neutron Flux (n/cm^{2}sec)
In Core	CT	1	~ 4.0×10^{14}
	IR	2	3.0 ~ 4.0×10^{14}
Out Core	OR	4	2.2 ~ 3.0×10^{14}
Reflector	HTS	1	8.0×10^{13}
	IP	17	2.5×10^{13} ~ 1.5×10^{14}
	LH	1	8.5×10^{13}

Facilities for RI Production

Hot Cells at RIPF

BANK I

BANK II

BANK III

BANK IV

- Hot Cell Bank I
  - 4 concrete cells (^{60}Co, ^{192}Ir)
- Hot Cell Bank II
  - 11 lead cells (^{32}P, ^{99m}Tc, ^{51}Cr, ^{192}Ir for RALS, etc.)
- Hot Cell Bank III
  - 6 lead cells (^{131}I, ^{125}I)
- Hot Cell Bank IV
  - 4 lead cells (^{99}Mo/^{99m}Tc generator)
- 120 RIs, 400 kCi/yr

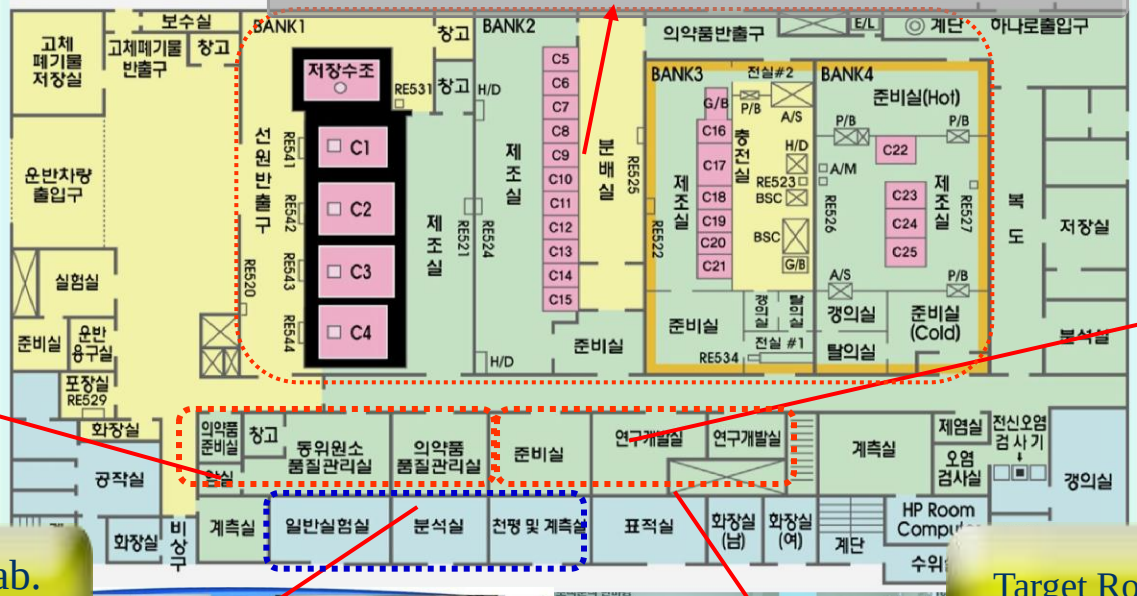
Facilities for RI Production

Layout- 1st Floor

Hot Cell

Hot Lab.

QC Room



Cold Lab.

Target Room

Facilities for RI Production

Layout - 2nd & 3rd Floor

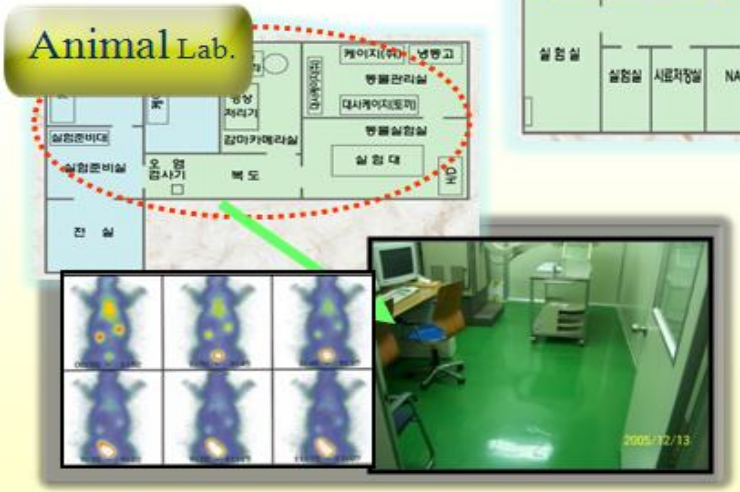
Production line of labeled compound and Tc-99m Cold Kits

Research Lab.

Hot Lab.

QC Room

Animal Lab.



Cold Lab.

Production of Radioisotopes

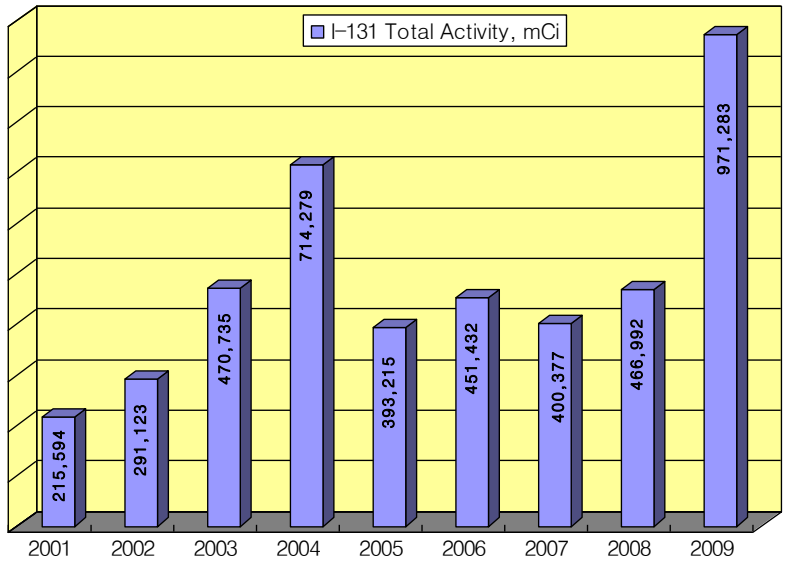
Development Status of RIs from HANARO

Type	Developed	Under development
Open RI	$^{99}Mo(^{99m}Tc)$ ^{131}I ^{166}Ho ^{165}Dy ^{198}Au ^{51}Cr ^{32}P ^{33}P ^{125}I ^{153}Sm, ^{186}Re	^{177}Lu ^{188}Re ^{90}Y ^{47}Sc, etc.
Sealed RI	^{192}Ir ^{60}Co ^{169}Yb	^{63}Ni ^{85}Kr ^{125}I, ^{131}Bs brachytherapy

Production of Radioisotopes

Open RI Sources : I-131

- ^{131}I for Thyroid - medical diagnosis and treatments of thyroid cancer
  - 40 - 60 Ci per Batch (week)
  - Supplied as Solutions and Capsules
  - 30 – 200 mCi capsules
  - ^{131}I MIBG for tumor diagnosis and treatment



- Year 2009
  - 971 Ci/yr, > 20 Ci/week
  - ~60% of domestic demand

Production System

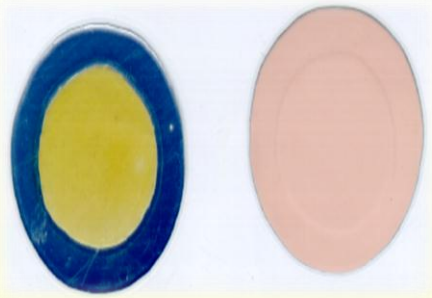
I-131 Solution

I-131 Capsule

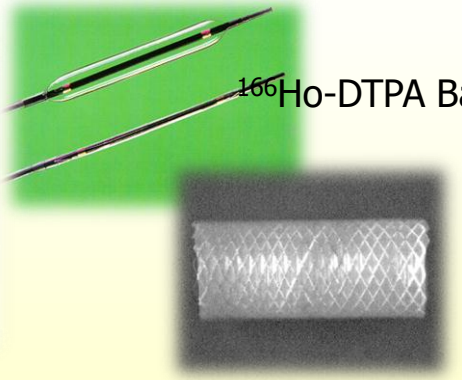
Production of Radioisotopes

Open RI Sources : ^{166}Ho based Medicines

- ^{166}Ho chitosan complex
  - for liver cancer treatment (Milican® injection)
- ^{166}Ho patch
  - for skin cancer treatment
- Other Applications
  - Malignant tumor treatments: Cystic Glioma, Peritoneal Cancer, Colon Cancer, etc.



^{166}Ho-Patch



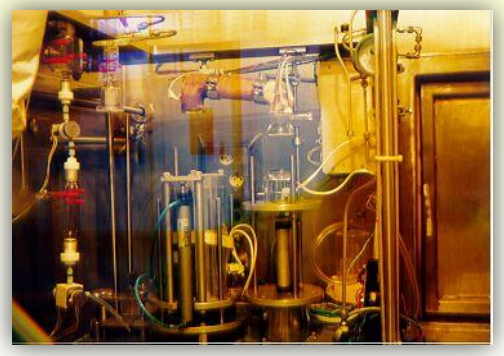
^{166}Ho-DTPA Balloon

^{166}Ho-Stent

Production of Radioisotopes

Open RI Sources : ^{51}Cr, ^{32}P, ^{51}Cr

- ^{51}Cr
  - High Specific Activity (> 200 Ci/g Cr) using Enriched Target
  - ^{51}Cr-EDTA
- ^{32}P
  - Reduced Pressure Sublimation Method
  - Production Capacity : ~30 Ci/batch
- ^{125}I
  - For RIA Kits and Seeds
  - Target : Enriched 124Xe
  - Production Capacity : 3~5 Ci/batch
  - Spec. Activity : > 17.5 Ci/mg I
  - $^{126}I/^{125}I$: < 4.3×10^{-4} %



^{32}P production

^{51}Cr production

^{125}I production

Radiopharmaceutical Production

- ^{99m}Tc Cold Kits produced at KAERI

Compound	Diagnosis
Phytate	Liver
MDP	bone & metastasized tumor
DISIDA	Hepatobiliary test
DTPA	Kidney
PYP	Myocardium infraction
Sn colloid	Liver
HSA	Plasma test
MAA	Lung
ASC	Lymph system
DMSA	Kidney
HMPAO	Brain
Mebrofenin	Liver & Biliary

Production Facility and Tc-99m Generator

^{99}Mo/^{99m}Tc generator

Production Facility for Tc-99m Generator

Tc-99m Solvent Extraction Unit

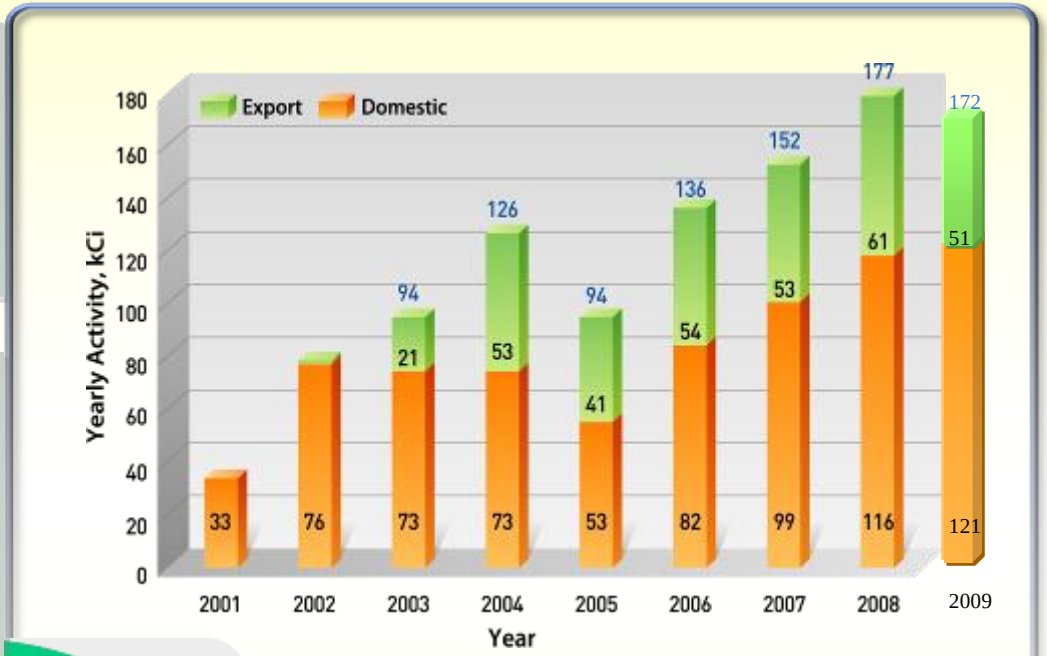
Sealed Source ^{192}Ir for Industrial Applications

^{192}Ir & Production System

- Activity : ~ 110 Ci/source
- Special Form Radioactive Material
- Production Capacity : 400 kCi/yr

Year 2009

- 172 kCi of source produced
- ~90% of domestic demand
- ~35% of production for export



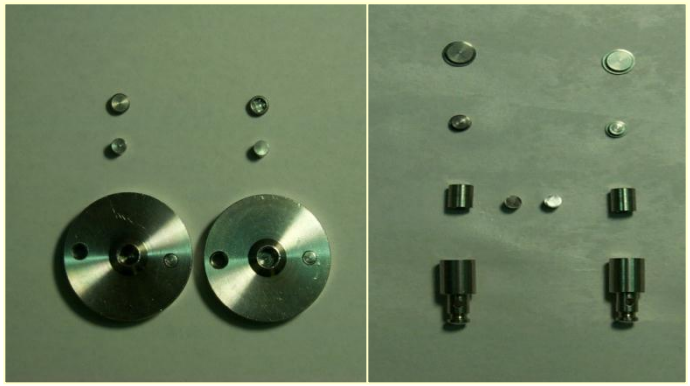
Ir-192 NDT Source

Production System

Sealed Source

^{60}Co for Industrial Applications

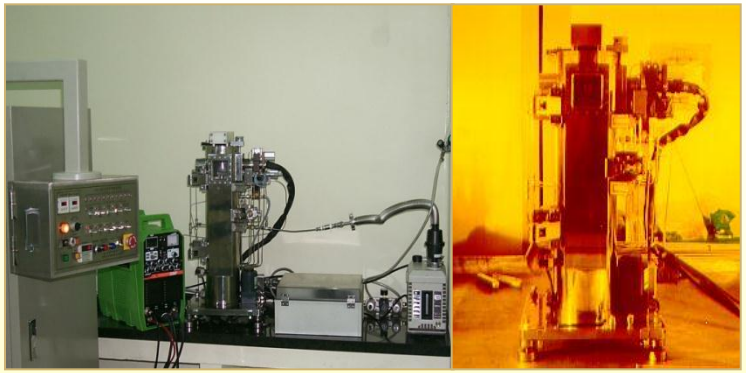
- ^{60}Co Sealed Source for Gauge
  - Dimension: Φ3.0mm x t.3.0mm
  - Activity: 0.1 ~ 1000mCi
  - Commercialized



^{60}Co sealed sources for gauge

- ^{60}Co Sealed Source for Food Irradiation

^{60}Co large scale source and its assembly

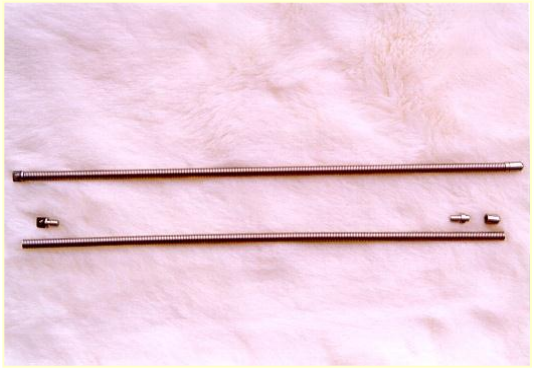


Source production system

Sealed Source

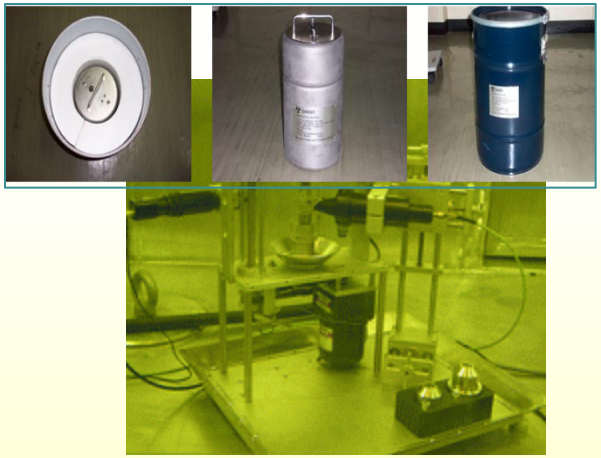
^{192}Ir for Medical Applications

^{192}Ir HDR Source, ϕ 1.1 mm



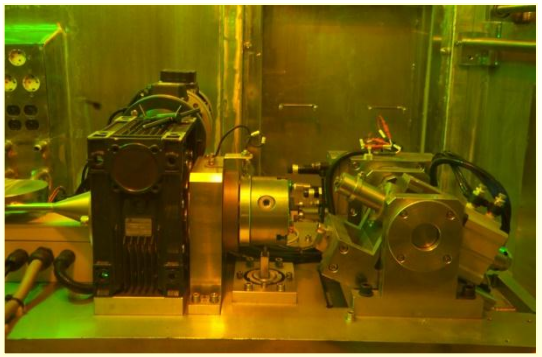
^{192}Ir HDR Source, ϕ 4.0 mm

^{192}Ir HDR Source, ϕ 3.0 mm



^{192}Ir HDR Source Fabrication System, transport cask

Welding System for ^{192}Ir HDR Source

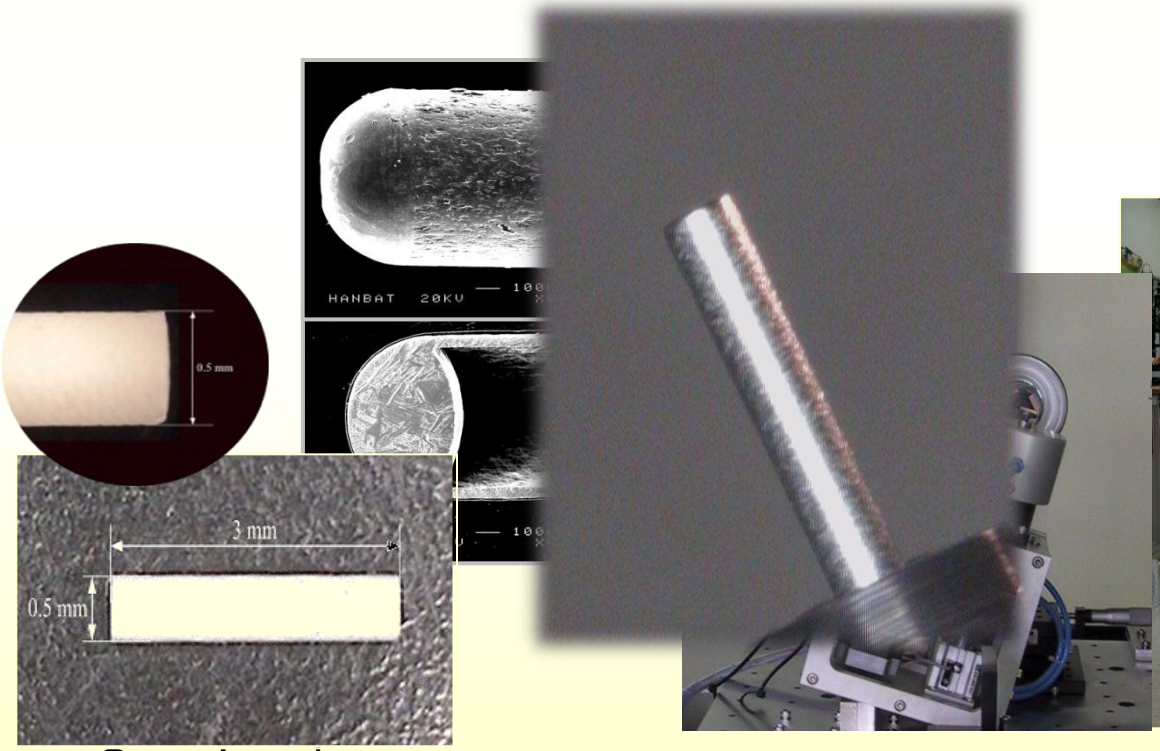


Fabrication System with Pressing machine

Sealed Source

^{125}I seed for Brachytherapy-Under Development

- Fabrication of ^{125}I seed using laser welding technique
- Development of adsorption process using ceramic rod



Ceramic rod

Fabrication System for ^{125}I seed

Supply Process for Radioisotopes at KAERI

Process I

I-131, Ho-166, etc

KAERI: RI Production, Final Products → Consignment Agent: Transport & Sales → Users

Process II

Ir-192 , Co-60 Sealed Source

KAERI: RI Production → Private Company: Final Products, Transport & Sales → Users (Export)

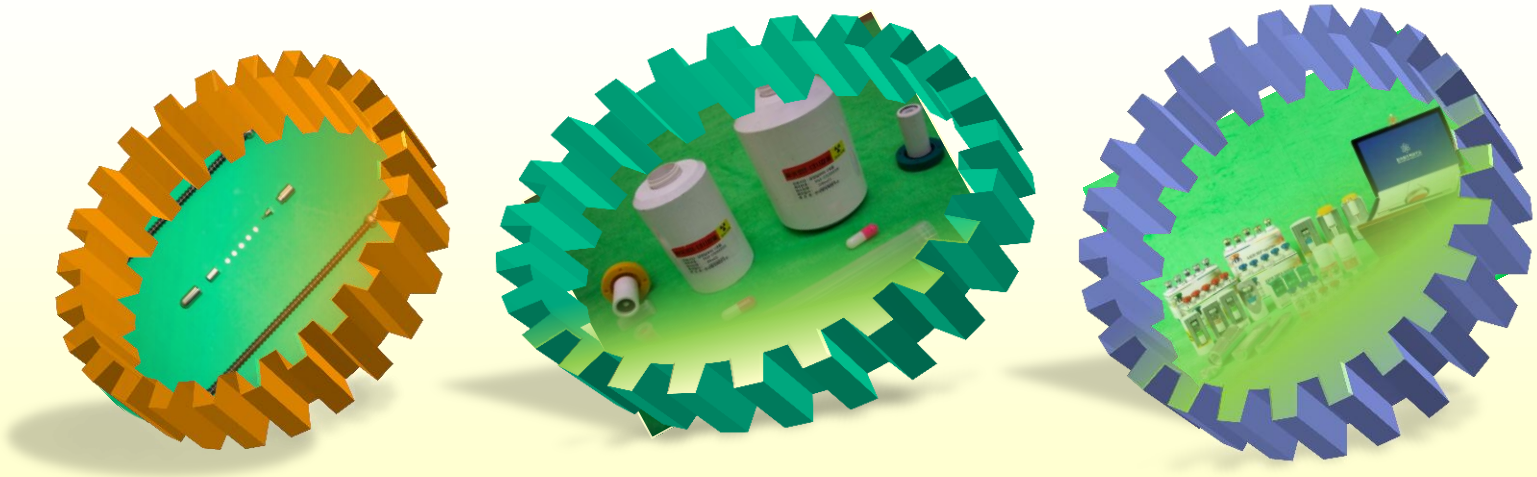
Process III

Tc-99m Generator

Private Company: Final Products → Consignment Agent: Transport & Sales → Users(Export)

Commercial Supply in 2009 (2009)

Nuclides	Activities (Ci)	Market Share(%)
^{192}Ir(NDT)	121,446	90
	51,788	Exported
^{131}I	978	60
^{60}Co	4.3	
^{198}Au	4.9	Exported



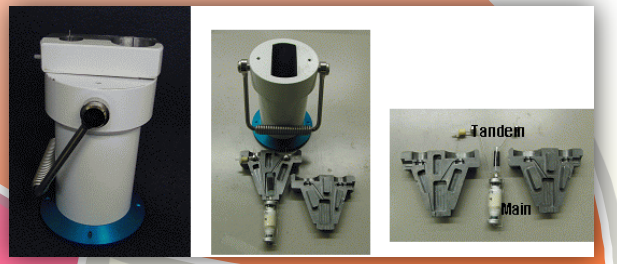
R&D Activities

- Production Technologies for Therapeutic RIs
- RI Generators for Treatments
- Sealed Sources for Instruments and Brachytherapy
- (n, γ)^{99}Mo Generator

RI Production

^{188}W/^{188}Re, ^{90}Sr/^{90}Y Generator

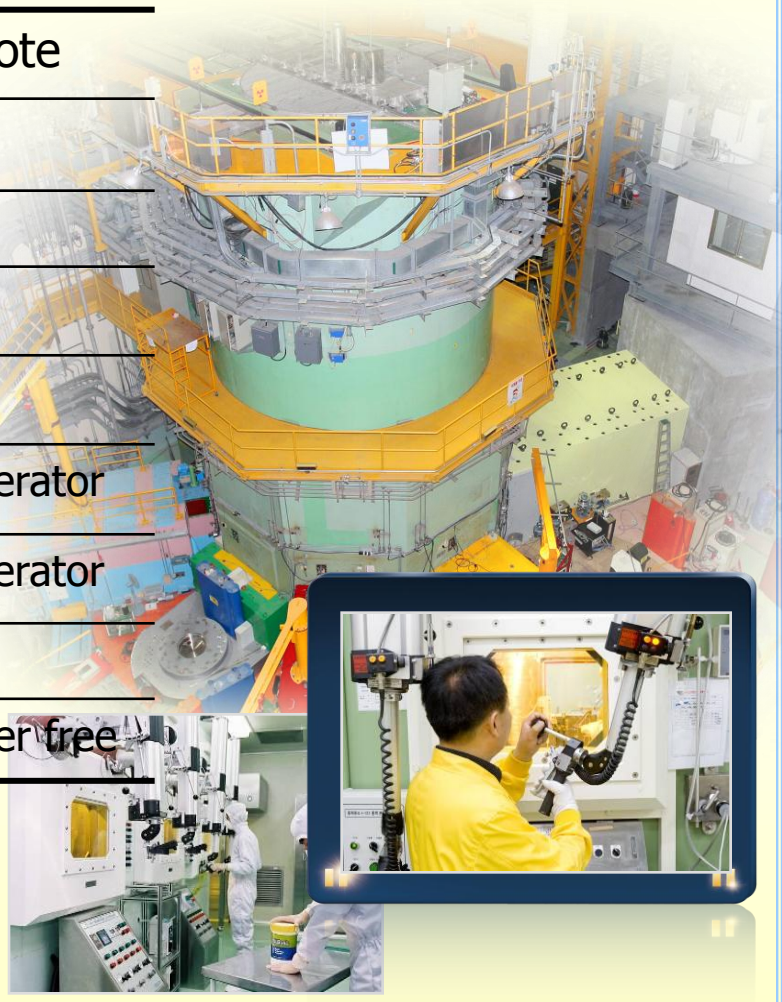
^{99}Mo/^{99m}Tc Generator



Beta-Emitting (^{90}Sr, ^{32}P) Gauge/Brachytherapy Source

Therapeutic RIs at KAERI

Radionuclide	Status	Note
I-131	Commercial Supply	
Ho-166	Commercial Supply	
Sm-153	Supply for Research	
Re-186	Supply for Research	
Re-188	Ready to Supply for Research	Generator
Y-90	Under Development	Generator
Lu-177	Supply for Research	
	Under Development	Carrier free

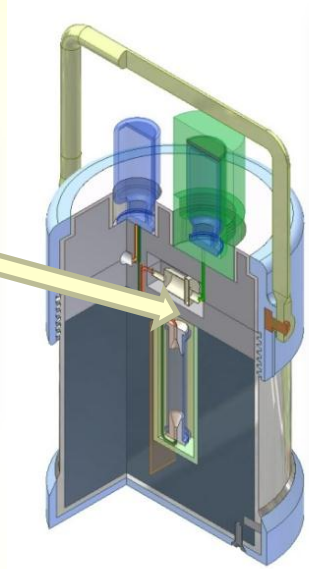


R&D Activities

^{188}Re Generator

Only 0.7g for 1Ci/
Up to 550mg W/g

Size comparison between KAERI column and a foreign column



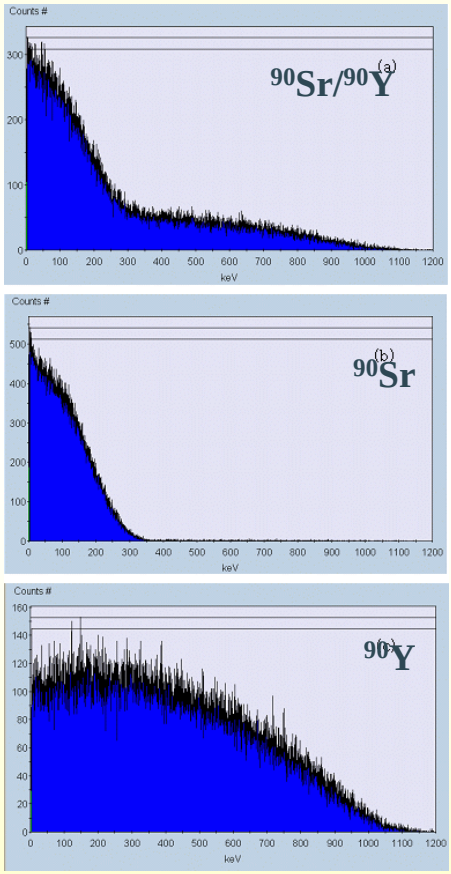
KAERI's ^{188}W/^{188}Re Generator

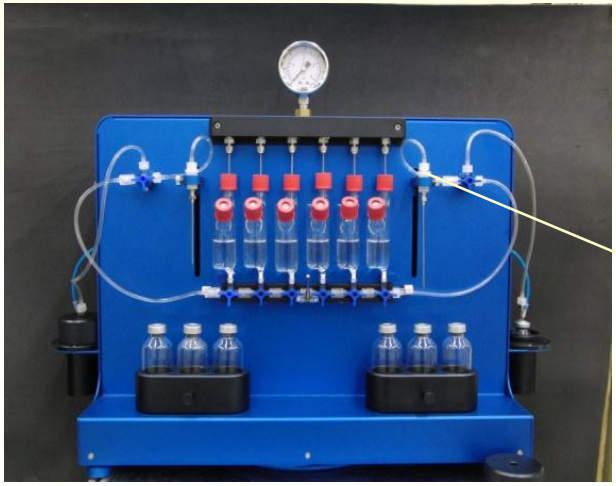
Comparison of Generator Specification

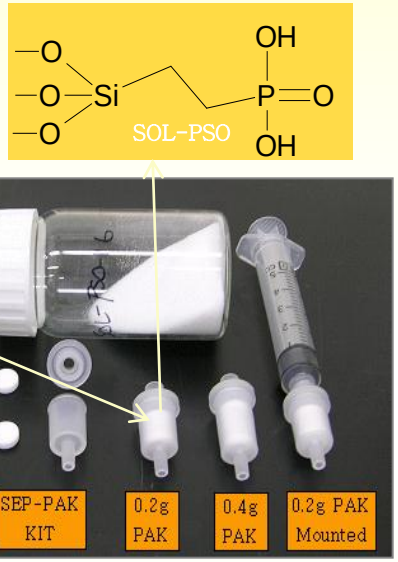
Country / Org.	Capacity (mCi)	Elution, % (Vol, ml)	^{188}W/^{188}Re, %	$^{188}ReO_4^-$, %
A	500~1,000	75~80 (10~20 ml)	5×10^{-4}	N.A.
B	50~1,000	≥80 (N.A.)	10^{-3}~10^{-4}	> 99
C	100~500	90~95 (8 ml)	0.5 (?)	> 98
Korea / KAERI*	1,000	≥80 (≤5 ml)	10^{-3}~10^{-4}	~ 100

*Demonstrated by a Real Scale Experiment (1Ci), ^{188}W from RIAR, Russia

^{188}Y Generator System



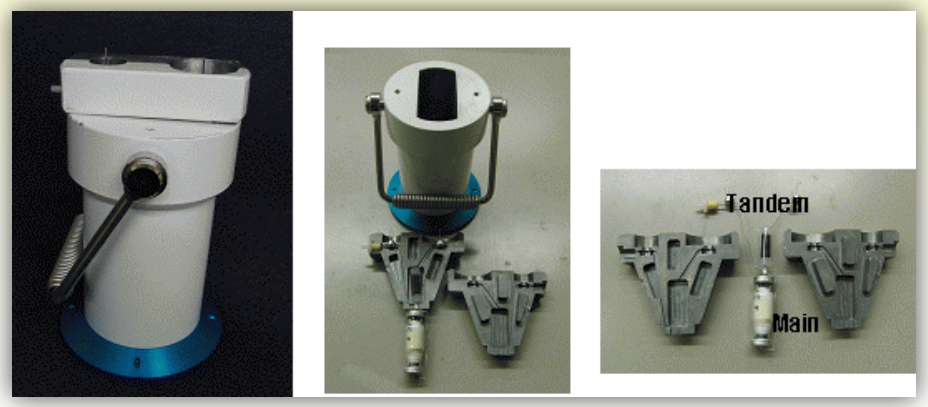




2 Column Pilot System(~70 % ^{90}Y Recovery)

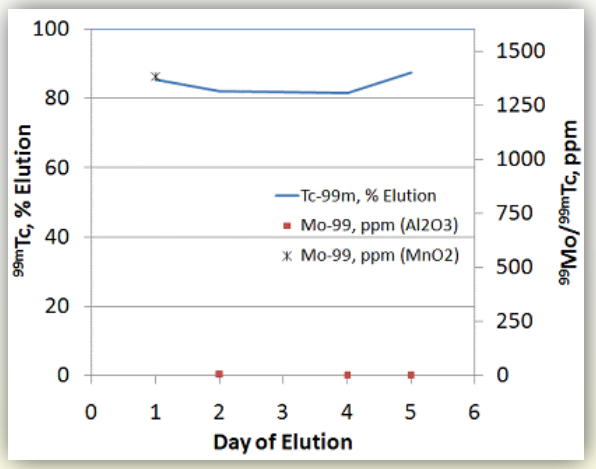
Producer	^{90}Y Purity (^{90}Sr/^{90}Y)
MDS Nordion	< 2 x10^{-6}
Perkin Elmer	< 2 x10^{-6}
CIS International	< 2 x10^{-6}
KAERI	10^{-10} ~ 10^{-11}

$(n,\gamma)^{99}Mo/^{99m}Tc$ generator



Test Model and Column Module

Column Module
- Main : 4g of ALSUL
- Tandem : 1.5g of Al_2O_3



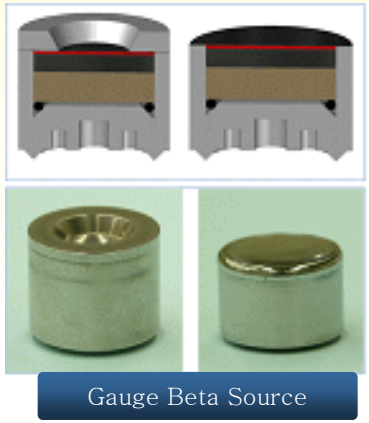
100mCi Experiment
- Purity: Meet FDA Standard

Generators with $(n,\gamma)^{99}Mo$ Produced at HANARO		
Irr. Hole / Mo Target	OR3	IP15
Natural	0.7 Ci	0.3 Ci
Enriched (98%)	2.0 Ci	1.0 Ci

^{99m}Tc Ci activities in 6 day reference

Sealed Source

Gauge & Brachytherapy Beta Sources



Gauge Beta Source

Test Sample

Gauge Beta Sources

Brachytherapy Beta Sources

Small-focal γ-ray source for radiography

- ^{192}Ir small-focal source
  - Activity : > 7 Ci/source
  - Dimension : D 1.5 X L 0.5 mm

Production Plan of Co-60 for Irradiator

Production Chain

- 4 PHWR type of power plants have been operating
- KAERI has concrete cells & storage pool for Co-60 production
- Maximum 11 MCi of Co-60 could be produced (20% of global demand)

PHWR reactor

Processing Facility

Production Plan

- Feasibility study : ~ Dec. 2010
- Modification of Reactors & Facility : Jan. 2011 ~ May. 2013
- First Production : Aug. 2014 ~

International Cooperation Activities

3 units for each since 2007

^{99m}Tc Extraction System

Export

^{192}Ir NDT Assembly System

^{131}I Dispensing System

Conclusion

- KAERI have made a great effort to develop high quality radioisotope products and the relevant mass production technologies.
  - A large portion of radioisotopes could be produced domestically and even exported to other countries
- RI's for Therapeutic and Research Purpose will be introduced to the Market.
  - Specially, research progress on carrier-free Ris and generators are getting breakthrough
- Feasibility project is on-going to construct a new research reactor
  - To meet the increasing needs for medical applications
  - To become the central supplier in the Asia region.
  - International cooperation of the below-mentioned areas exchange of information
    - Production of Fission Mo-99 by Using LEU and Design Requirements for the Facility
    - Therapeutic RI Production and Applications


Thank you !