

Enriched Stable Isotopes and Technical Services at ORNL



Nuclear Science and
Technology Division

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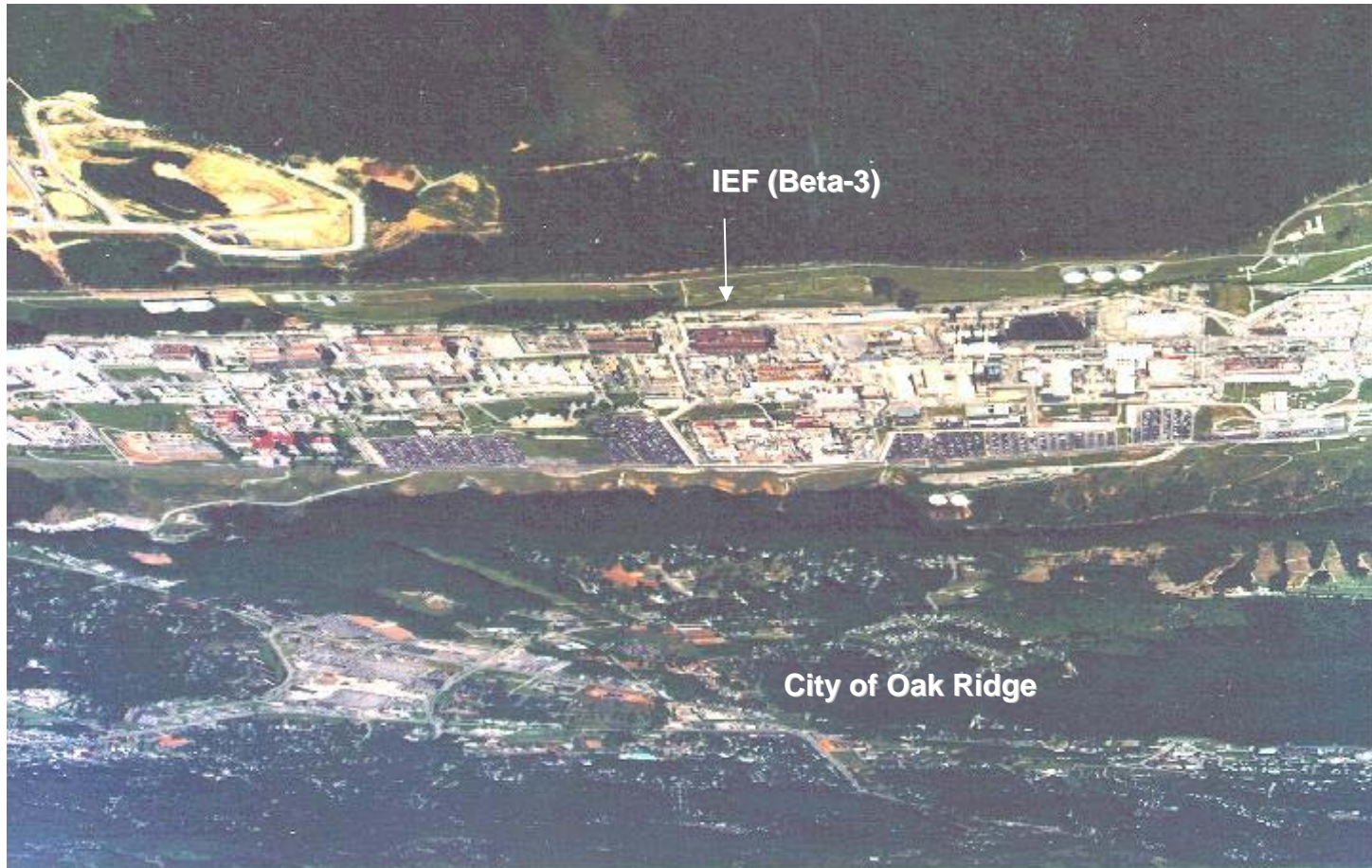
Isotope Development Group Activities

- **Calutrons**
 - Calutron operations, engineering, maintenance
 - Stable isotope enrichment not currently active
- **Products and Services**
 - Chemistry laboratories
 - Isotope Research Materials Laboratory
 - Stable isotope packaging and shipping
- **Nuclear Medicine Program**
 - Radioisotope development through clinical trial stages
- **Isotope Business Office (National Isotope Data Center)**
 - Administers contracts, sales, leases, and shipping of all ORNL, BNL, LANL, Y-12, PNNL and SRNL stable and radioactive isotopes for the DOE Isotope Program
- **Production and distribution of enriched stable isotopes which is ISO 9001 registered through Underwriters Laboratories, Inc.**
- **National security (nuclear nonproliferation) training**
- **Technical support to other R&D projects (ORELA, USEC, DHS, DOE-NNSA, etc.)**

What Is An Isotope And Why Enrich Them?

- **Atoms of the same chemical element with same number of protons in the nucleus, similar chemical behavior**
- **Different number of neutrons in the nucleus, very different nuclear behavior**
- **Mass difference (neutrons) used to separate the isotopes from their natural mixture**
- **Natural U is 0.01% U-234, 0.71% U-235, and 99.28% U-238**
- **U-235 is fissionable and used in weapons and nuclear fuel**
- **U-238 is fertile and used to make Pu-239 and as shielding and projectiles**
- **Isotopes must often be enriched to enhance desired properties or avoid undesirable properties**
- **Calutrons (*U* of *Cal*-ifornia *Cyclo*-trons) produced first large-scale quantities of U-235 but were replaced by gaseous diffusion**
- **Stable isotope production started in November 1945**

Y-12 National Security Complex Aerial View



Y-12 Production Calutrons - 1945

	Alpha - I	Alpha – II	Beta	Total
Buildings	3	2	4	9
Tracks	5	4	8	17
Calutrons/Track	96	96	36	-
Total Calutrons	480	384	288	1,152
Beam Radii (feet)	4	4	2	-
Beams per tank	2	4	2	-
Total Ion Beams	960	1,536	576	3,072

Pilot Plant: 2 Alpha-II and 2 Beta calutrons

Isotope Enrichment Facility



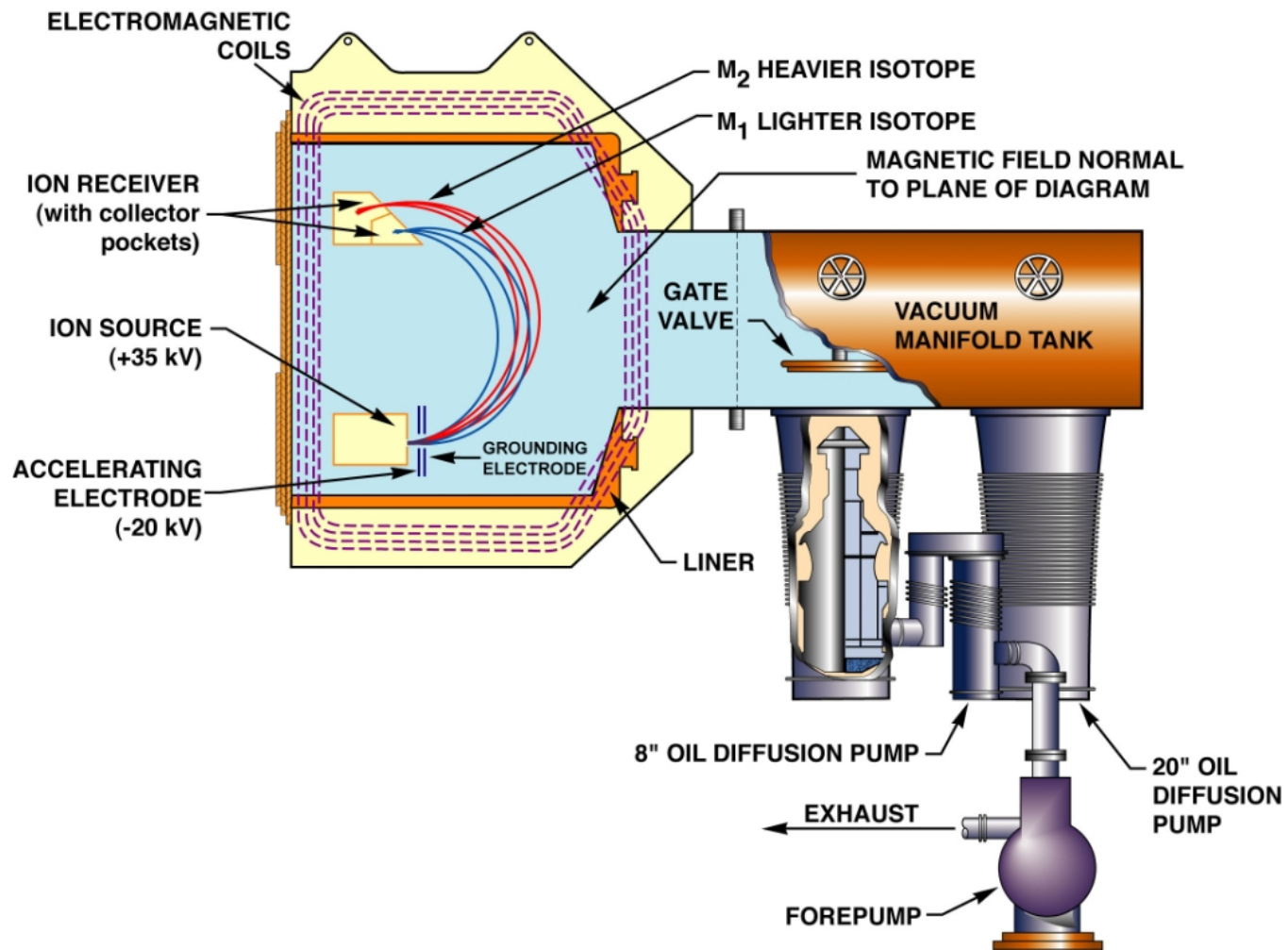
Isotope Enrichment Facility

- **Built in 1943 for U-235 enrichment (1 of 9 buildings)**
- **Second-pass for enrichment from 12-15% U-235 to greater than 90% for weapons use**
- **Top-off U-235 from early gaseous diffusion process**
- **IEF converted to stable and actinide isotope enrichment in the 1950s and early 1960s**
- **One of 2 production-scale calutron facilities in the world (other in Russia)**
- **Approximately 5 acres of floor space**
- **All stable isotope activities consolidated in the IEF in early 1990s (co-location resulted in ~40% savings), since moved to ORNL**
- **Originally staffed by 2,000 people, modern operations by a staff of 45 on a 3-shift/5-day rotating schedule (in operable stand-by since 1998)**
- **Enriched approximately 252 isotopes of about 58 elements**
- **One of 8 “Signature Facilities” of the Manhattan Project**
- **ANS Nuclear Historic Landmark**
- **DOE-NE requested and received an estimate (~\$17M) to reestablish a smaller production-scale electromagnetic isotope enrichment capability at ORNL in February 2008**

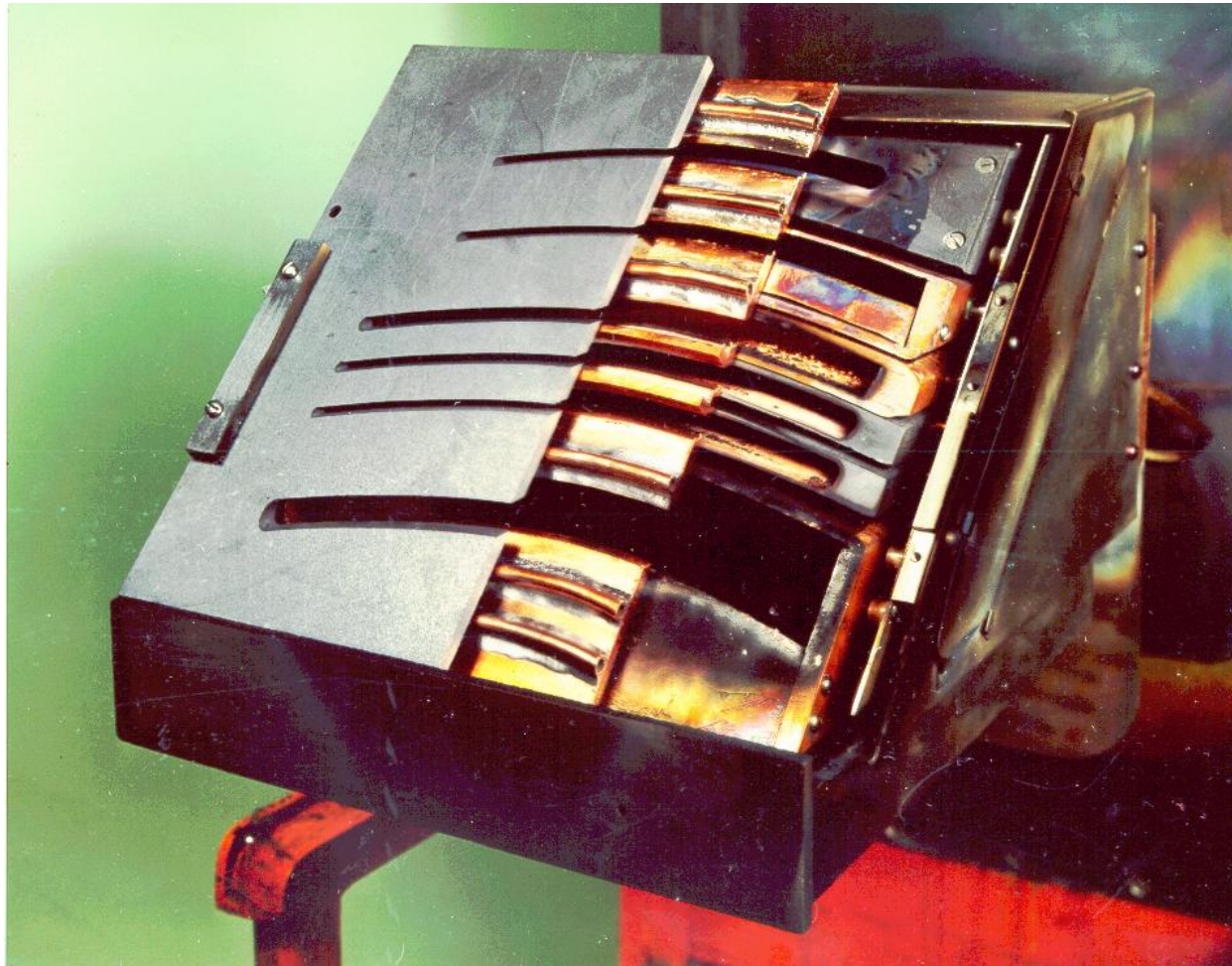
Isotope Enrichment Facility Calutrons



Schematic of a Calutron



Calcium Isotope Receiver



Examples of Stable Isotope Products and Applications

- **Approximately 233 stable isotopes for multi-disciplinary research**
- **Rb-87 (naturally occurring radioisotope) used as a timing standard or atomic clock in ge positioning systems, cellular telephone applications, etc.**
- **Tl-203 for production of Tl-201 for cardiac imaging**
- **Cd-112 for production of In-111 for cancer detection and monitoring, kidney function assessment**
- **Zn-68 for production of Ga-67 for detection of abscesses, active inflammation, and cancer**
- **W-186 for production of W-188/Re-188 generators for cancer diagnostics and treatment**
- **Sr-88 for production of Sr-89 for bone cancer treatment**
- **Mo-98 for Mo-99/Tc-99m production— major medical isotope, concentration process licensed to a private industry**
- **Ni-62 for Ni-63 production – explosives detection, power sources**
- **Lu-176 for HSA Lu-177 production – medical applications**
- **Many medical radioisotopes start from a stable isotope precursor**

WW-II Era Control Room

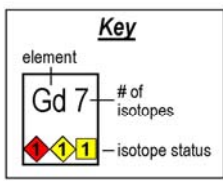


Current Control Room



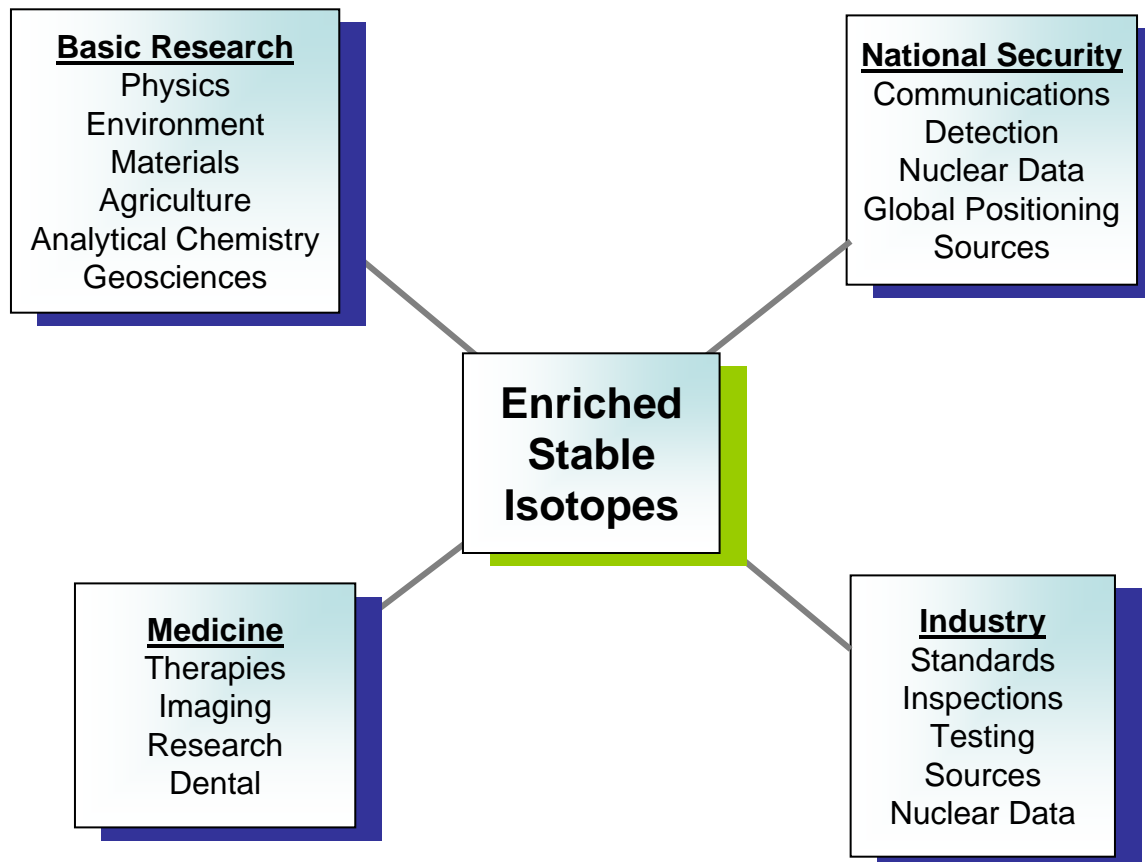
Isotopes Enriched by the Calutrons

Group IA												Inert Gases						
H																He		
Li 2	Be																	
Na	Mg 3																	
		III B	IV B	VB	VIB	VII B	VIII		IB	II B	III A	IV A	VA	VIA	VII A			
K 3	Ca 6	Sc	Ti 5	V 2	Cr 4	Mn	Fe 4	Co	Ni 5	Cu 2	Zn 5	Ga 2	Ge 5	As	Se 6	Br 2	Kr	
Rb 2	Sr 4	Y	Zr 5	Nb	Mo 7	Tc	Ru 7	Rh	Pd 6	Ag 2	Cd 8	In 2	Sn 10	Sb 2	Te 8	I	Xe	
Cs	Ba 7	La 2	Hf 6	Ta 2	W 5	Re 2	Os 7	Ir 2	Pt 6	Au	Hg 7	Tl 2	Pb 4	Bi	Po	At	Rn	
Fr	Ra	Ac																
			Ce 4	Pr	Nd 7	Pm	Sm 7	Eu 2	Gd 7	Tb	Dy 7	Ho	Er 6	Tm	Yb 7	Lu 2		
			Th 2	Pa	U 5	Np	Pu 6	Am 2	Cm 4	Bk	Cf	Es	Fm	Md	No	Lr		

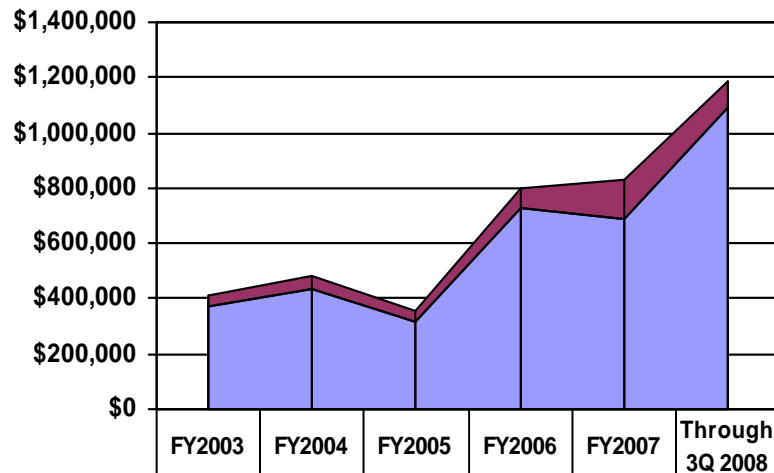


- Elements separated in Calutrons and number of isotopes collected
- Elements not separated in Calutrons
- Stable elements with no naturally occurring stable isotopes
- Number of isotopes currently sold-out
- ◆ Number of isotopes sold-out, second pass high enrichment
- Number of isotopes with <20 year supply
- ◆ Number of isotopes with <20 year supply, second pass high enrichment

Stable Isotopes are Used in Many Fields Either Directly or as Precursors to Radioisotopes

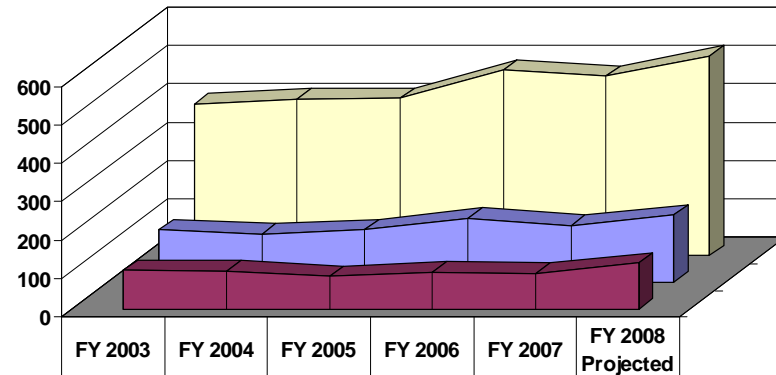


Stable Isotope Sales and Customers Vary Greatly



Sales can be highly variable and unpredictable with large contracts or single isotope sales taking total sales as high as \$2-9M/year

A wide variety of customers are served around the world; some single orders are for as many as 40-50 different isotopes



Unique Customers	101	98	84	96	93	120
Number of Technical Services	137	125	137	168	148	175
Number of Isotope Sales	396	409	410	484	468	521

Over the Years, Custom Products and Services Have Been Provided by the IDG for Most Elements and Their Respective Isotopes

Period ▼	Group IA																Inert Gases	
1	H											III A	IV A	V A	VI A	VII A	He	
2	Li	II A										B	C	N	O	F	Ne	
3	Na	Mg										Al	Si	P	S	Cl	Ar	
			III B	IV B	V B	VI B	VII B	VIII			I B	II B						
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La *	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac *															
			6 *	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			7 *	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

IEF Chemistry Laboratory

- **Development and preparation of feed materials for calutrons**
- **Recovery and purification of enriched stable isotopes**
- **Custom chemical conversion services**
 - **Wet chemistry for alternate compound synthesis**
 - **Hydrogen reduction of some metals**
 - **Selected pyrochemical reductions**
- **Recovery and purification of leased isotopes upon return to ORNL**
- **Technical support to other ORNL, DOE, and private programs**

Isotope Research Materials Laboratory

- **Pyrochemical metal conversions**
 - Reduction/distillation of Group IIA and selected rare earths
 - Calcium reduction on selected rare earth fluorides
 - Planned restoration of crystal bar reduction of Si, Ti, Zr, and Hf
- **Custom physical form processing services**
 - Metallurgical processing
 - Ceramic processing
 - High vacuum processing – thin films and coatings
- **Maintenance and distribution of a significant inventory of isotopes in metal form**
- **Technical support to other ORNL, DOE, and private programs**

Specific Chemical and Materials Processing Methods

CURRENT CAPABILITIES INCLUDE:

Inorganic chemical conversions

Arc melting and alloying

Arc melting and drop casting

Wire rolling

Metal and ceramic powder consolidation

Metal and ceramic hot-pressing

High-vacuum evaporation to produce thin films and coatings

Plasma sputtering to produce thin films and coatings

Pyrochemical conversions

Hot and cold rolling of metal foils

Crucible melting and casting

Wire swaging and drawing

Vanadium-encapsulated neutron dosimeters

CAPABILITIES CURRENTLY BEING RESTORED INCLUDE:

Ion beam sputtering to produce thin films and coatings (testing stage)

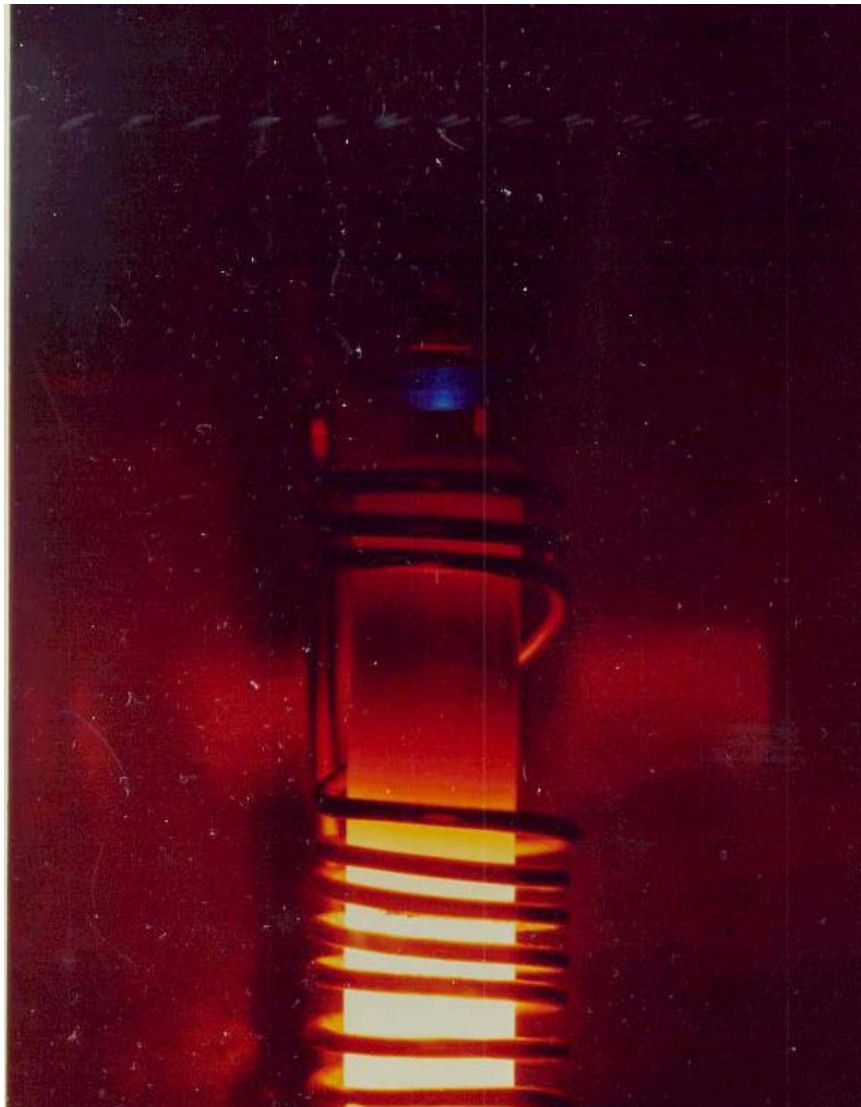
Crystal bar reduction processing (final component procurement stage)

Scanning electron microscopy/x-ray energy spectroscopy (procurement stage)

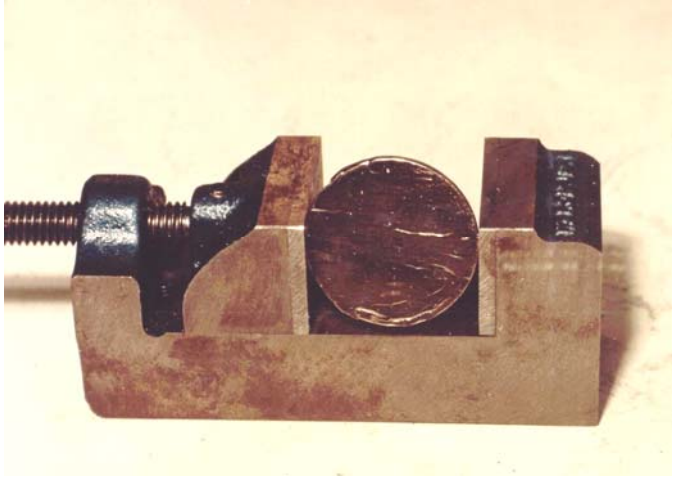
Pyrochemical Reduction/Distillation Is Used to Prepare a Wide Variety of High-purity Metals



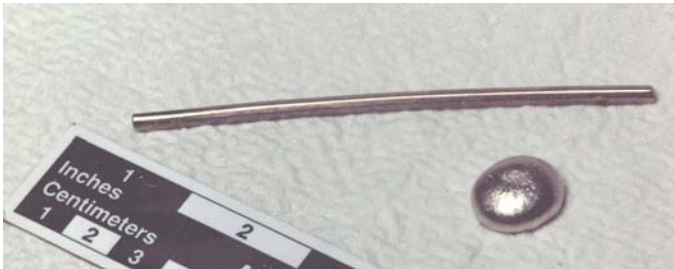
Magnesium Beads Grown Inside Still
by Reduction/Distillation



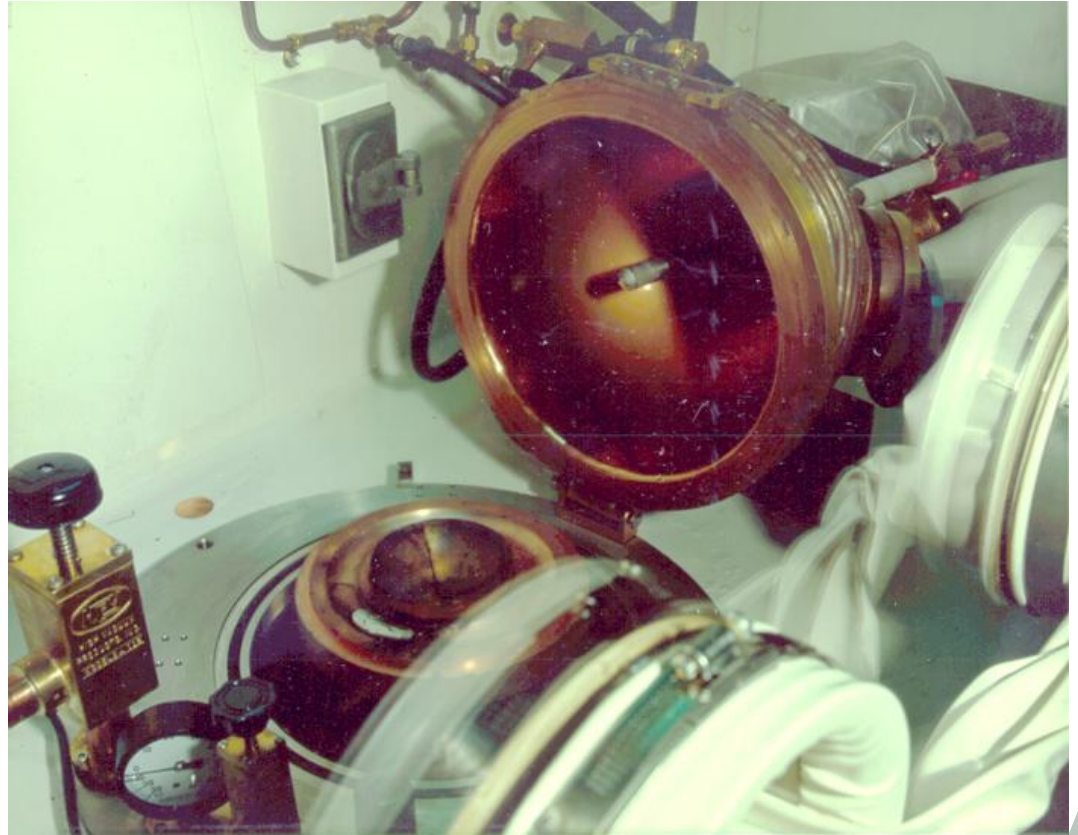
Arc Melter Used for Melting and Casting



Plutonium "Silver Dollar"



Enriched Pd-102 Button and Rod

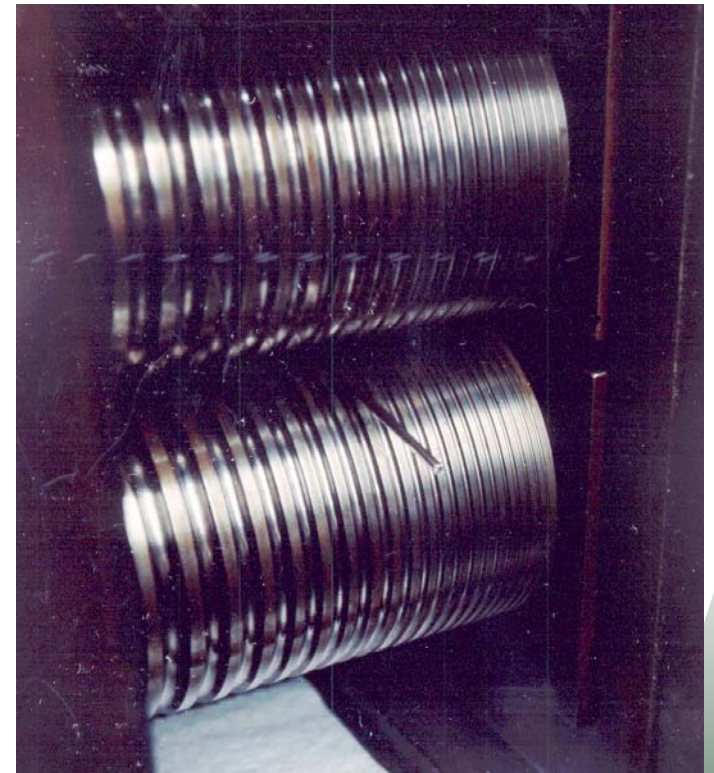


Metallurgical Processing Lab

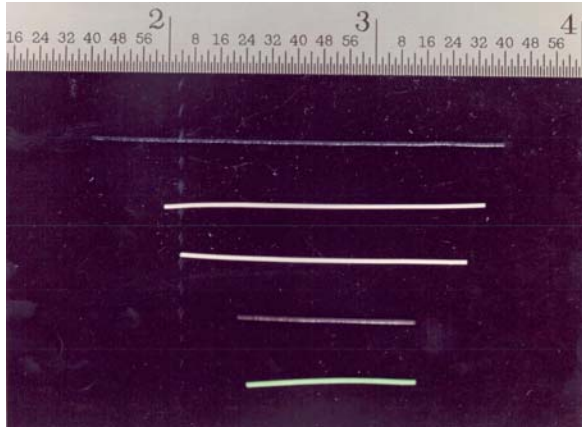


Swager, furnace, arcmelter and rolling mills

Rolling of Pd-102 Rod



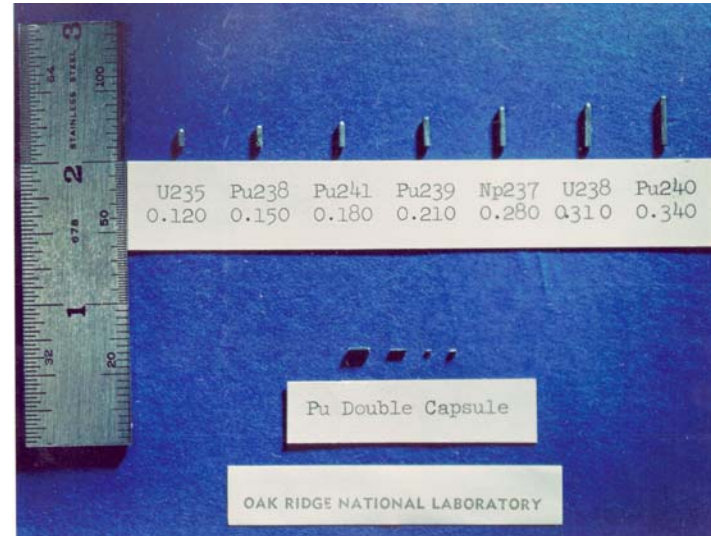
Ceramic Processing



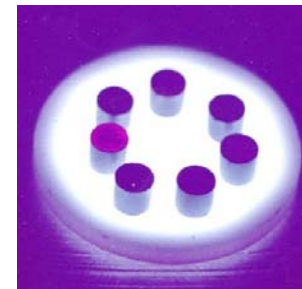
Ceramic Wires – IR 100 Award Winner



Vacuum hot
press and die



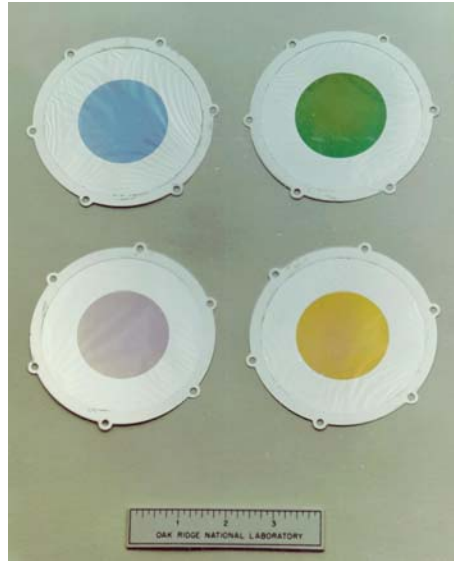
In-core Neutron Dosimeters



Hot-pressed
oxide pellets

Vacuum Coatings and Thin Films

Evaporated
U-235 Oxide
Coatings



Evaporated Aluminum Foil



Cm-248 Deposit: Accelerator target
for Element 109 Discovery

Materials Support to Other Programs

- **Thermographic phosphor coatings on jet engine turbine blades for laser-based temperature measurement**
- **Coatings to improve adiabatic diesel engine brazed joints**
- **Particle beam neutralizer foils developed for US Army/SDI**
- **Coating for ion implantation studies**
- **Coating for high-temperature diffusion barrier development**
- **Hardened radioactive source materials development**
- **Preparation of diagnostic samples for nuclear weapons program**
- **Pm-147 single crystals and glasses for laser development**
- **HFIR target material preparation**
- **Innumerable chemistry and materials technical service jobs for other programs**

Stable Isotope Packaging and Shipping

- **Maintain an inventory of over 1,600 batches of stable isotopes**
- **Dispense isotopes in inventory form (generally powders) to fill customer orders**
- **Maintain analytical certification and MSDS files**
- **Package all stable isotopes for shipment in conformance with DOT and international shipping regulations**
- **Process lease agreements for stable isotopes**
- **Dispense non-electromagnetic separated isotopes (solids and gases) transferred to ORNL from Mound Laboratory**

\$360M* Worth of Stable Isotopes

(* list price)



Dispensing Stable Isotope Products



Isotope Business Office (National Isotope Data Center)

- **Administer domestic and international contracts, quotes, sales, leases, billings , collections and shipments for the entire DOE Isotope Program: BNL, LANL, ORNL, PNNL, SRNL, Y-12**
- **Interface with hundreds of domestic and international customers**
- **Interface with Departments of Energy, Commerce, Justice, Homeland Security, and State**
- **Interface directly with DOE on a daily basis**
- **Coordinate irradiation services**
- **Ensure compliance in export control, NRC licensing and transportation**
- **Manage the Cf-252 Loan/Lease Program**