INVENTORY AND CHARACTERISTICS OF ^{233}U

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Briefing for
U.S. Department of Energy
Oak Ridge, Tennessee
March 22, 2000

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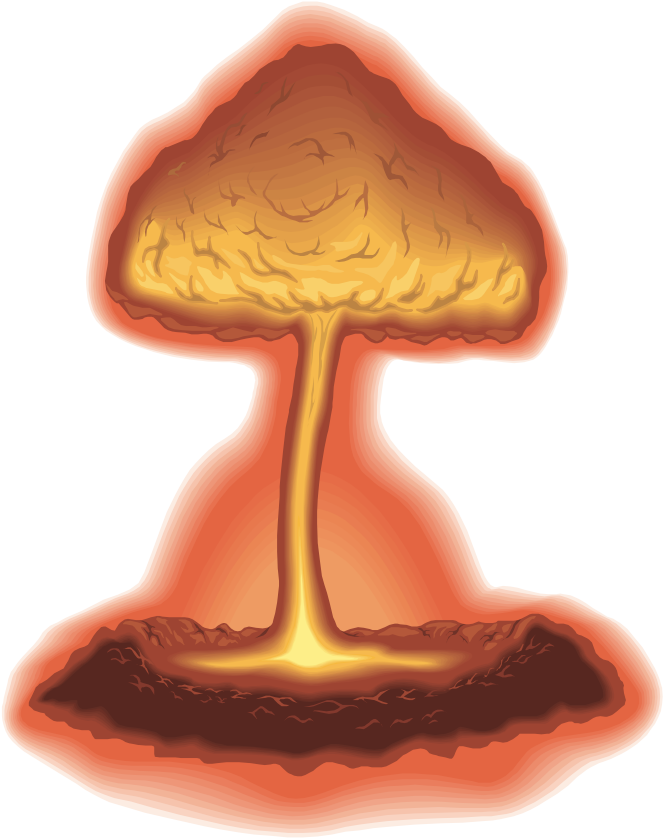
Outline

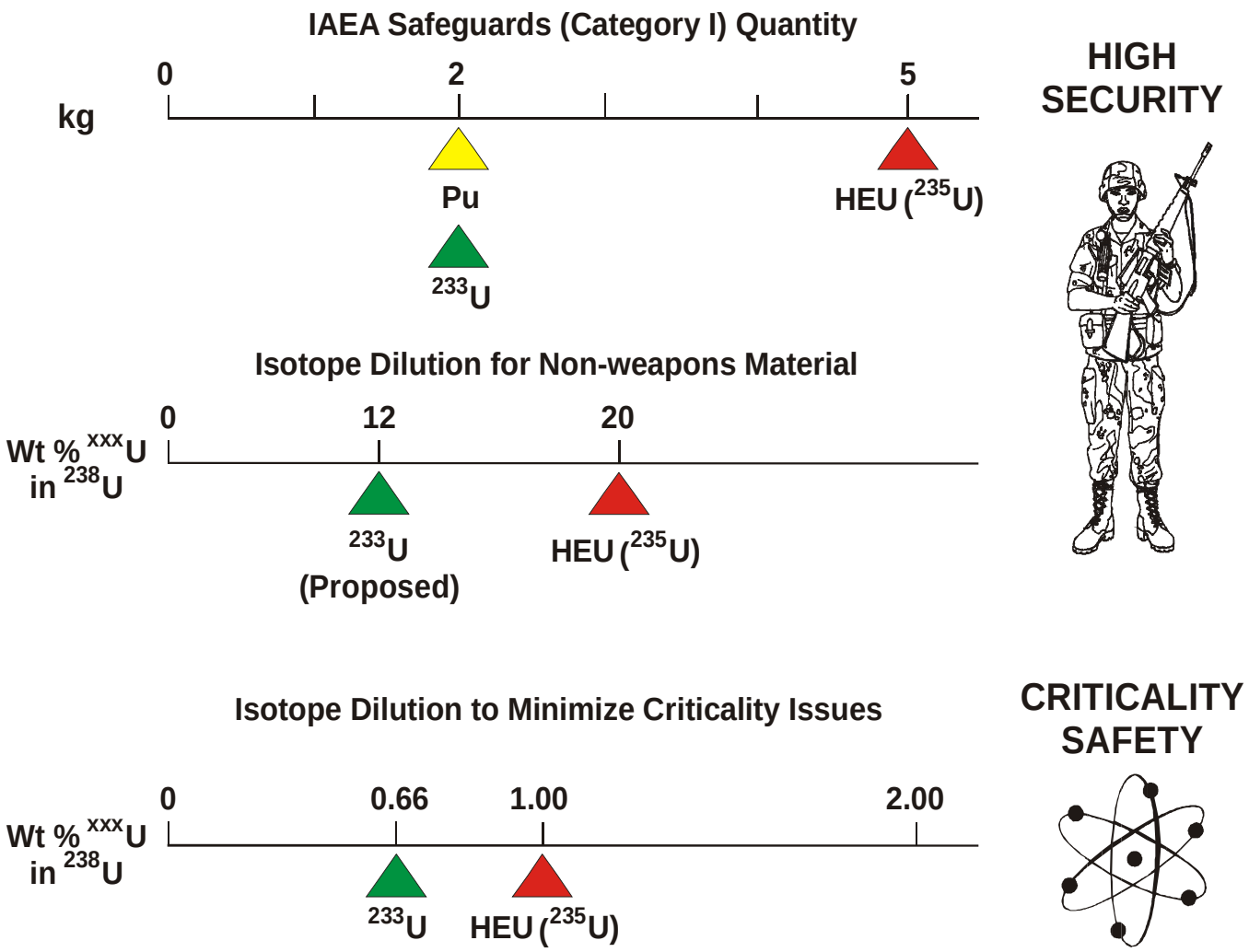
- Characteristics
- Categories
- Inventories

ORNL DWG 2000-90



Uranium-233, Like Plutonium and HEU, is a Weapons-Usable Material

ORNL DWG 2000-94

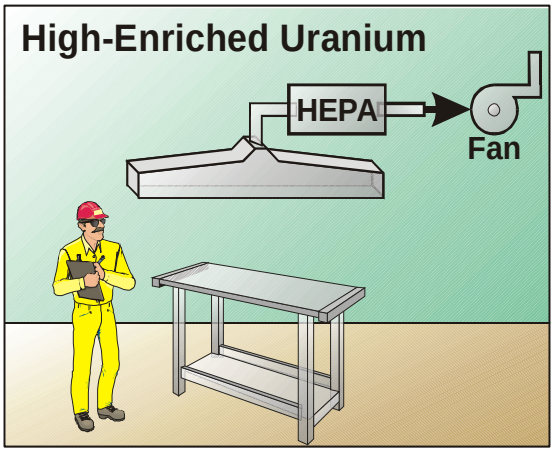


Nuclear Characteristics of Fissile Materials

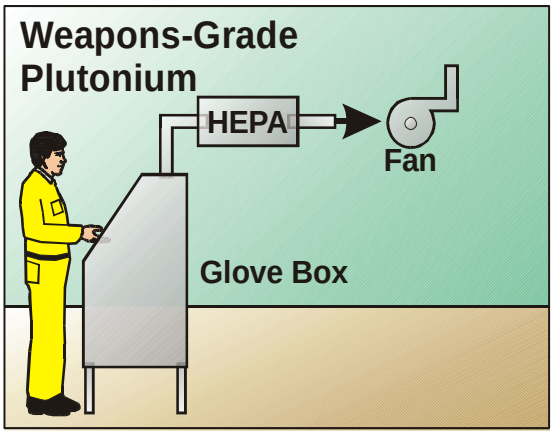
Key Characteristics Of ^{233}U

- Weapons-usable fissile material (one of three: ^{233}U, ^{235}U, and ^{239}Pu)
  - Produced by neutron irradiation of ^{232}Th
  - Produced and separated in the same facilities as those used for plutonium production
- Safeguards requirements similar to plutonium, better weapons-usable material than high-enriched uranium (HEU)
- Uranium-233 may be isotopically diluted with ^{238}U to change its nuclear properties, but the required isotopic dilution for the same effects is higher than that required for ^{235}U
  - Isotopic dilution to <12 wt % ^{233}U in ^{238}U converts it to a non-weapons-usable uranium (proposed)
  - Isotopic dilution to <0.66 wt % ^{233}U in ^{238}U minimizes criticality concerns

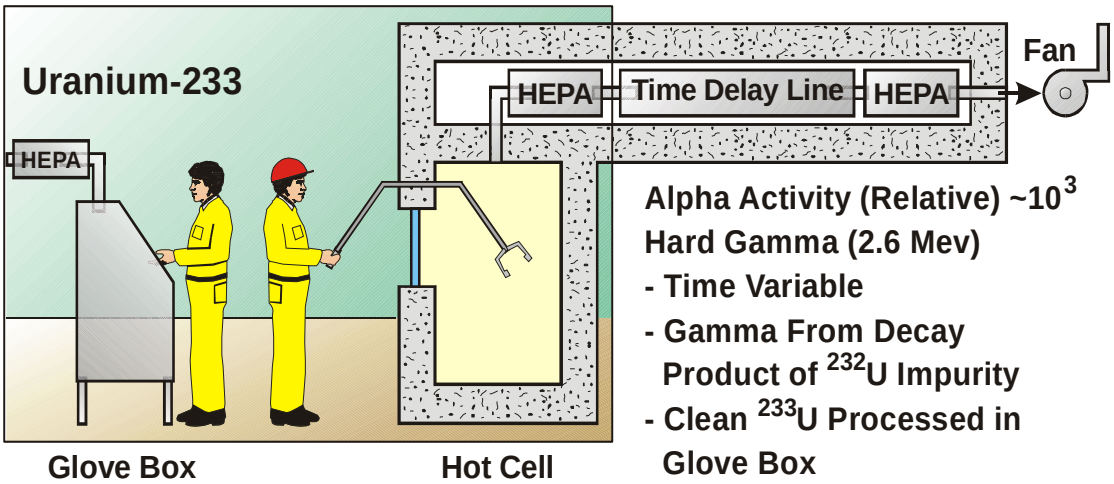
ORNL DWG 98C-488R



Alpha Activity (Relative) = 1
No Significant Gamma

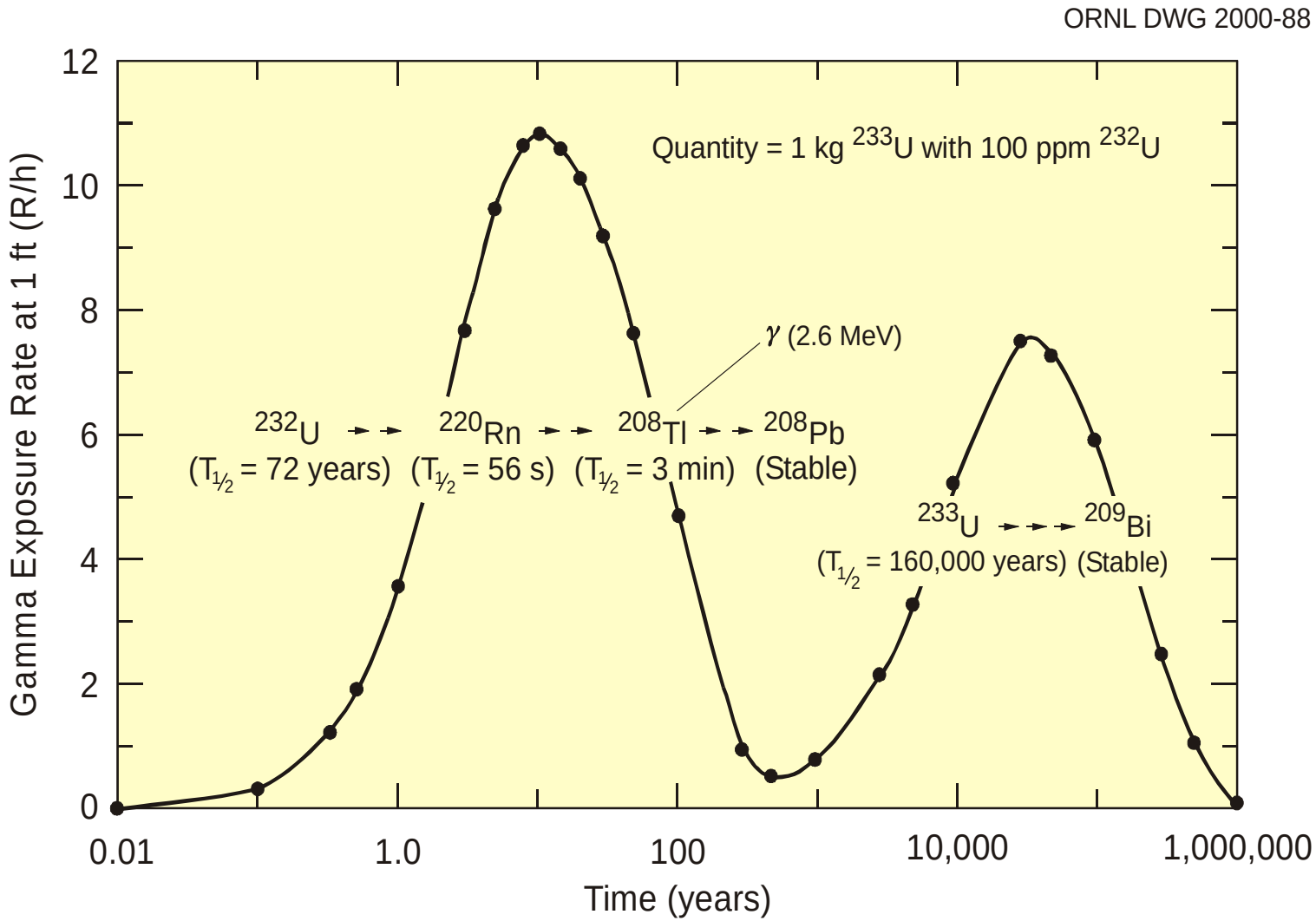


Alpha Activity (Relative) ~10^4
Soft Gamma
- Minimal Shielding
- Leaded Gloves Acceptable



Alpha Activity (Relative) ~10^3
Hard Gamma (2.6 Mev)
- Time Variable
- Gamma From Decay Product of ^{232}U Impurity
- Clean ^{233}U Processed in Glove Box

Different Fissile Materials Have Different Handling Requirements



Uranium-233 with Significant Quantities (100 ppm) of ^{232}U is a Significant Radiation Hazard

Handling Requirements For ^{233}U

- Alpha radiation hazard is similar to that of plutonium and thus requires similar handling procedures

- Uranium-233 contains varying levels of ^{232}U impurities from the production process

  - Uranium-232 ($t_{1/2}$ = 72 years) decays to ^{208}Tl

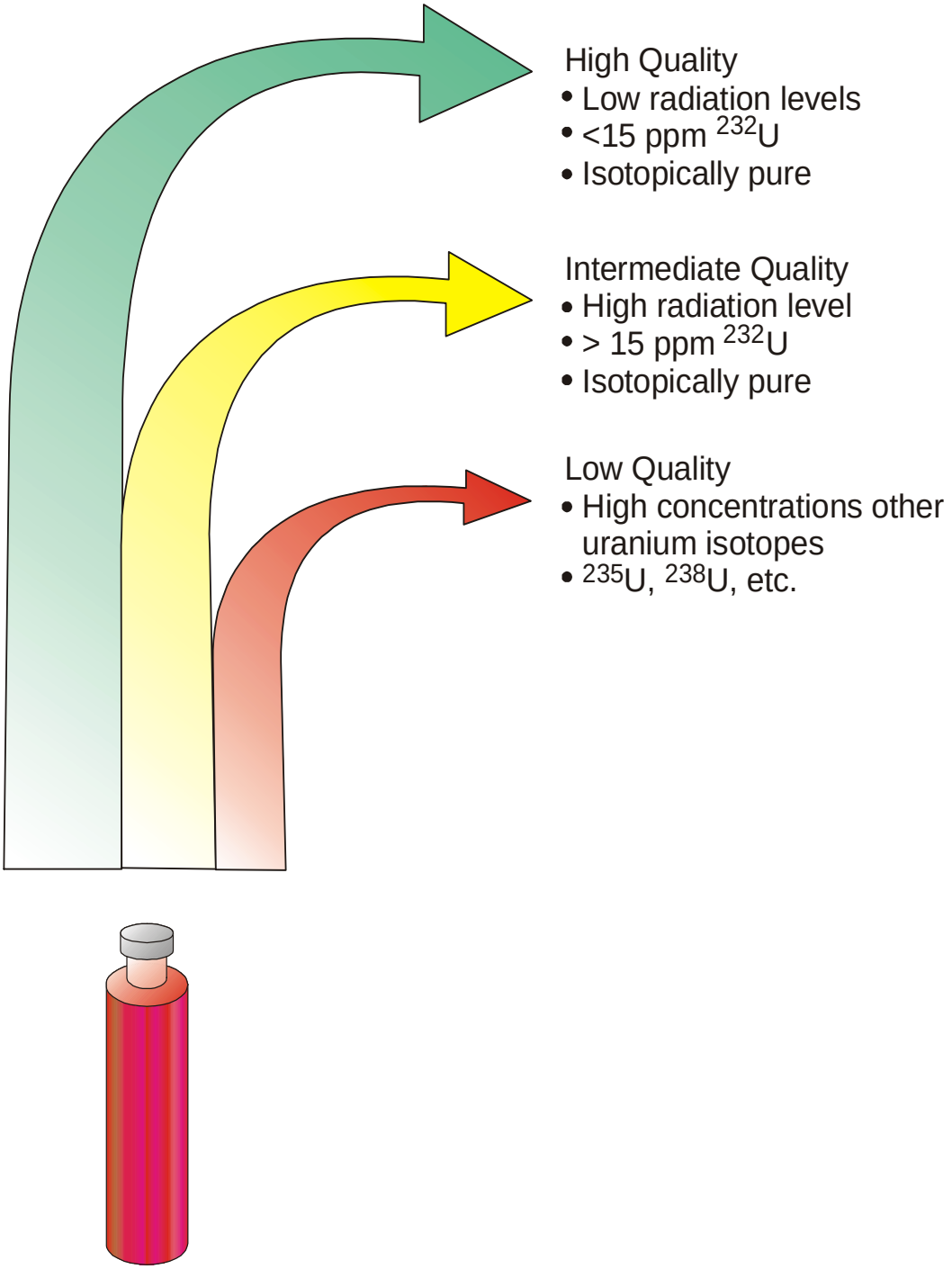
  - Thallium-208 decays, emitting high-energy (2.6 MeV) gamma rays

  - Uranium-232 content determines gamma radiation levels

  - Some ^{233}U may be handled in a shielded glovebox—depending upon (1) the ^{232}U content and (2) the time since the ^{233}U was last purified and the ^{232}U decay products were removed

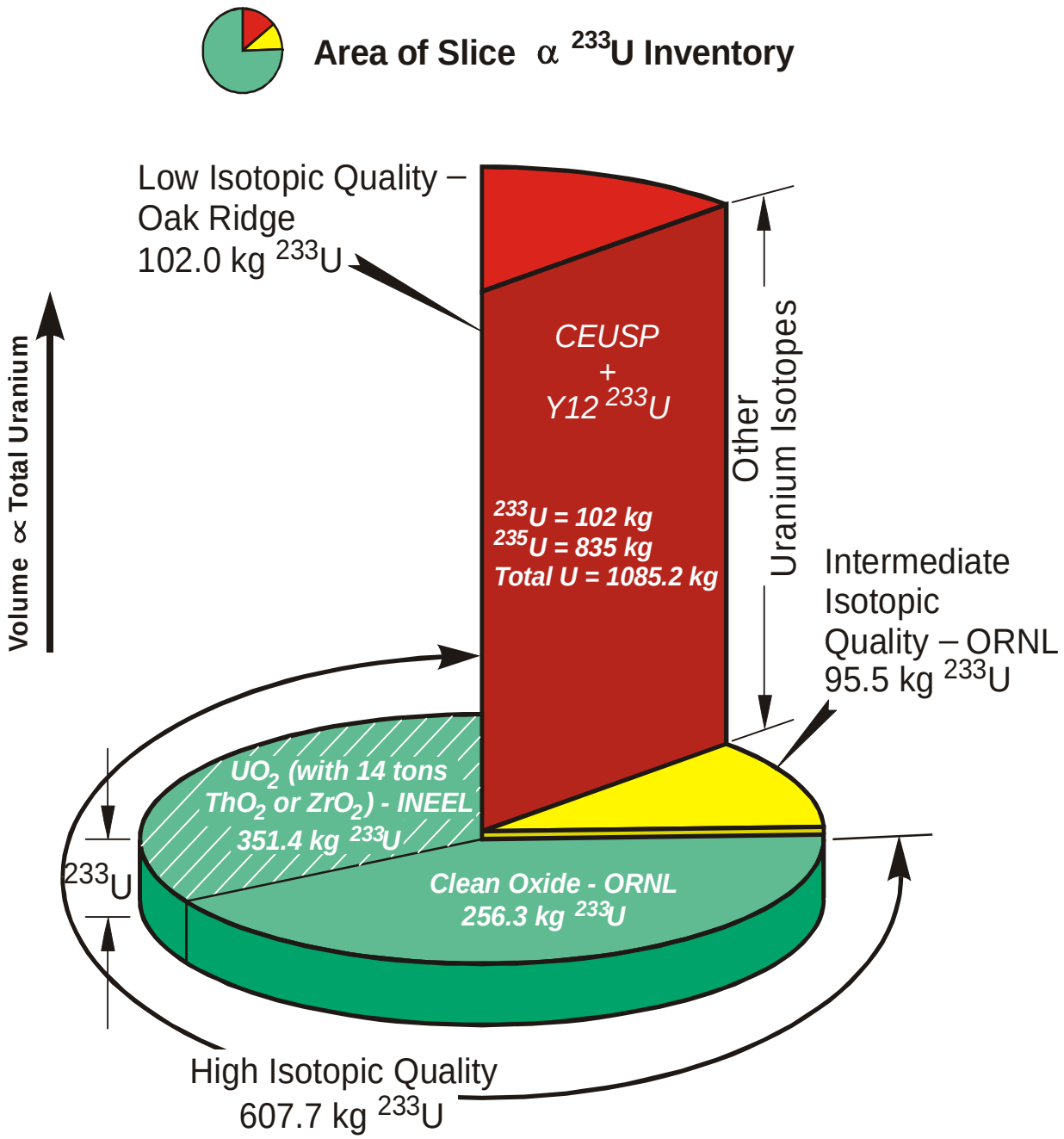
  - Aged ^{233}U with a significant ^{232}U content requires remote handling

ORNL DWG 2000-98



The Uranium-233 Inventory Was Divided Into Three Categories Based on Those Characteristics that Control its Potential Future Usage

ORNL DWG 2000-93



U.S. Separated ^{233}U Inventory

The Existing Separated ^{233}U Inventory Can Be Divided Into Three Major Categories

- **High-isotopic-quality ^{233}U[a]**
  - **Greater than 95% ^{233}U**
  - **Low ^{232}U content with relatively low gamma radiation levels**
- **Intermediate-Isotopic-Quality ^{233}U**
  - **Greater than 95% ^{233}U**
  - **High ^{232}U (>15 ppm) content with high gamma-radiation levels**
- **Low-Isotopic-Quality ^{233}U**
  - **Less than 50% ^{233}U**

[a]The high-isotopic-quality ^{233}U can be divided into two subcategories. The Idaho National Engineering and Environmental Laboratory (INEEL) high-isotopic-quality ^{233}U is from the Light-Water Breeder Reactor (LWBR) Program and contains 351.4 kg ^{233}U—most of which is in the form of UO_2 mixed with 14 tons of ThO_2. The remaining high-isotopic-quality ^{233}U is primarily stored at Oak Ridge National Laboratory (ORNL) in the form of uranium oxides and contains 256.3 kg of ^{233}U.

Quality Of Major Batches Of ^{233}U In Inventory[a]

Source	Isotopic quality	Total U (kg)	Isotopics: ^{233}U (kg)	Isotopics: ^{232}U (ppm)[c]	Uses[c]: Medical ^{229}Th (g)	Uses[c]: Other
Separated ^{233}U						
	High (ORNL)[b]	269.0	256.3	<15	23.9[c]	Yes
	High (INEEL)[b]	358.6	351.4	<15	0.0[c]	Yes
	Intermediate	108.0	95.5	>15	8.7	Yes
	Low	1,085.2	102.0		12.5	No
	Total	1,820.8	805.2		45.1	
In spent nuclear fuel (SNF)						
	High	0.0	0.0		0.0[c]	Yes
	Intermediate	523.7	501.0	220	0.0[c]	Yes
	Low	2,528.4	403.7		0.0[c]	No
	Total	3,052.1	904.7		0.0[c]	

[a]For comparison with other weapons-usable materials, the plutonium inventory is ~100 metric tons. The HEU inventory is several hundred metric tons.

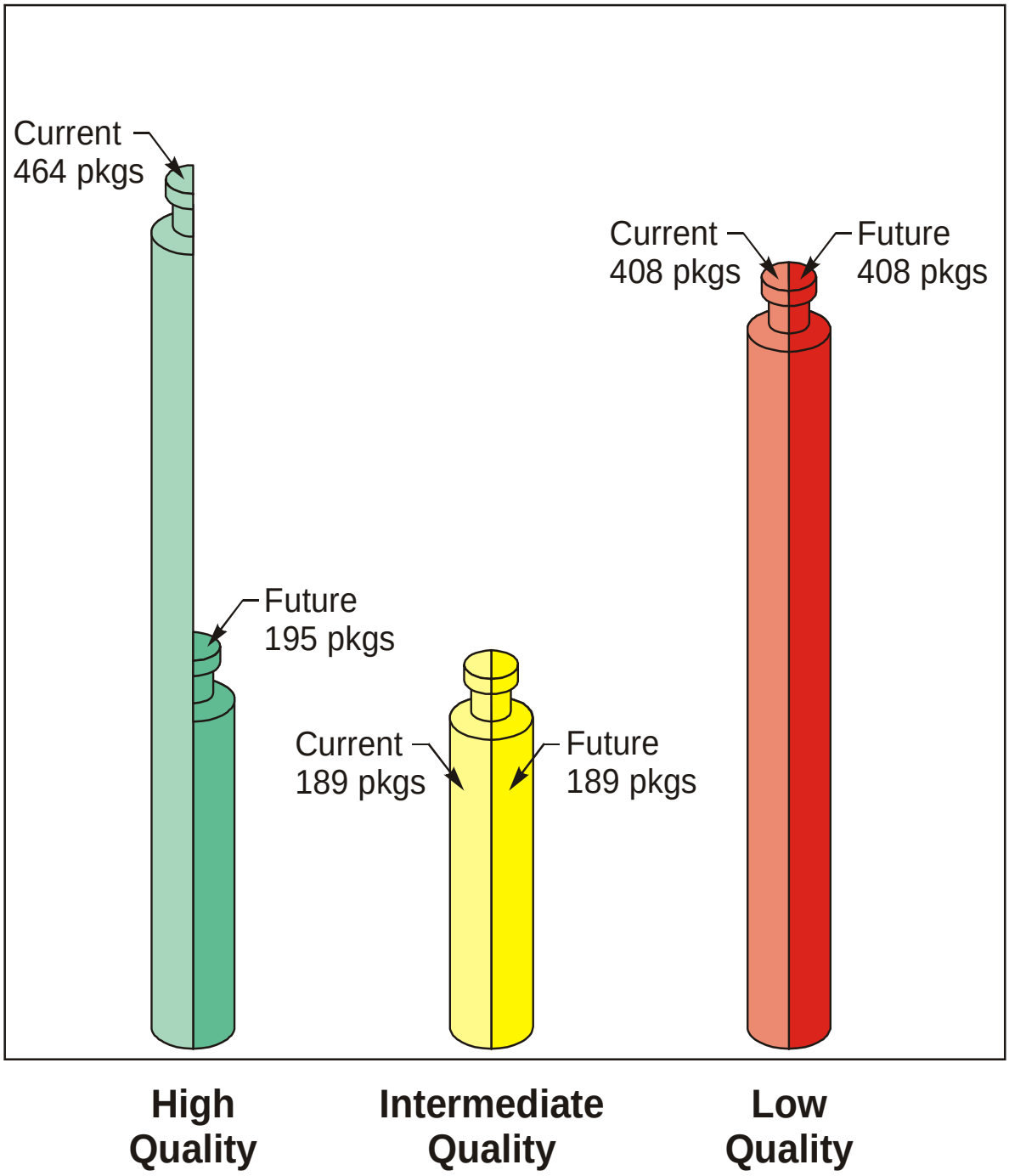
[b]The high-isotopic-quality ^{233}U can be divided into two subcategories. The INEEL high-isotopic-quality ^{233}U is from the LWBR Program and contains 351.4 kg ^{233}U—most of which is in the form of UO_2 mixed with 14 tons of ThO_2. The remaining high-isotopic-quality ^{233}U is primarily stored at ORNL in the form of uranium oxides and contains 256.3 kg of ^{233}U. All but <20 kg of this materials is stored at ORNL.

[c]About half of the high-quality separated ^{233}U (INEEL) and all of the SNF ^{233}U is mixed with thorium which prevents practical near-term recovery of medical isotopes. If it is desired to produce medical isotopes from this inventory, the thorium must be separated, the ^{233}U aged for several years for decay product buildup, and then the recovery of medical isotopes can be initiated.

The High-Quality Separated ^{233}U Inventory Can Be Divided Into Two Lots With Similar Isotopic Characteristics But Very Different Chemical Characteristics

- **Uranium-233 without chemical diluents**
  - **Chemically pure oxides (some small lots in different chemical forms)**
  - **Stored at ORNL**
- **Uranium-233 with chemical diluents**
  - **Unirradiated light-water reactor fuel assembly, pellets, and other miscellaneous forms**
  - **High fired (1,750°C for 12 h) mixture of UO_2 and ThO_2 with an average uranium content of ~2 wt %**
  - **Stored at INEEL**
  - **A major chemical processing activity would be required to purify this ^{233}U**
- **Uranium-233 with chemical diluents not further discussed herein**

ORNL DWG 2000-87



The Inspection and Repackaging Program Will Reduce the Number of ^{233}U Packages in Oak Ridge

Programs Are Underway To Inspect And Repackage (Where Appropriate) The Separated ^{233}U Inventory At ORNL

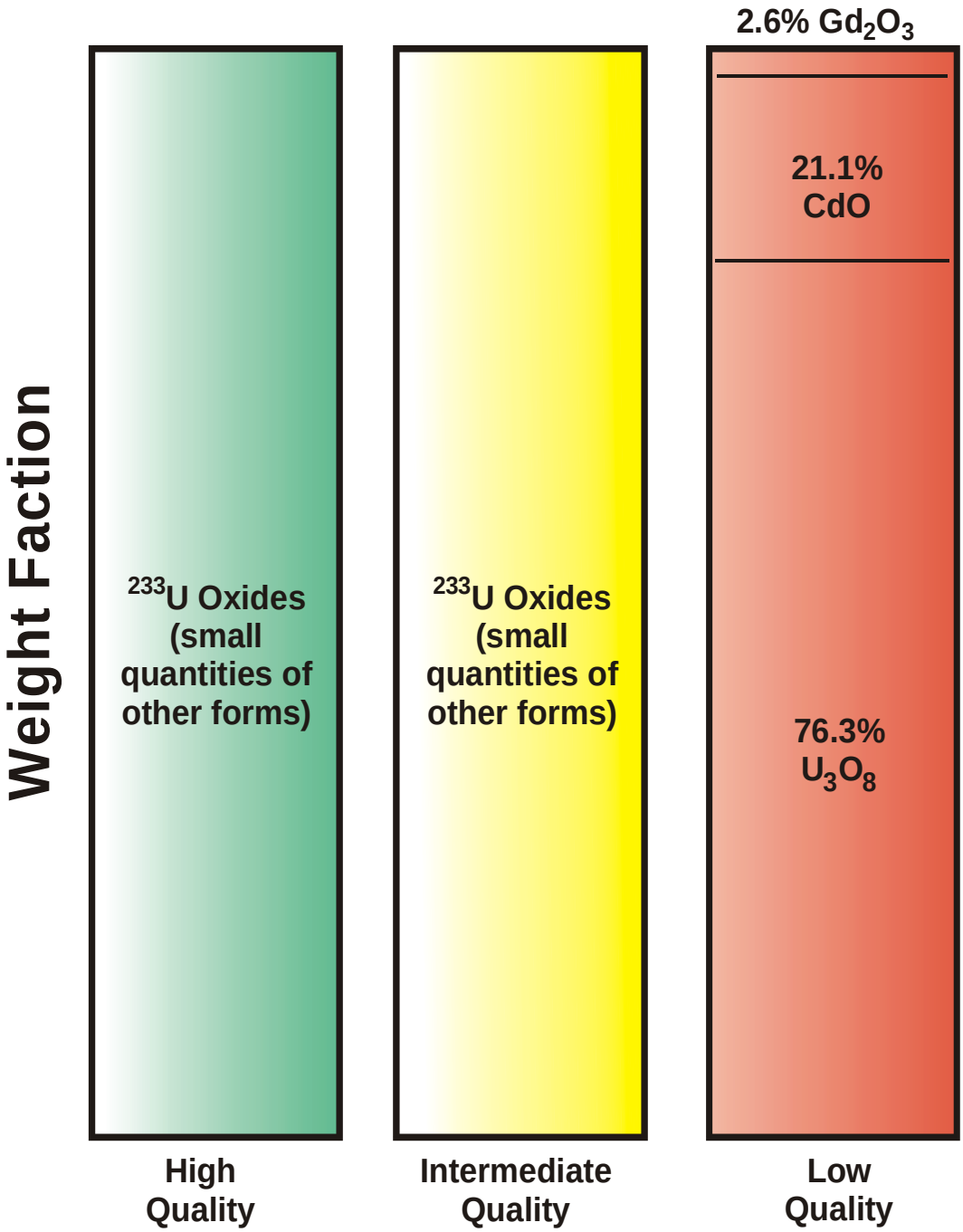
- **Many small packages will be consolidated into larger packages and thus reduce the number of packages but not the quantities of ^{233}U in inventory**

- **Some material will be processed and subsequently repackaged with a reduction in the number of packages**

  - **Some ^{233}U will be processed into more stable forms to meet safe storage goals**

  - **Some ^{233}U will be processed for recovery of medical isotopes**

ORNL DWG 2000-99



Chemical Composition of Repackaged Oak Ridge ^{233}U Inventory

The Separated ^{233}U Inventory In Oak Ridge Is In Several Chemical Forms

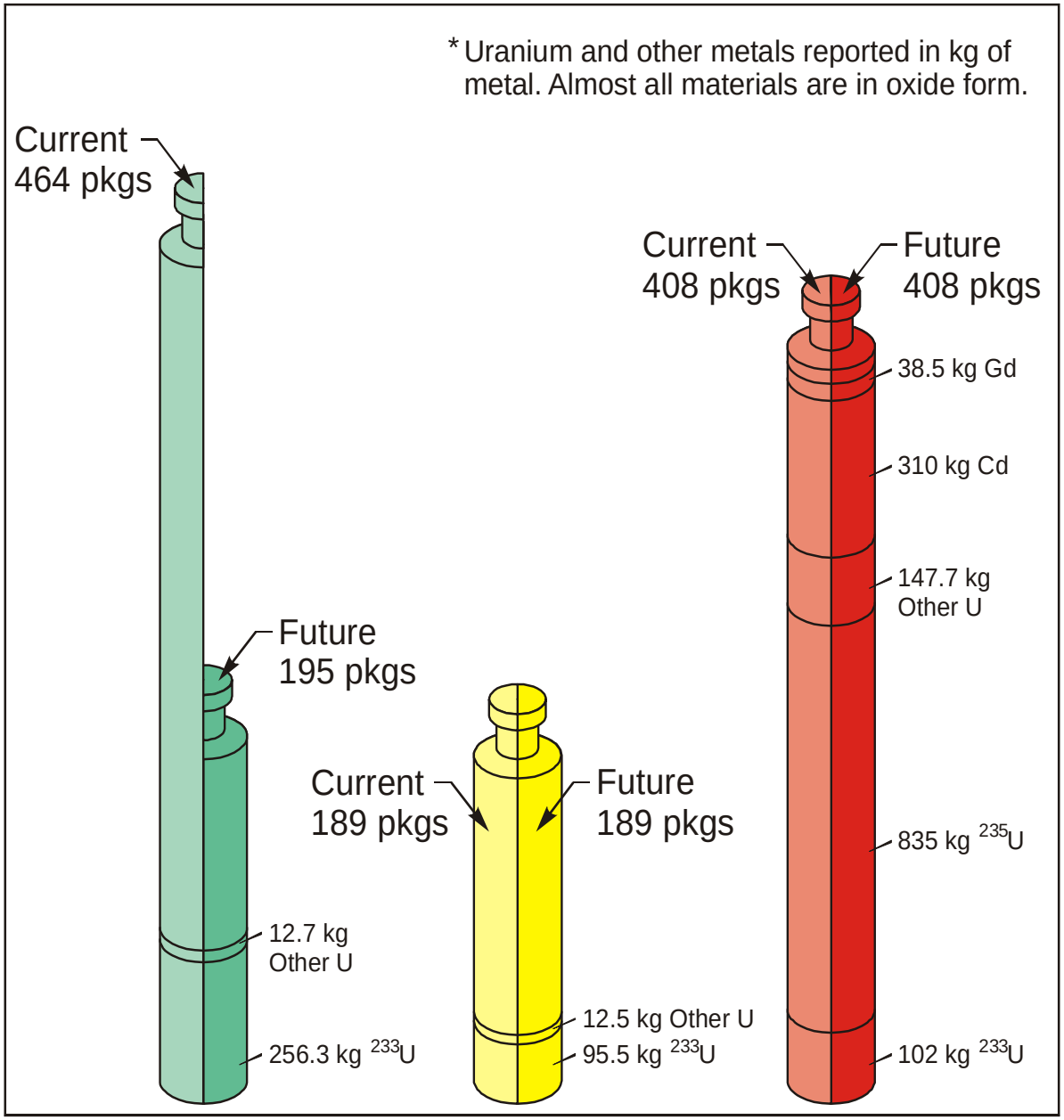
- The high- and intermediate-quality ^{233}U is primarily in the form of clean oxides with no other significant chemical impurities. There are a few other small lots in other chemical forms

- Most of the low-quality ^{233}U contains cadmium and gadolinium in the form of oxides

  - The cadmium and gadolinium were added as neutron absorbers for criticality control when the uranium was stored as a liquid solution

  - The cadmium and gadolinium were co-converted with the uranium to oxide form for storage

ORNL DWG 2000-101



High Quality (<15 ppm ^{232}U)

Intermediate Quality (>15 ppm ^{232}U)

Low Quality (High Average ^{232}U Content)

Current and Future Inventory of Separated ^{233}U in Oak Ridge

ORNL DWG 2000-103

Characteristics of major batches of separated ^{233}U in inventory in Oak Ridge

Batch no.	Location/designation	Material[a] and packaging	Total U (kg)	Uranium isotopics: ^{233}U (kg)	Uranium isotopics: ^{235}U (kg)	Uranium isotopics: ^{232}U (ppm)	Number of packages: Current	Number of packages: After repackaging
High Isotopic Quality								
1	Oak Ridge National Laboratory (ORNL)	U_3O_8 monolith in 27 welded stainless steel cans with tin-plated cover (same as CEUSP)	65.2	60.3	0.0	15	27	27
2	ORNL (2 similar batches)	UO_x powder in 247 stainless steel screw-top cans	108.8	103.1	0.0	4–9	247	73
3	ORNL	U_3O_8 powder in 1,645 welded stainless steel plates in 130 packages	46.0	45.0	0.0	6	130	62
4	Multiple/remaining small lots	Multiple forms-60 packages	49.0	47.9	0.0	b	60	33
Subtotal			***269.0***	***256.3***	***~0.0***		***464***	***195***
Intermediate Isotopic Quality								
5	ORNL/Savannah River Site (SRS)	UO_3 powder in 140 welded inner aluminum-in-aluminum cans	67.4	61.6	0.0	156	140	140
6	ORNL/Molten Salt Reactor Experiment (MSRE)	49 NaF traps to be converted to UO_X monolith-powder in 49 welded Haynes alloy 230 cans	40.6	33.9	~1.0	160–200	49	49
Subtotal			***108.0***	***95.5***	***~1.0***		***189***	***189***
Low Isotopic Quality								
7	ORNL/Consolidated Edison Uranium Solidification Program (CEUSP)	U_3O_8 monolith in 403 welded stainless steel CEUSP cans; Monoliths also contain CdO and Gd_2O_3	1,042.6	101.1	796.3	120	403	403
8	Y-12	5 cans	42.6	0.9	38.7	0.15	5	5
Subtotal			***1,085.2***	***102***	***835***		***408***	***408***
Total			***1,462.2***	***453.8***	***836***		***1,061***	***792***

[a]With minor exceptions, most of the material is in oxide form. Current programs will convert most non-oxide ^{233}U into an oxide form for long-term storage.
[b]Includes small lots to be shipped to Oak Ridge. Most small lots have <15 ppm ^{232}U, some lots have a higher ^{232}U content.