WHAT IS NON-WEAPONS-USABLE URANIUM-233 ?

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Outline

- Need to Define Weapons-Usable ^{233}U
- Approaches to Equivalency
- Results

There Is No Official Definition Of Weapons-Usable Or Non-Weapons-Usable Uranium-233

- In the case of ^{235}U, by definition, only high-enriched uranium (HEU) is weapons-usable ^{235}U

  —Many isotopic mixtures of ^{235}U with ^{238}U have been defined: depleted uranium, natural uranium, low-enriched uranium, and HEU

  —HEU is >20 wt % ^{235}U in ^{238}U

- Uranium-233 is made by the neutron irradiation of ^{232}Th

  —Production process yields weapons-usable ^{233}U (>99% ^{233}U)

  —Production of ^{233}U is similar to the production of plutonium

- Few incentives formerly existed to consider conversion of weapons-usable ^{233}U to non-weapons-usable ^{233}U or to define classes of ^{233}U

Need To Define Non-Weapons-Usable ^{233}U

Changing Conditions Imply A Need To Define Non-Weapons-Usable ^{233}U

- *Arms Control.* There is a national policy to reduce in parallel with Russia the inventories of *weapons-usable* materials. A definition of the term is required

- *Medical.* There is ongoing research to use the ^{233}U decay product ^{213}Bi to treat certain cancers. Separating medical isotopes from ^{233}U may be less expensive (because of lower security costs) if the ^{233}U can be converted to non-weapons-usable ^{233}U

- *Proliferation-resistant nuclear-power fuel cycles.* There is renewed interest in proliferation-resistant fuel cycles, but in order to pursue this interest, there must be first an agreed-to definition of weapons-usable ^{233}U

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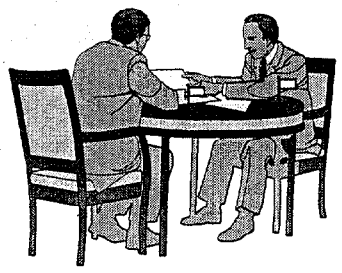
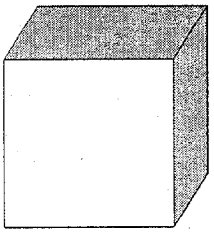


Depleted Uranium?
(^{238}U)

^{233}U
Weapons
Usable



^{233}U in ^{238}U
Non-Weapons
Usable

of Weapons-Usable Fissile Materials Require a
Definition of Non-Weapons-Usable ^{233}U

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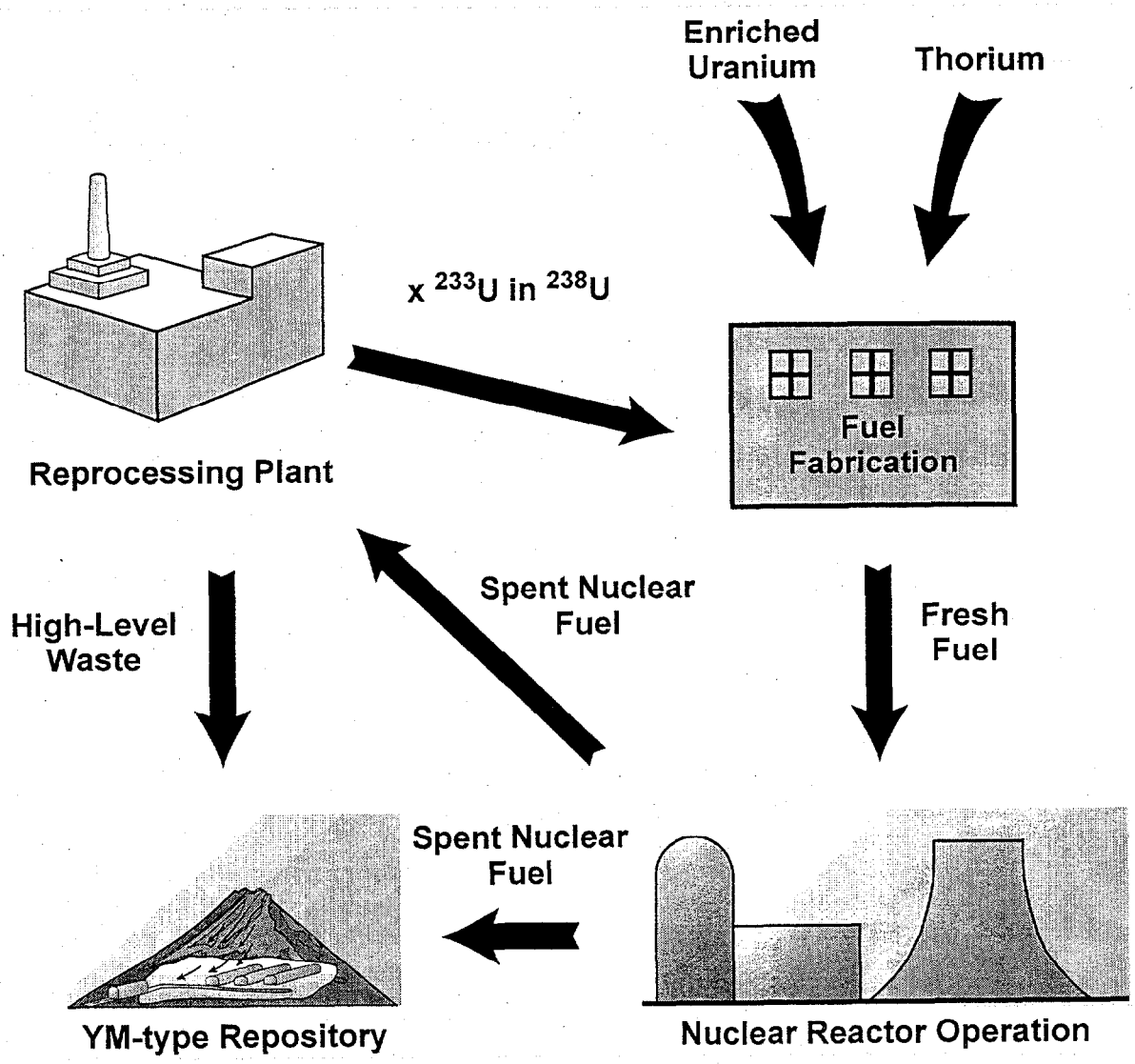

Development of Once-Through and Recycle Proliferation-Resistant Nuclear Power Fuel Cycles Requires a Definition of Non-Weapons-Usable ^{233}U

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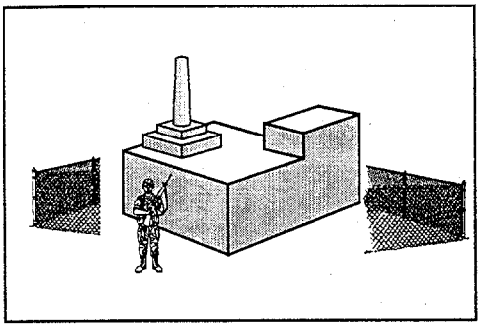
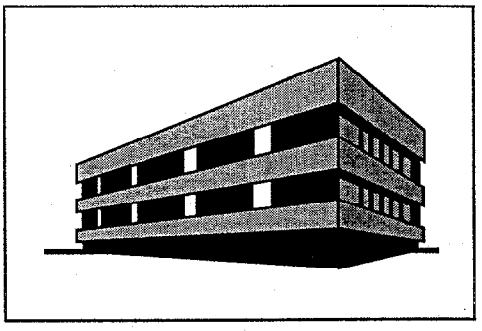
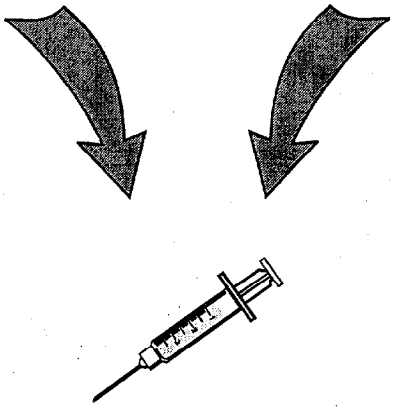
Processing Weapons-Usable ^{233}U



Processing Nonweapons-Usable ^{233}U





Medical (Cancer Treatment)

Clinical Trials Are Evaluating ^{213}Bi (a Decay Product of ^{233}U) for Treatment of Cancer: Processing Costs Depend upon Security Requirements and the Definition of Non-Weapons-Usable ^{233}U

There Are Two Approaches To Define Non-Weapons-Usable ^{233}U

- Spent Nuclear Fuel (SNF) Standard
  - —The International Atomic Energy Agency defines SNF as having a radiation dose as >100 R/h at 1 m
  - —Uranium-233 with a high ^{232}U content can have these radiation-dose rates. Fuel cycles can be developed to create such ^{232}U levels
- Isotopic dilution with ^{238}U (analysis herein)
  - —Use the logic that was used to define HEU
  - —Define weapons-usable ^{233}U as *x* wt% ^{233}U in ^{238}U, which is equivalent (in terms of neutronics) to 20 wt% ^{235}U in ^{238}U

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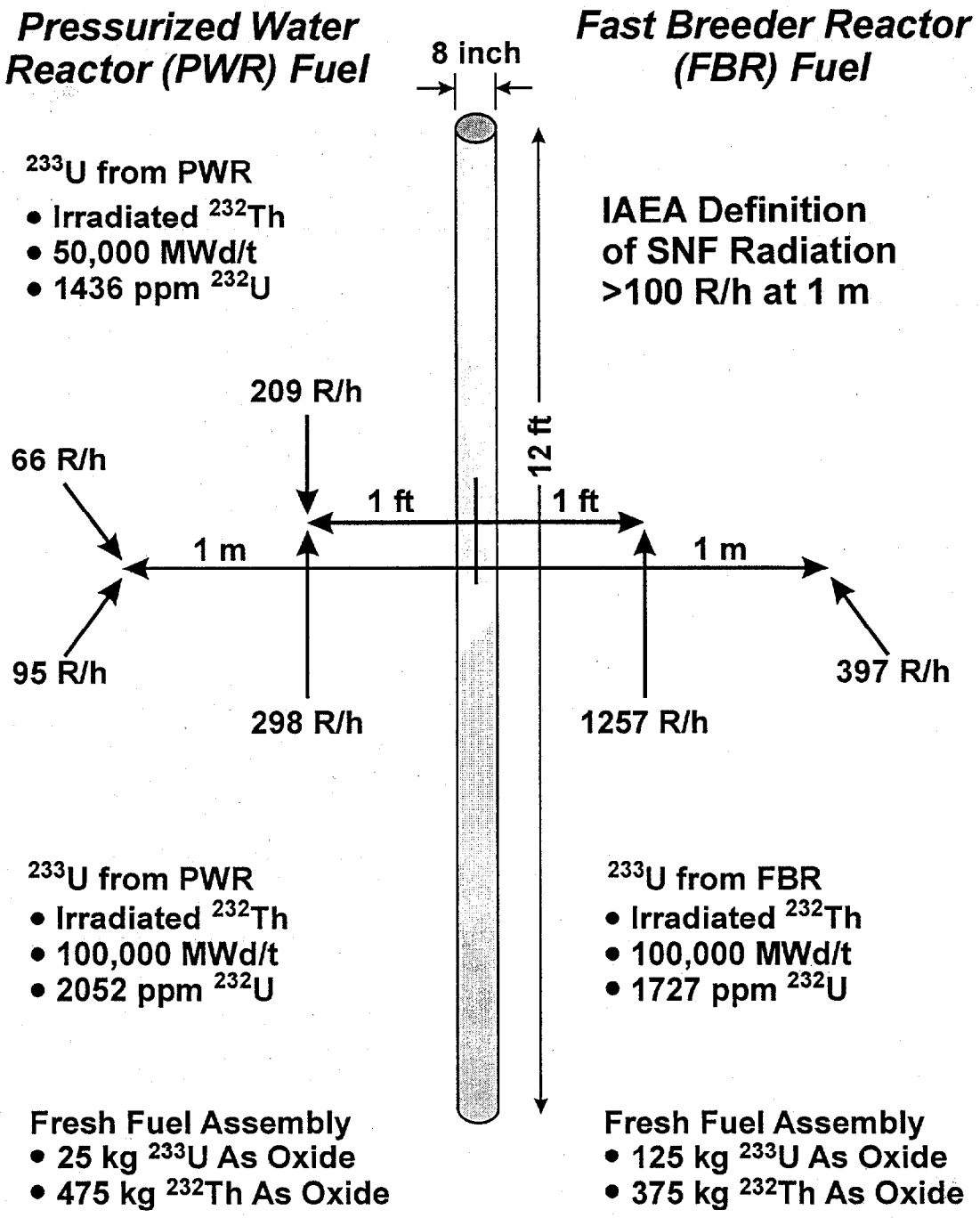

The Maximum Radiation Levels Of Fresh Fuel With High-Burnup ^{233}U Can Be Very High

Nuclear Equivalence Can Be Calculated For An Assumed Spherical Form

- Assume uranium metal sphere
  - —70 kg uranium[a]
  - —20 wt% ^{235}U in ^{238}U (boundary between weapons and non-weapons-usable ^{235}U)
- Calculate the neutron multiplication ratio (k_{eff}):k_{eff} ~ 0.49
- Calculate the ^{233}U concentration in ^{238}U required for k_{eff} = 0.49
  - —Assume same conditions: 70 kg uranium metal sphere
  - —Same k_{eff} for ~11.5 wt% ^{233}U in ^{238}U

[a]Seber, R. 1992. *The Los Alamos Primer*, University of California Press, Berkeley, California (originally published as L.A. 1 by the Los Alamos National Laboratory, Los Alamos, New Mexico)

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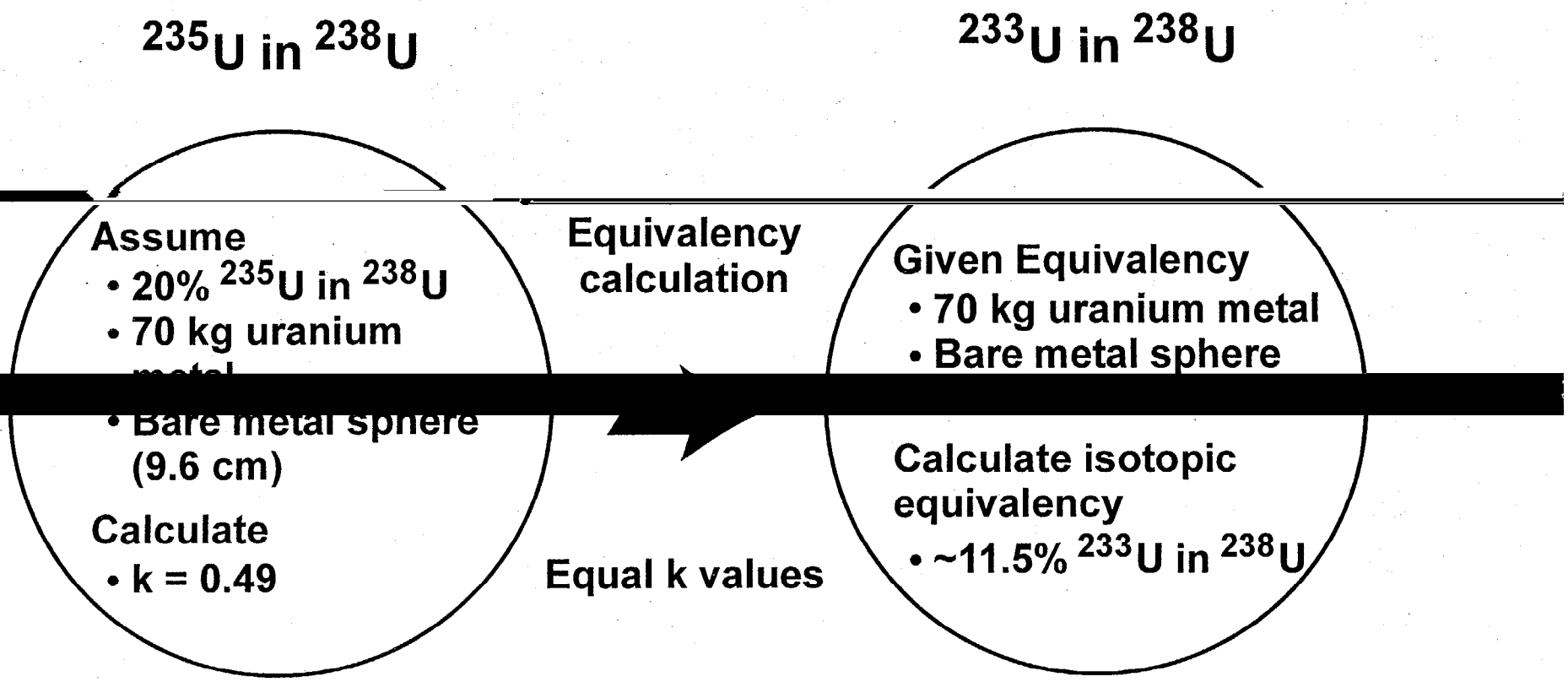

Nuclear Equivalency of Different Isotopic Mixtures Can Be Determined by Assuming a Set of Conditions and Matching Conditions

Nuclear Equivalence Can Be Calculated By Comparing The Spherical Mass Of Uranium Required For Nuclear Criticality

- Assume uranium metal sphere of 20 wt % ^{235}U in ^{238}U (boundary between weapons and non-weapons usable ^{235}U)
- Calculate the mass of uranium to achieve nuclear criticality: ~750 kg
- Calculate the ^{233}U concentration in ^{238}U required to achieve nuclear criticality under parallel conditions

  —Assume uranium metal sphere of 750 kg

  —Criticality occurs with ~12 wt ^{233}U in ^{238}U

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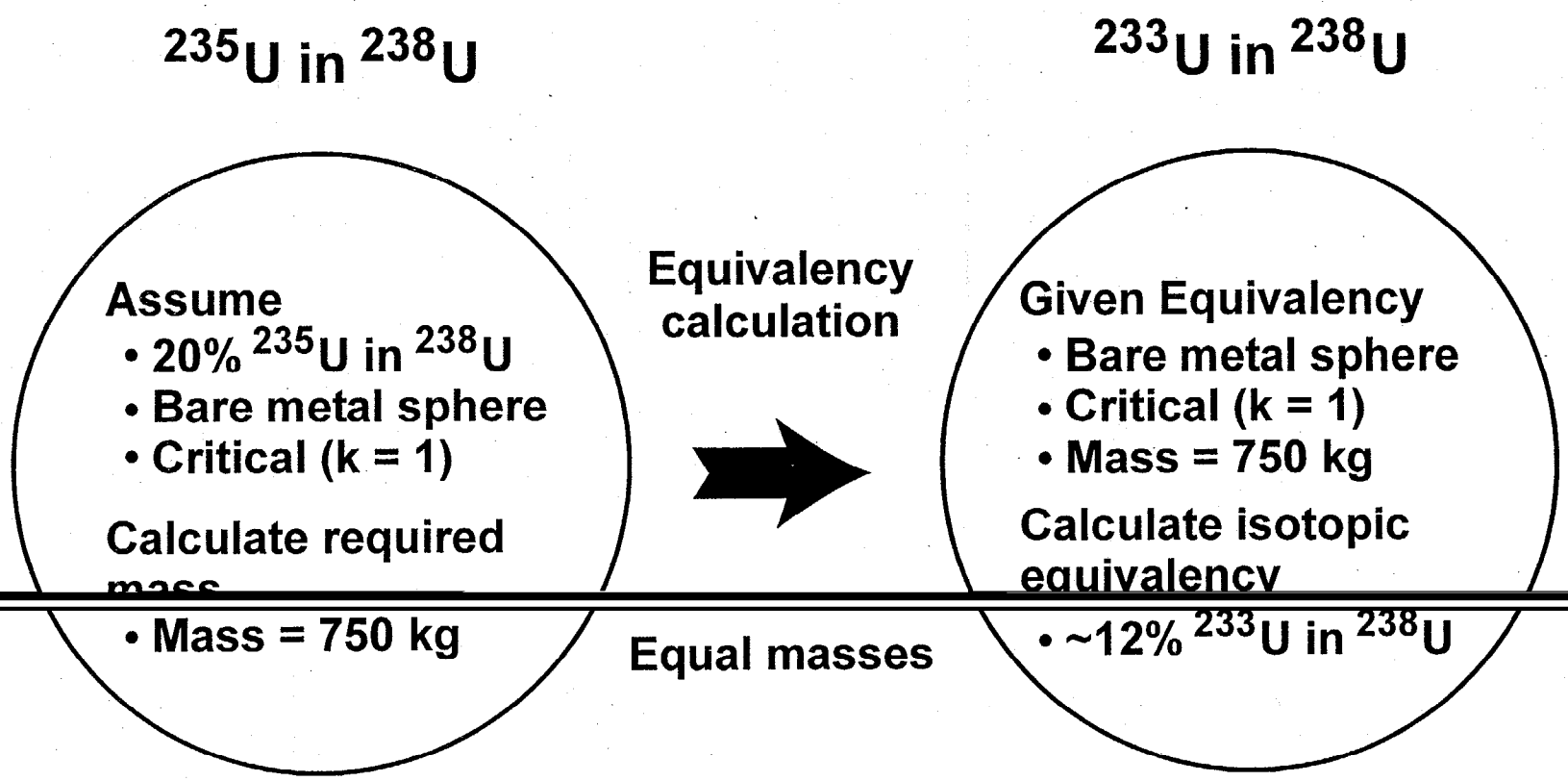

Nuclear Equivalency of Different Isotopic Mixtures Can Be Determined by Assuming a Set of Conditions and Matching Conditions

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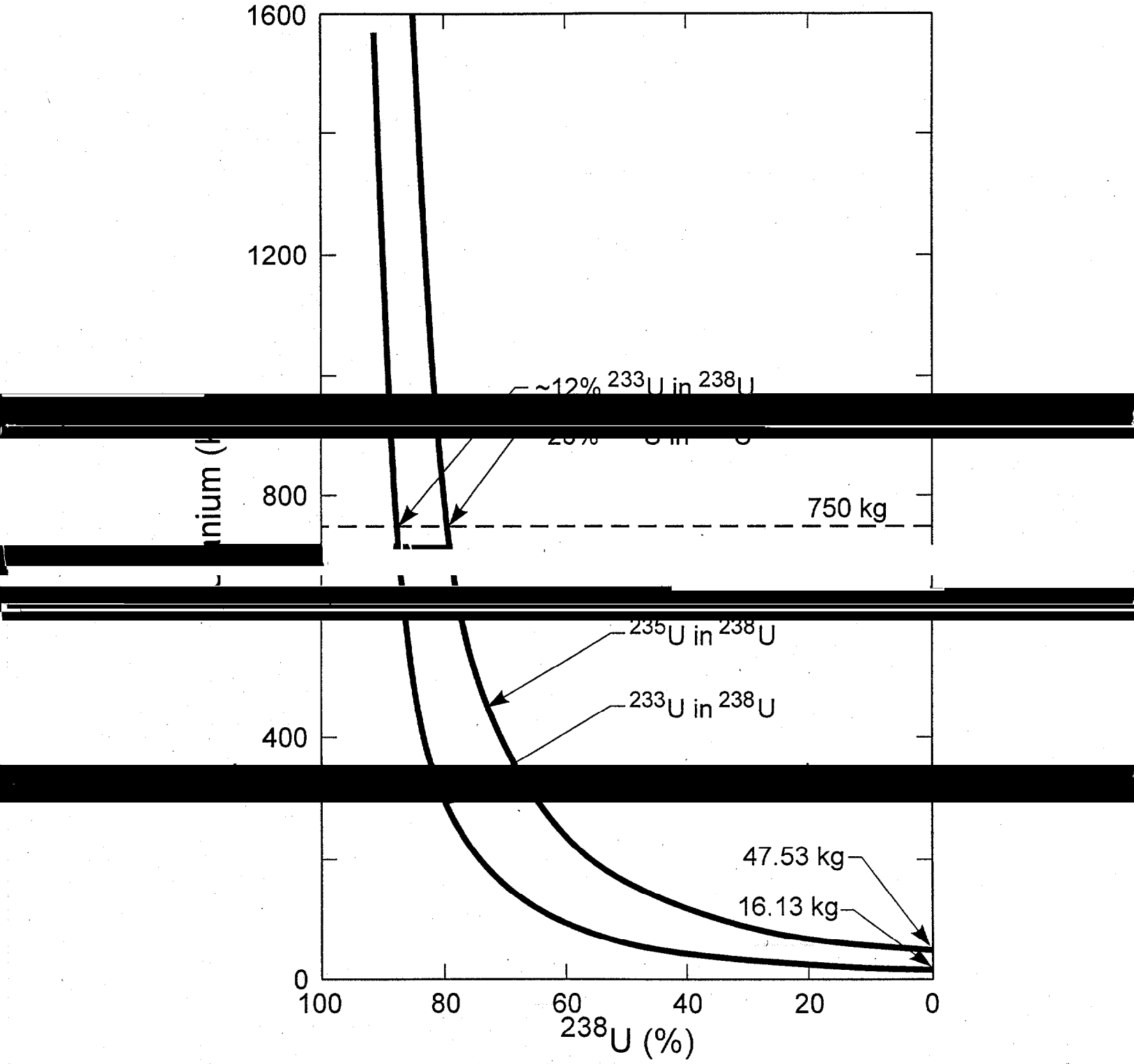

Critical Masses of ^{233}U in ^{238}U and ^{235}U in ^{238}U for a Bare Metal Sphere

It Is Recommended That 12 wt % ^{233}U In ^{238}U Become The Dividing Line Between Weapons-Usable And Non-Weapons-Usable ^{233}U

- Different neutronic calculations all yield the result that 12 wt % ^{233}U in ^{238}U is equal to ~20 wt% ^{235}U in ^{238}U
- Informal (undocumented) use of 12 wt% ^{233}U in ^{238}U as the dividing line between weapons-usable and non-weapons-usable ^{233}U
- Additional conservatism is that ^{233}U (except that produced under very unusual circumstances) is typically contaminated with ^{232}U and ^{232}U decay products that create significant radiation fields as compared to those created by HEU

Definition Of Non-Weapons-Usable ^{233}U For Mixtures Containing Multiple Uranium Isotopes

$$\frac{\textit{Weight Of } ^{233}U + 0.6 \textit{ Weight Of } ^{235}U}{\textit{Weight Of Total Uranium}} < 0.12$$

Actions Are Underway To Formalize The Boundary Between Weapons-Usable And Non-Weapons-Usable ^{233}U