Separative Work: Introduction

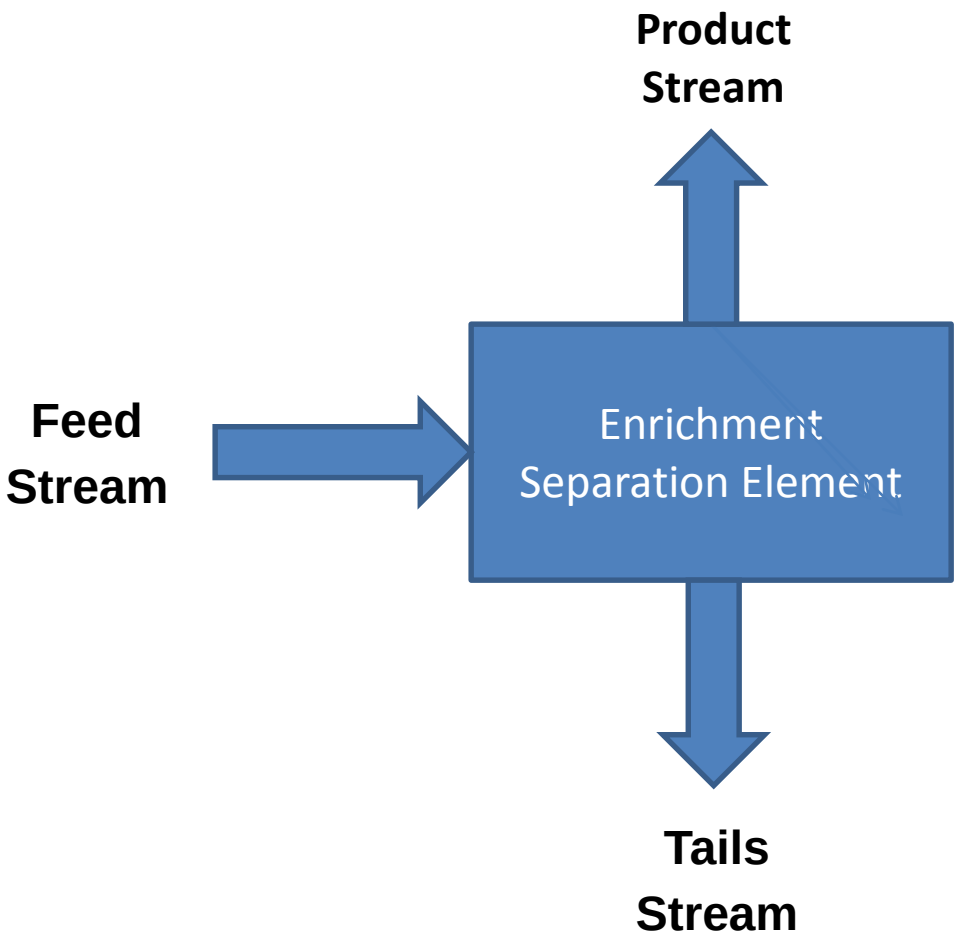
ISIS Course

October 30, 2014

Separative Work

- Separative work is a measure of the effort required in an enrichment facility to separate uranium of a given uranium 235 content into two fractions, one with a higher percentage of uranium 235 and one with a lower percentage. The common unit of measure is the kilogram uranium separative work unit, shortened to kg U swu and sometimes further shortened to swu or SWU. But be careful of units!
- Key terms include
  - feed and its percentage of uranium 235,
  - product and its percentage of uranium 235
  - waste or tails and its percentage of uranium 235

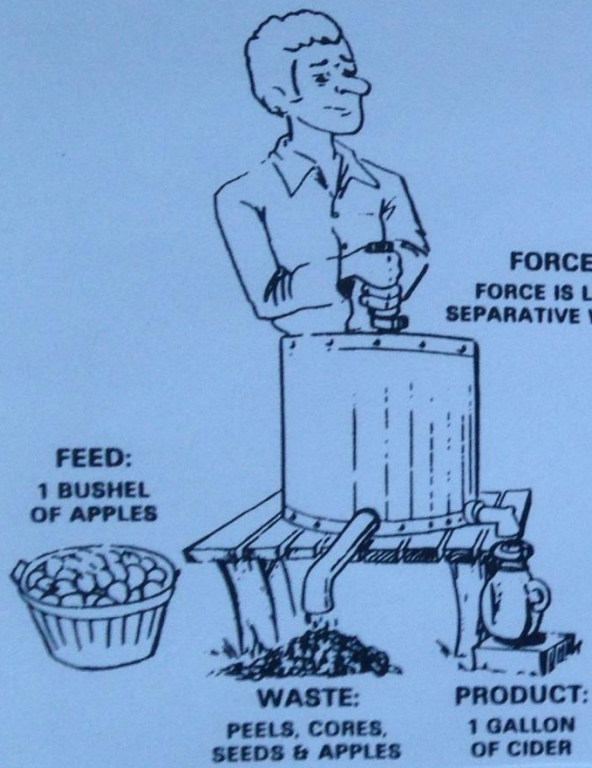
Basic Separation Element



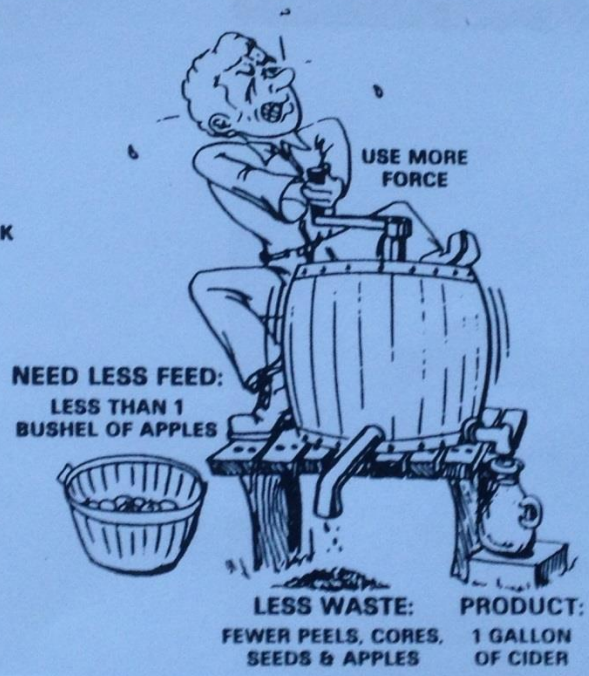
Separative Work & Tails Assay Analogy

Making *One Gallon* of Apple Cider

USUAL OPERATION



MORE *FORCE*, BUT LESS *FEED*



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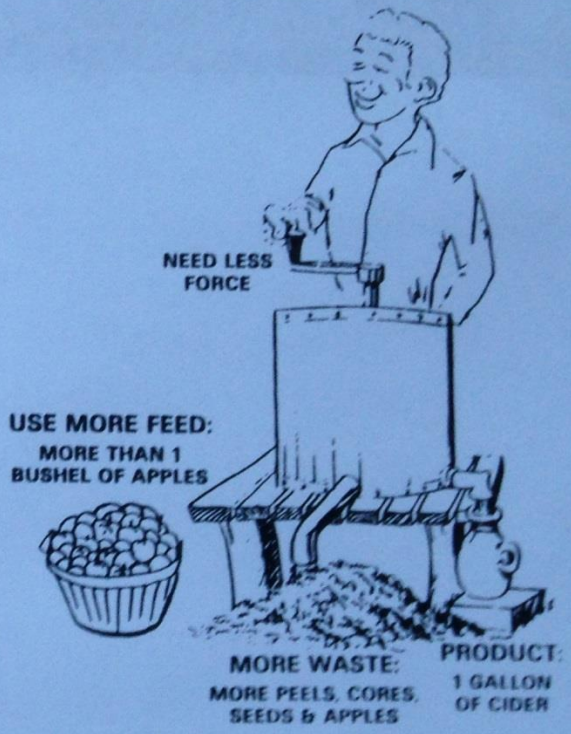

Cider pressing

Amount of cider
Cider content of apples
Pressing force
Amount of apples
Amount of waste
Cider content of waste

Uranium enrichment

Amount of enriched uranium
^{235}U content of feed uranium
Separative work
Amount of feed uranium
Amount of depleted uranium
^{235}U content of depleted uranium

MARTIN MARIETTA

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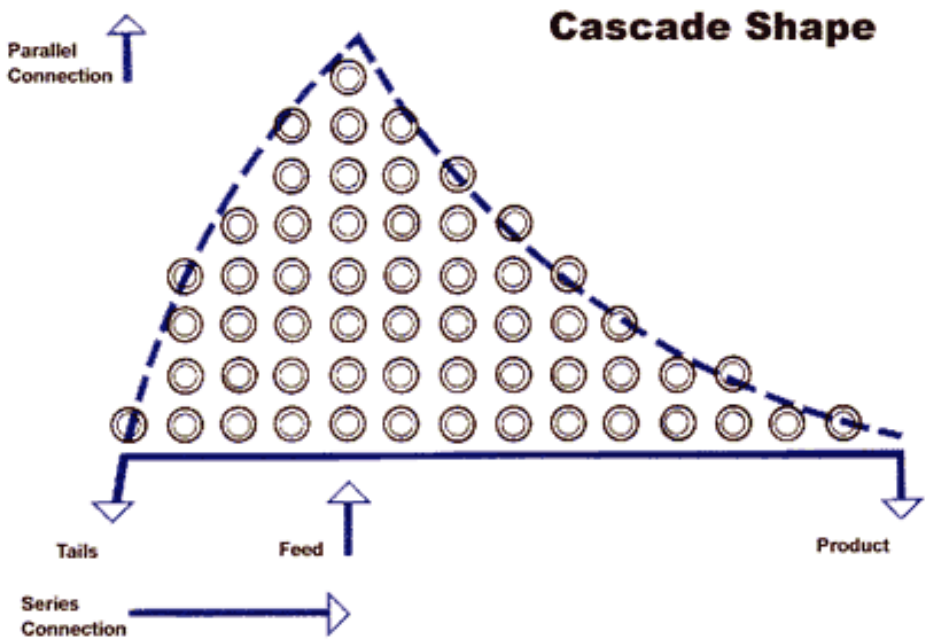
Cascades: A Network of Connected Separators

- The gaseous diffusion and gas centrifuge enrichment processes require that separator elements be combined in order to produce large quantities of enriched uranium.
- A cascade is the network of separators connected by piping.
- Stages are comprised of separators in parallel--to increase product enrichment, add stages
- Add more separators into a stage (in parallel) to increase the quantity of product.



Some Rules of Thumb,

where the waste or tails assay is 0.25 percent uranium 235 and the cascades are ideal

- It takes almost 5 swu to produce 1 kg of 3.5 percent enriched uranium from about 7 kg of natural uranium (with a tails assay of 0.25 percent uranium 235).
- It takes roughly 100,000 swu to fuel a 1,000 MWe light water reactor for one year of operation (with a tails assay of 0.25 percent uranium 235).
- It takes roughly 200 swu to produce about 1 kg of weapon-grade uranium (90% uranium 235) from roughly 200 kg of natural uranium (with a tails assay of 0.25 percent uranium 235).
- It takes roughly 5,000 swu to produce 25 kg of weapon-grade uranium, enough for a bomb, from roughly 5,000 kg of natural uranium (with a tails assay of 0.25 percent uranium 235).

Rules of Thumb: Enriched Uranium Feed

- It takes about 1,350 swu to produce about 25 kg of weapon-grade uranium from about 800 kg of 3.5 percent enriched uranium, assuming a tails assay of 0.72 percent.
  - This is about one quarter of the swu needed to go from natural uranium to 90 percent.
- It takes about 260 swu to produce about 25 kg of weapon-grade uranium from about 130 kg of 20 percent enriched uranium, assuming a tails assay of 3.5 percent enriched uranium.
  - This is one twentieth of the amount of swu needed to go to 90 percent product from natural uranium feed and one-quarter of the swu to go from 3.5 percent feed to 90 percent product.

Caveat and Limitations of Rules

- Key to remember: these values represent an ideal condition that often does not occur in reality; actual values can vary, depending on the enrichment process and the design of the enrichment plant. In addition, in the proliferation context the tails assay is usually greater than 0.25%.
- For those following the issue in more detail, these masses are all the mass of uranium, not uranium hexafluoride mass or uranium oxide mass.
- Despite their drawbacks, these rules of thumb provide a quick and easy way to understand the inputs and outputs of major enrichment programs and their proliferation significance.

Calculations

- Given a plant producing 100,000 swu/year, how many bomb's worth of weapon-grade uranium could it make annually from natural uranium feed, where a bomb's worth is 25 kg of weapon-grade uranium (assume 0.25 percent tails assay)?
- In a plant that has an enrichment output of 10,000 swu/year, how many bomb's worth of weapon-grade uranium could it produce annually from natural uranium feed, where a bomb's worth is 25 kg of weapon-grade uranium? What if the feed is not natural uranium but 1) 3.5 percent or 2) 20 percent enriched uranium?

Answers

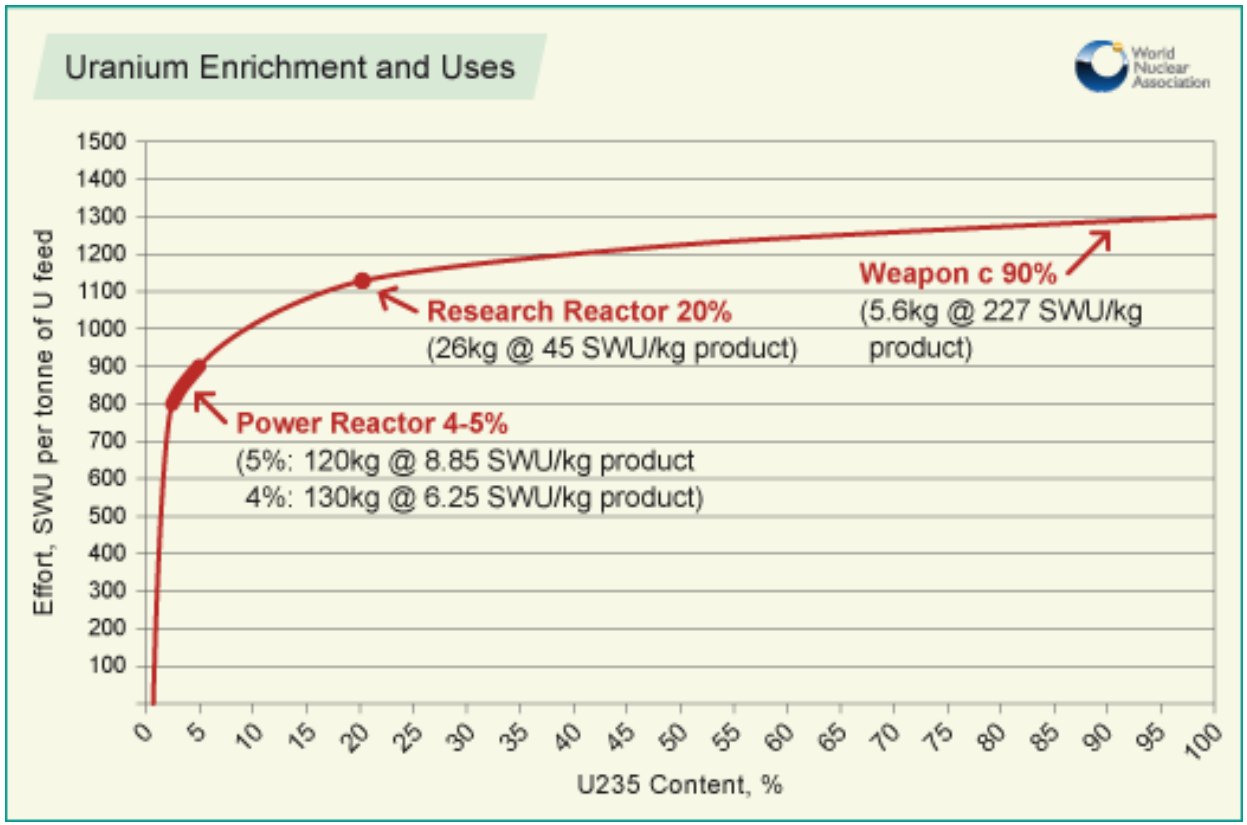
- Given a plant producing 100,000 swu/year, how many bomb's worth of weapon-grade uranium could it make annually from natural uranium feed, where a bomb's worth is 25 kg of weapon-grade uranium (assume 0.25 percent tails assay)?
  - **100,000 swu/y ÷ 5,000 swu per 25 kg of WGU = 20 bomb's worth**

Answers (cont.)

- In a plant that has an enrichment output of 10,000 swu/year, how many bomb's worth of weapon-grade uranium could it produce annually from natural uranium feed, where a bomb's worth is 25 kg of weapon-grade uranium?
  - **10,000 swu/y ÷ 5,000 swu per 25 kg of WGU = 2 bomb's worth**
- What if the feed is not natural uranium but 1) 3.5 percent
  - **10,000 swu/yr ÷ 1,350 swu per 25 kg of WGU = 7.4 bomb's worth**
- or 2) 20 percent enriched uranium?
  - **10,000 swu/yr ÷ 260 swu per 25 kg of WGU = 38 bomb's worth**

How one tonne of natural uranium feed might end up

The curve flattens because less enrichment effort is needed relative to what has already been expended to reach HEU.



Source: http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Conversion-Enrichment-and-Fabrication/Uranium-Enrichment/