22.251 System Analysis of the Nuclear Fuel Cycle
Fall 2009
Homework Set #2

Problem 1 The purpose of this problem is to gain some appreciation for how sensitive U and SWU requirements are to the tails enrichment used.

Assume that a nuclear plant has been operating since January 1, 1986, loading 30,000 kgU at 4 w/o EUP (enriched uranium product) every 18 months . Until 2006, the price of natural U has been very low, so the plant used the highest acceptable tails enrichment of 0.3 w/o to maximize the U usage compared to the SWU usage.

1.1 What were the feed to product and SWU to product ratios for each reload? How much natural uranium and SWU has the plant used for each reload, and total to date (Sept 24, 2009)?

1.2 Because the current price of natural uranium is higher than previous decades, the plant plans to switch to 0.2 tails, which will reduce U ore usage at the cost of more SWU use. What are the feed to product ratios now and how much natural uranium and SWU will the plant now use for each reload?

1.3 Because the current price of natural uranium is so high, the plant manager wonders if it would pay to feed all the 0.3 tails generated so far back into the enriching facility **and** use this to generate 4 w/o Enriched Uranium Prodcut at 0.2 w/o tails. What are the feed to product **and** SWU to product ratios for this operation? How many kgU of the 4 w/o EUP can it make? How many reloads is this? How many SWU does it use for this purpose?

1.4 Discuss any practical issues that might arise in the course of this re-enriching the tails procedure.

Problem 2 The purpose of this problem is to alert the students to the "minor" uranium isotopes in the fuel cycle and to demonstrate how the enrichment process affects their concentration

Spent fuel is not now being reprocessed in the United States but it was for a period in the past, may be in the future, and is presently being reprocessed in England and France. The reprocessed uranium contains U236 formed by neutron capture on U235. When the reprocessed uranium is re-enriched, the U236 gets enriched along with the U235. Unfortunately the U236 has a fair capture cross section which reduces the reactivity of the resulting fuel, and must be compensated by an additional increment of U235 enrichment.

1.1 Suppose that reprocessed uranium containing 0.8 w/o U235 and 0.3 w/o U236 is re-enriched to 5 w/o U235 using 0.3 w/o tails. Calculate the feed-to-product and waste-to-product ratios for this process.

2.1 Benedict, Pigford and Levy (available on-line to MIT affiliates from Klover: see the course references) show how to calculate the behavior of minor isotopes on pp 693-698. Read this and use their Eqs 12.326 and 12.327 on p 697 to calculate the U236 concentration in the re-enriched uranium. Note that the denominator of each of the 3 terms in Eq 12.327 is defined by Eq 12.317. Attached are

NOTE: In a later homework we will estimate the reactivity effect of the U236 and the amount of additional U235 needed to offset it.

Reference: Benedict, M., T. H. Pigford, and H. W. Levi. *Nuclear Chemical Engineering*. New York, NY: McGraw-Hill Book Company, 1981, pp. 693-697. ISBN: 9780070045316.

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