Nuclear Fuel Cycle

NUGN506 - Homework

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CHAPTER 1

Nuclear Fuel Resources, Mining and Milling

Several problems related to the nuclear fuel resources, the mining and the milling of said resources, are presented in this homework. Exercises 2.1 through 2.6 are considered..

1.1 Problem 2-1

1.1.1 Problem

Is the statement "The U.S. has 1,300,000 tons of uranium resources" complete?

1.1.2 Solution

This statement is not complete. Indeed, it does not categorize the form, local abundance or ease of mining associated with this number. These considerations are primordial to assess the cost and possibility of accessing the uranium resources.

1.2 Problem 2-2

1.2.1 Problem

A figure from the book shows the discovery rate of U3O8, per foot drilled, in a certain price range. Based on these data, estimate the total amount of uranium that can be recovered in this price range.

1.2.2 Solution

The trend can be approximated by $R = 17.6e^{-0.014F}$, where R is lb/ft and F is the amount of feet drilled.

Consequently, the amount of uranium that could be mined can be approximated by:

$$U = \int_0^{1.6e10} 17.6e^{-0.014x} x dx \tag{1.1}$$

We obtain $U \approx 90000\ lbs$

1.3 Problem 2-3

1.3.1 Problem

Assuming Equation 2.1 from the book is correct, what fraction of the earth's uranium can be found within the first 1000 m of the earth's crust?

1.3.2 Solution

Equation 2.1 states:

$$U(z) = U_0 e^{-z/6300} \tag{1.2}$$

$U_0 \approx 2.8\ ppm$. Consequently, with $z_a = 1000\ m$, $U(z_a) = 2.8 * e^{-10/63} = 2.4\ ppm$. Within the first 1000 m, 85% of the Uranium contained in the earth can be found.

1.4 Problem 2-4

1.4.1 Problem

In 1976, the U.S. nuclear industry needed about 10,000 tons of U3O8. Assuming that enrichment and tails requirements do not change and the industry increases at a rate of x% per year, how long would it take for the $130/kgU$ *resserves to be exhausted? Assume that the reserves are 600,000 tons of U3O8. After you develop the equation for the time, obtain numerical results for various values of x.*

We can write the solution to this problem, and solve for N:

$$\sum_{n=0}^{N} (1+x)^n = \frac{R}{U_0} \tag{1.3}$$

Unfortunately, there is no easy way, that i can think of, to solve this equation.

For x = 2%, the reserve can last 39 years. For x = 4%, it can last 30 years, and for x = 6%, it can last 25 years.

1.5 Problem 2-5

1.5.1 Problem

Assume that a decision is made to start ordering reactors at a constant rate per year from 1990 until 2030, at which time orders will stop, so that all known uranium reserves of 2.3 million tons (with prices up to $260/kgU) will be used up. Assume the following: (a) All plants are identical and need 150 tons of natural uranium per year, (b) it takes 10 years to build a plant, (c) every plant has a 30-y lifetime, (d) there are 120 plants operating in 1990 and (e) reactors operating in 1990 start retiring in 2000, at a rate of 10 a year. Calculate how many reactor per year could be ordered and the maximum number of reactors operating at any single time.

The model, taking into account the various constraints, shows that 11 plants a year would use 2,308,500 tons of Uranium over the whole "nuclear period". The maximum numbers of nuclear reactors operating at any given time would be 330, from 2029 to 2040, a time at which the nuclear reactor is maximum is stable due to the amount of reactor coming online being equal to the amount of reactors being taken offline.

1.6 Problem 2-6

1.6.1 Problem

How many 1000 MWe LWRs can the world reserves of uranium serve? Consider the price category up to $80/kgU. Assume that each reactor needs 150 tons of natural uranium per year and has a lifetime of 30 years. Also assume annual refuelings of one third of the core.

THe World RAR reserve under $80/kgU are 3,429,000 tons, as of 2009. We assume that each reactor needs 50 tons a year for refueling, so a need for 1600 tons over its lifetime (150 + 29*50). Consequently, the toal world RAR reserve inferior to $80/kgU could fuel a little shy of 2150 1000 MWe LWRs.

Table 1.1: Model evolution - 11 plants a year - 1990 to 2030

Year	# reactors	Uranium needs (tons)
1990	120	18,000
1991	120	18,000
1992	120	18,000
1993	120	18,000
1994	120	18,000
1995	120	18,000
1996	120	18,000
1997	120	18,000
1998	120	18,000
1999	120	18,000
2000	121	18,150
2001	122	18,300
2002	123	18,450
2003	124	18,600
2004	125	18,750
2005	126	18,900
2006	127	19,050
2007	128	19,200
2008	129	19,350
2009	130	19,500
2010	131	19,650
2011	132	19,800
2012	143	21,450
2013	154	23,100
2014	165	24,750
2015	176	26,400
2016	187	28,050
2017	198	29,700
2018	209	31,350
2019	220	33,000
2020	231	34,650
2021	242	36,300
2022	253	37,950
2023	264	39,600
2024	275	41,250
2025	286	42,900
2026	297	44,550
2027	308	46,200
2028	319	47,850
2029	330	49,500
2030	330	49,500

Table 1.2: Model evolution - 11 plants a year - 2030 to 2070

Year	# reactors	Uranium needs (tons)
2031	330	49,500
2032	330	49,500
2033	330	49,500
2034	330	49,500
2035	330	49,500
2036	330	49,500
2037	330	49,500
2038	330	49,500
2039	330	49,500
2040	330	49,500
2041	319	47,850
2042	308	46,200
2043	297	44,550
2044	286	42,900
2045	275	41,250
2046	264	39,600
2047	253	37,950
2048	242	36,300
2049	231	34,650
2050	220	33,000
2051	209	31,350
2052	198	29,700
2053	187	28,050
2054	176	26,400
2055	165	24,750
2056	154	23,100
2057	143	21,450
2058	132	19,800
2059	121	18,150
2060	110	16,500
2061	99	14,850
2062	88	13,200
2063	77	11,550
2064	66	9,900
2065	55	8,250
2066	44	6,600
2067	33	4,950
2068	22	3,300
2069	11	1,650
2070	0	0

Bibliography