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EFFECT OF CHANGES IN DOE PRICING POLICIES FOR ENRICHMENT AND REPROCESSING ON RESEARCH REACTOR FUEL CYCLE COSTS

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ABSTRACT

Fuel cycle costs with HEU and LEU fuels for the IAEA generic 10 MW reactor are updated to reflect the change in DOE pricing policy for enrichment services as of October 1985 and the published charges for LEU reprocessing services as of February 1986. The net effects are essentially no change in HEU fuel cycle costs and a reduction of about 8-10% in the fuel cycle costs for LEU silicide fuel.

INTRODUCTION

During the past year, the U.S. Department of Energy (DOE) announced two important changes in its pricing policies for enrichment and reprocessing services that have a direct influence on the fuel cycle costs of the research and test reactors that utilize these services. The intention of this paper is to document the changes in HEU and LEU fuel cycle costs due to these pricing changes using the IAEA generic 10 MW reactor as an example.

ENRICHMENT SERVICES

Before October 1, 1985, DOE had a single price ($153) for each separative work unit (SWU) required for uranium with all enrichments for short-term fixed-commitment contracts and only a single tails assay of 0.2% was allowed. Since facilities with different operating costs are used for different enrichment ranges, a more equitable cost allocation procedure for SWUs was needed to satisfy the U.S. Government legal requirement for full-cost recovery. In addition, a higher tails assay is more economical with today's feed prices.

After October 1, 1985, the new SWU prices for short-term fixed-commitment contracts are a weighted average of $492/SWU for the SWU required to enrich uranium beyond 10% and $153/SWU for those required up to and including 10%. Customers can also select a tails assay of 0.2% or 0.3%. It is our understanding that the cutoff enrichment was chosen as 10% rather than 20% for purely economic reasons.

In the enrichment process, the bulk of the SWU are required to bring natural uranium feed up to about 10% enrichment. For example, 236 total SWU

are required to obtain 1 kg of uranium with an enrichment of 93.15% if the tails assay is 0.2%. About 224 SWU (95% of the total) are required up to 10% enrichment and about 12 SWU (5% of the total) are required from 10% to 93.15% enrichment. For 1 kg of uranium with an enrichment of 19.75%, the total requirement is 38.8 SWU for a tails assay of 0.3%. Almost 99% of these SWU are required to bring the feed to 10% enrichment.

Rather than consider SWU prices alone, it is more appropriate to consider the cost per gram of ^{235}U (in the form of UF_6) as a function of feed cost and tails assay for enrichments of 93.15% and 19.75%. Some comparative prices before and after October 1, 1985 are shown in Table 1.

Table 1. Some Enriched Uranium Prices as a Function of Enrichment, Tails Assay, and Feed Cost for DOE SWU Prices Before and After October 1, 1985

	$/g ^{235}U* Before October 1, 1985 $153/SWU		$/g ^{235}U* After October 1, 1985 $492/SWU > 10% $153/SWU < 10%			
	93.15% Enr.	19.75% Enr.	93.15% Enr.		19.75% Enr.	
$/lb U_3O_8	Tails Assay 0.2%	Tails Assay 0.2%	Tails Assay 0.2%	0.3%	Tails Assay 0.2%	0.3%
17.00	48.68	44.80	52.88	49.43	45.46	42.11
39.43	60.07	56.09	64.27	63.57	56.75	56.08
45.00	62.89	58.90	67.09	67.08	59.56	59.55

*as UF_6. Prices include $3/lb U charge for conversion of U_3O_8 to UF_6.

The current price for feed on the spot market is about $17/lb U_3O_8. The DOE price for feed, which is sold in emergency cases only, is $39.43/lb U_3O_8. It is important to note, however, that credits for uranium recovered during reprocessing are computed by DOE using this price for feed. For SWU prices after October 1, 1985, the prices per gram of ^{235}U are the same for tails assays of 0.2% and 0.3% at a feed price of about $45/lb U_3O_8. Thus, it is adventageous to choose a tails assay of 0.3% if the price of feed is less than $45/lb U_3O_8.

Before October 1, 1985, the price for 1 gram of ^{235}U contained in uranium (in the form of UF_6) with an enrichment of 93.15% was $48.68 for a feed price of $17/lb U_3O_8. The corresponding price after October 1, 1985 with a tails assay of 0.3% was $49.43, an increase of 1.5%. Under the same comparison conditions, the price of uranium with an enrichment of 19.75% is lower by about 6% for the new SWU prices.

REPROCESSING SERVICES

In February 1986, DOE published in the U.S. Federal Register a revised policy[1] on receipt and financial settlement for nuclear research reactor fuels. The new features are that the DOE will accept for reprocessing aluminum-clad LEU silicide, oxide, and aluminide research reactor fuels (containing uranium enriched in the U.S.) and the charges associated with this service for each of the different fuels. This policy is effective through December 31, 1992. No changes were made in the previous policy[2] (effective through December 31, 1987) for acceptance and disposition of aluminum-clad HEU alloy, oxide, and aluminide fuels and aluminum or stainless steel clad uranium-zirconium-hydride fuel. The published reprocessing charges are listed in Table 2.

Table 2. DOE Reprocessing Charges as of February 18, 1986.

Initial Enrichment, wt% ^{235}U	Fuel Types(s)	$/kg of Delivered Weight
>20	alloy	1000
	oxide	1000
	aluminide	1000
<20	oxide	660
	silicide	835
	aluminide	1100
<20	zirconium-hydride	1050

Note that, in lieu of reprocessing uranium-zirconium-hydride fuels, DOE will agree[1] to provide disposition services for such fuels. In this case, no compensation for recovered uranium will be made. Research reactor operators may prefer to write off the value of the uranium contained in the fuel and accept this service.

REACTOR DATA

The reactor selected for comparison of fuel cycle costs with HEU and LEU fuels is the IAEA generic 10 MW reactor on which a number of safety and economic studies[3,4] have already been performed. Briefly, the core consists of a 5 x 6 arrangement of 23 standard fuel elements, 5 control fuel elements, and 2 flux traps. Two faces are reflected with graphite. The HEU and LEU standard (control) elements contain 23 (17) fuel plates with the identical geometry. Reactor data with HEU and LEU fuels used in this comparison are shown in Table 3.

Table 3. IAEA Generic 10 MW Reactor Data[4] with HEU and LEU Fuels.

	HEU		LEU	
	Standard	Control	Standard	Control
Fuel Type	UAl_x	UAl_x	U_3Si_2	U_2Si_2
Enrichment, %	93.15	93.15	19.75	19.75
U Density, g/cm^3	0.68	0.68	4.45	4.45
Fuel Meat Thick., mm	0.51	0.51	0.51	0.51
^{235}U per Element, g	280	207	390	288
Cycle Length, days	21.43		30.61	
No. Elements/Year at 100% Duty Factor	28.00	6.09	19.60	4.26
Ave. ^{235}U Discharge Burnup, %	49.9	55.3	48.5	53.8
Spent Fuel Element Weight, kg	5.00	4.67	6.41	5.71

FUEL CYCLE COST DATA

The fuel cycle cost components, assumed prices for products and services, and annual fuel cycle costs with a 100% duty factor for the specified HEU and LEU fuels are shown in the Attachment. The fabrication cost of LEU fuel has been parameterized in terms of an LEU/HEU fuel fabrication cost ratio since more commercial experience needs to be accumulated before LEU fuel fabrication prices stabilize.

All fuel cycle cost input data that are not affected by the recent DOE pricing changes (such as the cost for natural uranium feed, UF_6 conversion, fuel fabrication, and shipping costs) were kept constant in the model in order to provide a fair assessment of the price changes.

Cost Components Affected by New DOE Prices

The fuel cycle cost components affected by the new DOE prices are: (1) enriched uranium costs, (2) reprocessing costs, and (3) uranium credits. The subtotal costs for these components as of 9/85 (before the enrichment price change) and after 2/86 (publication of the new reprocessing charges) are summarized in Table 4.

Table 4. Components of Annual Fuel Cycle Costs Affected by Recent DOE Pricing Changes.

Product or Service	HEU UAl_x Fuel with 280 g ^{235}U/Std. El.		LEU U_3Si_2 Fuel with 390 g ^{235}U/Std. El.	
	9/85	2/86	9/85	2/86
Enriched Uranium	454.1	461.1	407.3	382.9
Reprocessing	168.4	168.4	165.0*	125.2
Uranium Credit	-254.4	-264.9	-220.5	-217.1
SUM	368.1	364.6	351.8	291.0

* Based on an assumed[4-6] 1985 reprocessing charge of $1100/kg of delivered weight for LEU silicide fuel. This value would be 150.0 if the 1985 reprocessing charge for LEU fuel had been assumed to be $1000/kg of delivered weight.

These data show that the sum of the affected HEU fuel cycle cost components are actually smaller by about 1% with the new DOE SWU prices. The higher average SWU cost is more than compensated for by the increase in the uranium credit. The uranium credit is larger because the DOE feed price of $39.43/lb U_3O_8 and a tails assay of 0.3% is used to compute the value (see Attachment) of the recovered uranium, which has an enrichment of about 76%.

In the LEU case in Table 4, the sum of the affected fuel cycle cost components is smaller by about 17% due to the lower DOE SWU prices for LEU after October 1, 1985 and the lower actual reprocessing charges for LEU silicide fuel than were previously estimated.[4-6] If 1985 reprocessing charges for LEU silicide fuel had been assumed to be the same as for HEU fuel (i.e. $1000/kg of delivered weight), the sum of the affected LEU fuel cycle cost components in 2/86 would be about 14% lower than the 9/85 cost.

Total Fuel Cycle Costs

Table 5 summarizes all of the fuel cycle cost components shown in the Attachment, including UF_6 services, fuel fabrication, and shipping costs.

Table 5. Summary of Total Annual Fuel Cycle Costs for IAEA Generic 10 MW Reactor with 100% Duty Factor.

Product or Service	HEU UAl_x Fuel with 280 g ^{235}U/Std. El. 9/85	HEU UAl_x Fuel with 280 g ^{235}U/Std. El. 2/86	LEU U_3Si_2 Fuel with 390 g ^{235}U/Std. El. 9/85	LEU U_3Si_2 Fuel with 390 g ^{235}U/Std. El. 2/86
Enriched Uranium	454.1	461.1	407.3	382.9
UF_6 Services	6.0	6.0	27.6	27.6
Fuel Fabrication	234.4	234.4	164.0 x[a]	164.0 x
Ship Fresh Fuel	15.2	15.2	17.4	17.4
Ship Spent Fuel	68.2	68.2	47.7	47.7
Reprocessing	168.4	168.4	165.0[b]	125.2
Uranium Credit	-254.4	-264.9	-220.5	-217.1
TOTAL	691.9	688.4	444.5 + 164.0 x	383.7 + 164.0 x

[a] x = LEU/HEU fuel fabrication cost ratio.

[b] Same footnote as in Table 4.

x	9/85 Total LEU	2/86 Total LEU
1.0	608.5	547.7
1.5	690.5	629.7
2.0	772.5	711.7

Several conclusions that can be drawn from the data in Table 5 are:

(1) For HEU fuel, the total fuel cycle costs are essentially the same with the 9/85 and 2/86 DOE prices for enrichment and reprocessing services.

(2) For LEU silicide fuel and an LEU/HEU fuel fabrication cost ratio of 1.0-2.0, the effect of the DOE price changes between 9/85 and 2/86 is to reduce the total fuel cycle cost by 8-10%.

(3) With 9/85 DOE prices, the HEU and LEU fuels considered would have the same total fuel cycle cost if the LEU/HEU fuel fabrication cost ratio were about 1.5. With the 2/86 DOE prices, the corresponding LEU/HEU fabrication cost ratio is about 1.9.

SUMMARY AND CONCLUSION

As of October 1, 1985, DOE pricing policy for enrichment services in short-term fixed commitment contracts includes a substantially higher price for the SWU required to enrich uranium beyond 10 wt% of ^{235}U, but also allows a choice of either 0.2% or 0.3% tails assay. Because 95% of the total SWU requirement for 93.15% enriched uranium is utilized in bringing natural uranium to an enrichment of 10%, and because fewer SWU are required with a tails assay of 0.3%, the net price for uranium with an enrichment of 93.15% increased by about 1.5%.

For 19.75% enriched uranium, almost 99% of the total SWU are required to bring the feed to 10% enrichment. Combined with a tails assay of 0.3% and current feed prices, the net effect of the DOE price change is to reduce the cost of 19.75% enriched product by about 6%.

In February 1986, DOE revised its terms and conditions for acceptance and disposition of research reactor fuels to include silicide, oxide, and aluminide fuels containing uranium (of U.S. origin) with an initial enrichment of <20%. The reprocessing charges per kg of delivered weight for LEU silicide and oxide fuels are substantially lower than for HEU fuels, while the charge for LEU aluminide fuel is about 10% higher than for HEU fuel. Most research reactors planning conversions to LEU are expected to utilize the new silicide fuels.

The fuel cycle cost components affected by the DOE policy and pricing changes are enriched uranium costs, reprocessing costs, and uranium credits. Using the IAEA generic 10 MW reactor with typical HEU aluminide fuel as an example, the sum of these three cost components is about 1% lower with the new DOE SWU prices and a tails assay of 0.3%. The higher average SWU cost is more than compensated for by the increase in uranium credit computed using current DOE feed prices and a tails assay of 0.3%. For the same example reactor using a likely LEU silicide fuel and fissile loading, the sum of the affected cost components is lower by about 14-17% after the DOE policy and pricing changes.

The conclusions reached regarding total fuel cycle costs are: (1) For HEU fuel, the total fuel cycle costs are essentially the same with the 9/85 and 2/86 DOE prices for enrichment and reprocessing services, (2) For LEU silicide fuel and an LEU/HEU fuel fabrication cost ratio of 1.0-2.0, the effect of the DOE price changes between 9/85 and 2/86 is to reduce the total fuel cycle cost by about 8-10%, and (3) The HEU and LEU fuels considered would have the same total fuel cycle costs if the LEU/HEU fuel fabrication cost ratio were about 1.5 using the 9/85 DOE prices and about 1.9 using the 2/86 DOE prices.

REFERENCES

1. U.S. Department of Energy, "Receipt and Financial Settlement Provisions for Nuclear Research Reactor Fuels," U.S. Federal Register, Vol. 51, No. 32, p. 5754, February 18, 1986, and U.S. Federal Register, Vol. 51, No. 42, p. 7487, March 4, 1986.

2. U.S. Department of Energy, "Receipt and Financial Settlement Provisions for Nuclear Research Reactor Fuels," U.S. Federal Register, Vol. 47, No. 217, p. 50737, November 9, 1982.

3. J. E. Matos and K. E. Freese, "A Mixed Core Conversion Study with HEU and LEU Fuels," Proceedings of the 1984 International Meeting on Reduced Enrichment for Research and Test Reactors, 15-18 October 1984, Argonne, Illinois, ANL/RERTR/TM-6, CONF-8410173, pp. 263-274 (July 1985).

4. J. E. Matos and K. E. Freese, "A Fuel Cycle Cost Study with HEU and LEU Fuels," Proceedings of the 1984 International Meeting on Reduced Enrichment for Research and Test Reactors, 15-18 October 1984, Argonne, Illinois, ANL/RERTR/TM-6, CONF-8410173, pp. 223-233 (July 1985)

5. W. Krull, "Remarks on the Influence of Enrichment Reduction on Fuel Cycle Costs," Proceedings of the 1984 International Meeting on Reduced Enrichment for Research and Test Reactors, 15-18 October 1984, Argonne, Illinois, ANL/RERTR/TM-6, CONF-8410173, pp. 211-222 (July 1985).

6. R.L. Moss and P. May, "A Comparative and Predictive Study of the Annual Fuel Cycle Costs for HEU and LEU Fuels in the High Flux Reactor, Petten 1985-1993," Proceedings of an International Meeting on Reduced Enrichment for Research and Test Reactors, 14-16 October 1985, Petten, The Netherlands, pp. 327-342, D. Reidel Publishing Company, Dordrecht, Holland (1986).

ATTACHMENT

Annual Fuel Cycle Costs (in Thousands of Dollars) for IAEA Generic 10 MW Reactor with HEU (280 g U-235/Std. El.) and LEU (390 g U-235/ Std. El.)

PRODUCT OR SERVICE	9/85 HEU Price	2/86 HEU Price	9/85 LEU Price	2/86 LEU Price	Annual Fuel Cycle Cost ($000) 9/85 HEU Cost	2/86 HEU Cost	9/85 LEU Cost	2/86 LEU Cost
URANIUM								
Natural U3O8, $/lb U3O8	17	17	17	17	80.5	100.0	77.8	96.3
Conv. of U3O8 to UF6, $/lb U	3	3	3	3	12.0	15.0	11.6	14.4
Enrichment, $/SWU	153.00	172.53	153.00	156.46	361.5	346.1	317.8	272.2
Tails Assay, wt% U-235	0.2	0.3	0.2	0.3				
TOTAL URANIUM	»	»	»	»	**454.1**	**461.1**	**407.3**	**382.9**
UF6 SERVICES								
Fill and Rent UF6 Cyl., $/kg U	200	200	200	200	2.0	2.0	9.2	9.2
Conv. UF6 to U Metal, $/kg U	400	400	400	400	4.0	4.0	18.4	18.4
TOTAL UF6 SERVICES	»	»	»	»	**6.0**	**6.0**	**27.6**	**27.6**
FABRICATION								
HEU Standard Element, $/El.	7000	7000	7000	7000	196.0	196.0	137.2 x	137.2 x
HEU Control Element, $/El.	6300	6300	6300	6300	38.4	38.4	26.8 x	26.8 x
TOTAL FABRICATION	»	»	»	»	**234.4**	**234.4**	**164.0 x**	**164.0 x**
SHIP FRESH FUEL								
Ship UF6, $/kg U	500	500	300	300	5.0	5.0	13.8	13.8
Ship Fresh Elements, $/El.	300	300	150	150	10.2	10.2	3.6	3.6
TOTAL SHIP FRESH FUEL	»	»	»	»	**15.2**	**15.2**	**17.4**	**17.4**
SHIP SPENT FUEL, $/El.	2000	2000	2000	2000	68.2	68.2	47.7	47.7
TOTAL SHIP SPENT FUEL	»	»	»	»	**68.2**	**68.2**	**47.7**	**47.7**
REPROCESS., $/kg Metal	1000	1000	1100	835	168.4	168.4	165.0	125.2
TOTAL REPROCESSING	»	»	»	»	**168.4**	**168.4**	**165.0**	**125.2**
URANIUM CREDIT, $								
Natural U3O8, $/lb U3O8	39.43	39.43	39.43	39.43	-87.7	-108.9	-85.9	-106.8
Enrichment, $/SWU	153.00	169.04	153.00	153.09	-167.8	-157.1	-142.6	-118.4
Conv. + Ship., $/kg U	198	198	198	198	1.1	1.1	8.0	8.0
TOTAL U CREDIT, $	»	»	»	»	**-254.4**	**-264.9**	**-220.5**	**-217.1**
TOTAL FUEL CYCLE COST	»	»	»	»	**691.9**	**688.4**	**444.5**	**383.7**
							+164.0 x	**+164.0 x**

x = LEU/HEU Fabrication Cost Ratio (treated as a variable here).