

《Review》

Fuel Cycle Cost Calculation

Chang Kun Lee and Jae Ho Kang

Nuclear Engineering Division A.E.R.I. Seoul, Korea

요 약

1974년도에稼動될古里원자력발전소(Westinghouse 600 MWe PWR)의核燃料週期費를計算했다.適用한假定과가격은현재핵공학계에서인용하는것에기준을두었고,한국이라는局地的조건을참작하였다.제산방식은가장적절하다고생각되는것을Normal로두어,이보다좋거나나쁜조건을고려하였다.마지막으로각Parameter가주어진범위내에서변하는것을Normal과비교하고준비용중에서각각이차지하는비율을검토했는데그결과Uranium原鑛費,成型加工費가가장비율이크고,그다음이利子率,Plutonium Credit,Plant Capacity Factor 등의순이었다.

1. Parameter Assumptions

Parameters		Worse	Normal	Better
1. Plant Capacity Factor	%	55	70	85
2. Commercial Interest and Fuel Carrying Charge (Annually)	%	9	7.5	6.0
3. Uranium Ore (U_3O_8)	\$/lb	9	7.75	6.5
4. Fabrication Price				
Initial Core	\$/Kg	125	115	95
Reload Core	\$/Kg	110	100	85
5. Ship Spent Fuel and Casks	\$/T	20,000	14,000	10,000
6. Reprocessing Cost	\$/KgU	33	31.5	30
Time Period:				
7. Ship to Site, Storage, and Testing				
Initial Core	mo.	7	6	4
Reload Core	mo.	3	3	2
8. Cooling	mo.	5	4	3
9. Ship to Reprocessing Site	mo.	4	3	2
10. Reprocessing	mo.	3	3	2
11. Losses in Reprocessing				
a) Plutonium	%	2.0	1.0	0.8
b) Uranium	%	2.0	1.3	1.0
12. Plutonium Credits (fissile)	\$/gm	6	8	10

. Remark

(1) Plant Capacity Factor

A). 55%: The Nuclear Power Group, Limited

(TNPG) of the United Kingdom mentioned in their proposal that the plant capacity factor of the American Light Water Reactors has shown to be 55% on the average. There-

fore, we regarded it here as the worse plant capacity factor.

- B). 70%: The average plant capacity factor of Magnox type reactors (on-load refueling system) was reported to be 78% in TNPG's proposal. We considered it as the normal one in the nuclear plants.

Since Westinghouse proposed that the time period necessary for refueling is about 14 days, we have come to the conclusion that the actual practical refueling time would be 28 days, under the condition of two shifts and 0.75 working efficiency during the refueling operation. This 28 day refueling time corresponds to 8% of the calendar year. Therefore, this 8% was subtracted out of the TNPG's normal 78%, thus arriving at 70% of normal plant capacity factor.

- C). 85%: Westinghouse stated it to be 80% as the achievable plant capacity factor in their proposal whereas General Electric assumed it to be 85% in their offer: however, we would like to take the latter as an optimistic condition, considering the fact that nuclear power plants which have had less experience in utilities seem difficult to attain this goal. Therefore, 85% was taken as the better side.

(2) Commercial Interest and Fuel Carrying Charge (Annually)

Mention must be made here that this is not the fixed charge rate but the fuel carrying charge rate per annum. The Ministry of Finance recently announced that the Government will authorize foreign banks, now operating in Korea, to make loan to the local money-borrowers at the interest rate of 9% per year. That's why we took it as the worse one.

On the other hand, 6% was proposed in Westinghouse's offer. We are taking, however, 7.5% as the most practical and reasonable carrying charge rate.

(3) Uranium ore

It has been proposed by many tenders that the uranium ore's price is between \$7.50 and \$8.00

per pound in the form of U_3O_8 . According to the papers submitted to Oak Ridge Seminar on Nuclear Fuels (held in 7 November 1968), uranium ore price is expected to fall down up to \$5.70. Being based upon this assumption, \$6.50/lb was taken as the better side, whereas \$9.00 was the worse one. In accordance with the Westinghouse's proposal, \$7.75 was used as the normal price. In a rough expression, the band in the range of the normal price $\pm \$1.25$ was taken for granted here as the practical price range.

(4) Fabrication Price

Initial Core

- A). The better fabrication price in the amount of \$95.00 was simply copied from that quoted in the Second Core in Westinghouse proposal.
- B). Westinghouse proposed it to be \$115.00 per kilogram: it seems to be rather expensive and must be lowered, but we took it as the normal one for adjusting the price range.
- C). The worse side is \$125.00: various curves in the books and reports, including Economics of Nuclear Fuels and Gilbert Study of Mihama #2 Nuclear Power Station in Japan, show this range. We took it for granted that this price is placed as the worse case.

Reload Core

\$110.00 \$100.00 and \$85.00: These worse, normal and better conditions were arbitrarily adjusted in consideration of increase in handling quantity and possible improvement in fabrication technique and so on.

(5) Shipping Charge of Spent Fuel and Casks

- A). \$20,000/T: This Westinghouse's quotation looks too much and seems to have been offered simply by the rule of thumb. Therefore, we would like to think it as the worse condition.

\$14,000/T: At the international conference on spent fuel transportation held in Tokyo last year, the trans-Pacific freight charge between the west coast of the United

States and Far East was reported to be \$14,000/T, and this price was simultaneously backed-up by computer calculation.*

This price as to be the normal condition has rather logical basis to be defended.

\$10,000/T: In case chemical reprocessing could be handled in Asian area, presumably in Japan or India, the shipping charge would be lowered well below to \$10,000/T. This better price is not the impossible one to be realized.

(6) Reprocessing Cost

\$33.00: This is commercially prevailing price in the United States as was quoted in Burns & Roe's report. Price in the future would certainly show in downward trend as time goes on, so we took it as the worse side.

\$31.50: This one is Westinghouse-Proposed price.

\$30.00: Messrs. General Electric quoted it as approximately \$29.00. By rounding it up, the better condition was taken as \$30.00.

Time Period

The time periods proposed by Westinghouse quotation, namely, 6 months for the shipping to site, storage and testing for the initial core, 3 months for the reload core 4 months for cooling after irradiation, 3 months for shipping to reprocessing site, and another 3 months for chemical reprocessing, were accepted here as the normal condition. By

adding or subtracting one, two or no month to and from this normal period of time, the better condition and worse condition were adjusted to our best judgement.

Losses in Reprocessing

A). Plutonium:

2.0% Loss: Burns & Roe considered it as 2.0%, and we took it here as the worse condition.

1.0% Loss: Westinghouse quoted it as 1.0%, which we regarded as the normal one.

0.8% Loss: This is simply arbitrary rate of loss assumed for our calculation. Technological improvement and increase in handling quantity may reduce the loss up to this line.

B). Uranium:

2.0% Loss: This again was Burns & Roe's loss rate.

1.3% Loss: This is Westinghouse-proposed loss rate.

1.0% Loss: This is simply arbitrary loss rate for the benefit of our calculation.

(7) Plutonium Credits (fissile)

The U.S. AEC has been purchasing fissile plutonium at the buy-back price of \$10.00 per gram for the several years in the past. It seems, however, to be dropped down to \$8.00, and this eight dollar line was taken as the normal condition.

On the other hand, \$6.50/gram quoted by General Electric was taken for granted, and we took \$6.00/gram as the worse side.

* Royes Salmon, "A Computer Code (CDC 1604A or IBM 7090) for Calculating the Cost of Shipping Spent Reactor Fuel as a Function of Burnup, Specific Power, Cooling Time, Fuel Composition, and Other Variables," ORNL-3648.

3. Computation Table

			<i>Worse</i>					
<i>Item</i>			1	2	3	4	5	6
A.	Region Output (Thermal)	MW	623.0	640.8	537.0	605.2	593.3	593.3
B.	Region Lifetime at Full Load	Hr.	9,120	15,460	22,240	19,990	20,390	20,390
Y.	Region Life time at 55, 70, 85 % Plant Factor	mo	22.65	38.40	55.24	49.65	50.65	50.65
D.	Burnup	MWD/MTU	14,800	25,800	31,100	31,500	31,500	31,500
E.	Initial Uranium Weight	KgU	16,000	16,000	16,000	16,000	16,000	16,000
F.	Final Uranium Weight	KgU	15,660	15,440	15,340	15,330	15,330	15,330
G.	Initial Enrichment	w/o	2.4	2.77	3.47	3.38	3.38	3.38
H.	Unit Cost of G	\$/KgU	192.55	232.24	308.60	298.71	298.71	298.71
I.	Final Enrichment	w/o	1.16	0.89	1.10	1.03	1.03	1.03
J.	Unit Cost of I	\$/KgU	66.03	41.39	60.46	53.95	53.95	53.95
K.	Plutonium Produced (fissile)	KgPu	74.6	93.8	103.7	103.4	103.4	103.4
L.	Unit Value of K as Nitrate	\$/KgPu	6,000	6,000	6,000	6,000	6,000	6,000
M.	Value of Initial Uranium (ExH)	10 ³ \$	3,080.8	3,715.8	4,937.6	4,779.4	4,779.4	4,779.4
N.	Value of Final Uranium (FxJ)	10 ³ \$	1,034.0	639.1	927.5	827.1	827.1	827.1
O.	Uranium Depletion (M-N)	10 ³ \$	2,046.8	3,076.7	4,010.1	3,952.3	3,952.3	3,952.3
P.	Value of Plutonium (KxL)	10 ³ \$	447.6	562.8	622.2	620.4	620.4	620.4
Q.	Core Fabrication	10 ³ \$	2,064	2,064	2,064	1,824	1,824	1,824
V.	Ship Spent Fuel and Cask(s)	10 ³ \$	320	320	320	320	320	320
X.	Ship to Site, Storage, and Testing	mo	7	7	7	3	3	3
Z.	Cooling	mo	5	5	5	5	5	5
AA.	Ship to Reprocessing Site	mo	4	4	4	4	4	4
BB.	Reprocessing	mo	3	3	3	3	3	3
CC.	Monthly Carrying charge on Fuel	%	0.75	0.75	0.75	0.75	0.75	0.75
DD.	Monthly Commercial Interest Rate	%	0.75	0.75	0.75	0.75	0.75	0.75
R.	Reprocessing							
a.	Reprocessing Unit Cost	\$/KgU	33	33	33	33	33	33
b.	Product (a × F)	10 ³ \$	516.78	509.52	506.22	505.89	505.89	505.89
c.	Uranyl Nitrate to UF ₆ Conversion (5.6 × 0.99 × F)	10 ³ \$	87	86	85	85	85	85
d.	R = (b + c)	10 ³ \$	603.78	595.52	591.22	590.89	590.89	590.89
S.	Losses in Reprocessing							
a.	Plutonium	w/o	2.0	2.0	2.0	2.0	2.0	2.0
b.	Uranium	w/o	2.0	2.0	2.0	2.0	2.0	2.0
T.	Value of Reprocessing Losses							
a.	Plutonium = P × Sa	10 ³ \$	8.95	11.26	12.44	12.41	12.41	12.41
b.	Uranium = N × Sb	10 ³ \$	20.68	12.78	18.54	16.54	16.54	16.54
c.	T = (a + b)	10 \$	29.63	24.04	30.98	28.95	28.95	28.95
RR.	Total Reprocessing Cost = R+T	10 ³ \$	633.41	619.56	622.20	619.84	619.84	619.84
FF.	Interest Charge for Core Fabrication							
	During Fabrication + [Q×DD/100(X+Y/2)]							
a.	During Fabrication (per payment schedule)	10 ³ \$	181.12	181.12	181.12	61.56	61.56	61.56

<i>Normal</i>						<i>Better</i>					
1	2	3	4	5	6	1	2	3	4	5	6
623.0	640.8	537.0	605.2	593.0	593.0	623.0	640.8	530.7	605.2	593.3	593.2
9,120	15,460	22,240	19,990	20,390	20,390	9,120	15,460	22,240	19,990	20,390	20,390
17.80	30.17	43.40	39.01	39.39	39.79	14.66	24.85	35.74	32.13	32.77	33.77
14,800	25,800	31,100	31,500	31,500	31,500	14,800	25,800	31,100	31,500	31,500	31,500
16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000
15,660	15,440	15,340	15,330	15,330	15,330	15,660	15,440	15,340	15,330	15,330	15,330
2.4	2.77	3.47	3.38	3.38	3.38	2.4	2.77	3.47	3.38	3.38	3.38
176.47	213.46	284.69	275.46	275.46	275.46	162.39	196.11	263.77	255.10	255.10	255.10
1.16	0.89	1.10	1.03	1.03	1.03	1.16	0.89	1.10	1.03	1.03	1.03
59.20	36.51	54.00	48.04	48.04	48.04	52.65	32.10	48.24	42.75	42.75	42.75
74.6	93.8	103.7	103.4	103.4	103.4	74.6	93.8	103.4	103.4	103.4	103.4
8,000	8,000	8,000	8,000	8,000	8,000	10,000	10,000	10,000	10,000	10,000	10,000
2,823.5	3,425.4	4,550.0	4,407.4	4,407.4	4,407.4	2,598.2	3,137.8	4,220.0	4,081.6	4,081.6	4,081.6
927.1	563.7	828.4	736.5	736.5	676.5	824.5	495.6	740.0	655.4	655.4	655.4
1,996.4	2,851.7	3,726.6	3,670.9	3,670.9	3,670.9	1,773.7	2,642.2	3,480.0	3,426.2	3,426.2	3,426.2
596.8	750.4	829.6	827.2	827.2	827.2	746.0	938.0	1,037.0	1,034.0	1,034.0	1,034.0
1,904	1,904	1,904	1,664	1,664	1,664	1,584	1,584	1,584	1,424	1,424	1,424
224	224	224	224	224	224	160	160	160	160	160	160
6	6	6	3	3	3	4	4	4	2	2	2
4	4	4	4	4	4	3	3	3	3	3	3
3	3	3	3	3	3	2	2	2	2	2	2
3	3	3	3	3	3	2	2	2	2	2	2
0.625	0.625	0.625	0.625	0.625	0.625	0.5	0.5	0.5	0.5	0.5	0.5
0.625	0.625	0.625	0.625	0.625	0.625	0.5	0.5	0.5	0.5	0.5	0.5
31.5	31.5	31.5	31.5	31.5	31.5	30	30	30	30	30	30
493.3	486.4	483.2	482.9	482.9	482.9	469.8	463.2	460.2	459.9	459.9	459.9
87	86	85	85	85	85	87	86	85	85	85	85
580.3	572.4	568.2	567.9	567.9	567.9	556.8	549.2	545.2	544.9	544.9	544.9
1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8
1.3	1.3	1.3	1.3	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5.97	7.50	8.30	8.27	8.27	8.27	6.60	3.96	5.92	5.24	5.24	5.24
12.05	7.33	10.76	9.57	9.57	9.57	8.25	4.96	7.40	6.55	6.55	6.55
18.02	14.83	19.06	17.84	17.84	17.84	14.85	8.92	13.32	11.79	11.79	11.79
598.32	587.23	587.26	585.74	585.74	585.74	571.65	558.12	558.52	556.69	556.69	556.69
13.23	139.23	139.23	46.8	46.8	46.8	92.66	92.66	92.66	32.04	32.04	32.04

Item		1	2	3	4	5	6
b. X (Repeat Regions Only)	mo	included in a. above			3	3	3
c. Y/2	mo	11.23	19.20	27.62	24.83	25.33	25.33
d. (b + c)	mo	11.33	19.20	27.62	27.83	28.33	28.33
e. Q × DD/100 × (d)	10 ³ \$	175.39	297.22	427.56	380.71	387.55	387.55
f. Total Interest Charge (a+e)	10 ³ \$	356.51	478.34	608.68	442.27	449.11	449.11
GG. Fuel Carrying Charge CC/100 [(M×X)+{(M+N)/2×Y}+[N(Z+AA+BB)]] + Other Estimated Charges							
a. (Z + AA + BB)	mo	12	12	12	12	12	12
b. (M × X)	10 ³ \$—mo	21,567	26,012	34,566	14,337	14,337	14,337
c. (M+N)×Y/2	10 ³ \$—mo	46,623	83,616	161,991	139,197	142,000	142,000
d. N (a)	10 ³ \$—mo	12,408	7,669	11,130	9,925	9,925	9,925
e. b+c+d	10 ³ \$—mo	80,598	117,297	207,687	163,459	166,262	166,262
f. CC/100 (e)	10 ³ \$	604.49	879.73	1,557.65	1,225.94	1,246.97	1,246.97
g. Other Estimated Charges	10 ³ \$	346.14	243.58	319.36	309.57	309.57	309.57
h. GG=f+g	10 ³ \$	950.63	1,123.31	1,877.01	1,535.51	1,556.54	1,556.54
HH. Capital Set Aside to Pay for Reprocessing and Reprocessing Losses							
a. (Y/2+Z+AA+BB)	mo	23.33	31.20	39.62	36.83	37.33	37.33
b. DD/100×(a)+1		1.175	1.234	1.297	1.276	1.280	1.280
c. HH=RR/b	10 ³ \$	539.07	502.07	479.72	485.77	484.25	484.25
II. "Effective" Plutonium Credit							
a. Item (b) of HH		1.175	1.234	1.297	1.276	1.280	1.280
b. P/a (Credit)	10 ³ \$	380.94	456.08	479.72	486.21	484.69	484.69
KK. Capital Set Aside to Pay for Ship of Spent Fuel and cask(s)							
a. (Y/2+Z+AA)	mo	20.33	28.20	36.62	33.83	34.33	34.33
b. DD/100×(a)+1		1.152	1.122	1.275	1.254	1.257	1.257
c. KK = V/a	10 ³ \$	277.78	264.03	250.98	255.18	254.57	254.57
Results							
O. Uranium Depletion	10 ³ \$	2,046.8	3,076.7	4,010.1	3,952.3	3,952.3	3,952.3
Q. Core Fabrication	10 ³ \$	2,064	2,064	2,064	1,824	1,824	1,824
FF. Interest Charge for Core Fabrication	10 ³ \$	356.51	478.34	608.68	442.27	449.11	449.11
GG. Fuel Carrying Charge	10 ³ \$	950.63	1,123.31	1,877.01	1,535.51	1,556.54	1,556.54
HH. Capital Set Aside to Pay for Reprocessing and Reprocessing Losses	10 ³ \$	539.07	502.07	479.72	485.77	484.25	484.25
II. "Effective" Plutonium Credit	10 ³ \$	380.94	456.08	479.42	486.21	484.69	484.69
KK. Capital Set Aside to Pay for Ship of spent Fuel and (Casks)	10 ³ \$	277.78	264.03	250.98	255.18	254.57	254.57
LL. Total O through KK above	10 ³ \$	5,853.85	7,052.37	8,811.07	8,008.82	8,036.08	8,036.08
MM. (Thermal) Energy	10 ¹¹ BTU	193.97	338.13	407.59	412.84	412.84	412.84
NN. Fuel Cost (LL/MM)	¢/10 ⁶ BTU	30.18	20.86	21.62	19.40	19.47	19.47
Average (Per Core)	¢/10 ⁶ BTU		23.11			19.45	
Average (in Mill)	Mill/KWH		2.293			1.929	

*Thermal Efficiency 9920 BTU/KWH

Normal						Better					
1	2	3	4	5	6	1	2	3	4	5	6
included in a above			3	3	3	included in a above			2	2	2
8.09	15.09	21.0	19.51	19.90	19.90	7.33	12.43	17.87	16.37	16.39	16.39
8.90	15.09	21.70	22.51	22.90	22.90	7.33	12.43	17.87	18.07	18.39	18.39
105.91	179.57	158.22	234.09	238.15	238.15	58.05	98.45	141.53	128.66	130.94	130.94
245.14	318.80	397.45	280.89	284.95	284.95	150.71	191.11	234.19	160.70	621.98	162.98
10	10	10	10	10	10	7	7	7	7	7	7
16,944	20,490	27,330	13,221	13,221	13,221	10,393	12,551	16,881	8,163	8,163	8,163
33,384	60,923	116,811	100,340	102,320	102,320	25,088	45,163	88,641	761,24	77,639	77,639
9,270	5,640	8,280	7,360	7,360	7,360	5,772	3,469	5,180	4,588	4,588	4,588
59,598	86,153	152,421	120,091	122,901	122,901	41,253	61,183	110,702	88,875	90,390	90,390
372.49	538.46	952.63	755.76	768.13	768.13	206.27	305.92	553.90	444.38	451.95	451.95
258.7	182.2	240.4	232.9	232.9	232.9	186.2	131.3	173.9	168.5	168.5	168.5
631.19	720.66	1,193.03	988.66	1,001.03	1,001.03	392.47	437.22	727.40	612.88	620.45	620.45
18.90	25.09	31.70	29.51	29.90	29.90	14.33	19.43	24.87	23.07	23.39	23.39
1.118	1.157	1.198	1.184	1.187	1.187	1.072	1.097	1.124	1.115	1.117	1.117
535.17	507.55	490.20	494.71	493.46	493.46	533.26	508.77	496.90	499.27	498.38	498.38
1.118	1.157	1.198	1.184	1.187	1.187	1.072	1.097	1.124	1.115	1.117	1.117
533.81	648.57	692.49	698.65	696.88	696.88	695.90	855.06	922.60	937.35	925.69	925.69
15.90	22.09	28.70	26.51	26.90	26.90	12.33	17.43	22.87	21.07	21.39	21.39
1.095	1.138	1.179	1.166	1.168	1.168	1.062	1.087	1.114	1.105	1.107	1.107
204.57	196.84	190.00	192.11	191.78	191.78	150.66	147.19	143.63	144.80	144.53	144.5
1,986.4	2851.7	3,726.6	3,670.9	3,670.9	3,670.9	1,773.7	2,642.2	3,480.0	3,426.2	3,426.2	3,426.2
19,04	19,04	1,904	1,664	1,664	1,664	1,584	1,584	1,584	1,424	1,424	1,424
245.14	318.80	397.45	280.89	284.95	284.95	150.71	191.11	234.19	160.70	162.98	192.98
631.19	720.66	1,193.03	988.66	1,001.03	1,001.03	392.47	437.22	727.40	612.88	620.45	620.45
535.17	507.55	490.20	494.71	493.46	493.46	533.26	508.77	496.90	499.27	498.38	498.38
533.81	648.57	692.49	698.65	696.88	696.88	695.90	855.06	922.60	927.35	925.69	925.6
204.57	196.84	190.00	192.11	191.78	191.78	150.66	147.19	143.63	144.80	144.53	144.53
4,882.66	5,850.98	7,208.79	6,592.62	6,609.24	6,609.24	3,88.908	4,655.43	5,743.52	5,340.90	5,350.85	5,350.85
193.97	338.13	407.59	412.84	412.84	412.84	193.97	338.13	407.59	412.84	412.84	412.84
25.18	17.30	17.69	15.97	16.01	16.01	20.05	13.77	14.09	12.94	12.96	12.96
	19.10			16.00			15.21			12.80	
	1.895			1.587			1.509			1.270	

4. Computed Numbers in Better and

Item	Change Region	Better					
		1	2	3	4	5	6
1. Y2 (Y: Region Lifetime) mo	70%—85%	7.33	12.43	17.87	16.37	16.39	16.39
FF. Deviation from the Normal		-18.69	-31.67	-45.58	-35.77	-36.51	-36.51
GG. Deviation from the Normal		-36.81	-66.15	-128.86	-110.57	-112.86	-112.86
HH. Deviation from the Normal		+4.83	+7.56	+10.00	+8.94	+9.32	+9.32
II. Deviation from the Normal		(+4.82)	(+9.68)	(14.15)	(12.61)	(13.16)	13.16)
KK. Deviation from the Normal		+0.93	+2.98	+3.94	+3.69	+3.68	+3.68
Sub Total		-54.56	-96.96	-174.65	-146.32	-149.53	-149.53
Ratio to Total Cost		-1.12	-1.66	-2.42	-2.22	-2.26	-2.26
2. Interest Rate & Fuel Carrying Charge	7.5%—6%						
FF. Deviation from the Normal		-49.03	-63.76	-79.49	-56.16	-56.98	-56.98
GG. Deviation from the Normal		-125.10	-144.10	-238.52	-197.65	-200.02	-200.02
HH. Deviation from the Normal		+11.24	+14.43	+16.50	+15.52	+15.88	15.88
II. Deviation from the Normal		(+11.21)	(+18.45)	(+23.30)	(+21.91)	(+22.42)	(+22.42)
KK. Deviation from the Normal		+2.10	+4.96	+5.80	+5.60	+5.58	+5.58
Sub Total		-172.00	-206.92	-319.01	-254.60	-257.96	-257.96
Ratio to Total Cost		-3.52	-3.54	-4.43	-3.86	-3.90	-3.90
3. Uranium Ore Price (U ₃ O ₈)	7.75 \$/lb—6.5 \$/lb						
D. Deviation from the Normal		-124.7	-210.2	-247.3	-245.2	-245.2	-245.2
GG. Deviation from the Normal		-59.33	-65.14	-98.37	-82.95	-83.77	-83.77
Sub Total		-184.03	-275.34	-345.67	-328.15	-328.97	-328.97
Ratio to Total Cost		-3.77	-4.71	-4.80	-4.98	-4.98	-4.98
4. Fabrication (+Transportation)	119—99 \$/kg 104—89 \$/kg						
Q. Deviation from the Normal		-320	-320	-320	-240	-240	-240
FF. Deviation from the Normal		-41.20	-53.58	-66.79	-40.55	-41.09	-41.09
Sub Total		-361.20	-373.58	-386.79	-280.55	-281.09	-281.09
Ratio to Total Cost		-7.40	-6.39	-5.37	-4.26	-4.25	-4.25
5. Ship Spent Fuel and Cask	14,000—10,000 \$/T						
KK. Deviation from the Normal		-58.45	-56.24	-54.29	-54.89	-54.79	-54.79
Ratio to Total Cost		-1.19	-0.96	-0.75	-0.83	-0.82	-0.82
6. Reprocessing Cost	31.5—30.0 \$/kgU						
R. Deviation from the Normal		-23.5	-23.2	-23.0	-23.0	-23.0	-23.0
Ratio to Total Cost		-0.48	-0.39	-0.31	-0.34	-0.34	-0.34
7. Ship to Site, Storage and Testing	6—4 mo 3—2 mo						
FF. Deviation from the Normal		0	0	0	-10.38	-10.39	-10.39
GG. Deviation from the Normal		-38.30	-42.68	-56.93	-27.54	-27.54	-27.54
Sub Total		-35.30	-42.68	-56.93	-37.93	-37.93	-37.93
Ratio to Total Cost		-0.72	-0.72	-0.79	-0.58	-0.57	-0.57
8. Cooling	4—3 mo						
GG. Deviation from the Normal		-5.80	-3.52	-5.17	-4.60	-4.60	-4.60
HH. Deviation from the Normal		+2.89	+2.64	+2.47	+2.52	+2.51	+2.51
II. Deviation from the Normal		(+2.88)	(+3.38)	(+3.48)	(+3.56)	(+3.54)	(+3.54)
KK. Deviation from the Normal		+0.56	+1.04	+0.96	+1.16	+0.99	+0.99

Worse Conditions

<i>Change</i> <i>Region</i>	1	2	3	<i>Worse</i> 4	5	6
70%—55%	11.33 +28.91 +56.96 -7.09 (-7.07) -3.67 +82.18 +1.68	19.20 +48.91 +102.21 -11.16 (-14.25) -4.40 +149.81 +2.56	27.62 +70.45 +199.14 -14.69 (-20.75) -5.79 +269.86 +3.74	24.83 +55.33 +170.97 -13.81 (-19.50) -5.29 +226.70 +3.44	25.33 +56.48 +174.53 -13.74 (-19.40) -5.42 +231.25 +3.50	25.33 +56.48 +174.53 -13.74 (-19.40) -5.42 +231.25 +3.50
7.5%—9%	+49.03 +126.70 -11.25 (-11.22) -4.39 +171.31 +3.51	+63.75 +144.29 -13.25 (-16.92) -4.73 +206.98 +3.54	+79.51 +238.73 -15.84 (-22.38) -5.64 +319.14 +4.43	+56.19 +197.75 -14.99 (-21.17) -5.29 +254.83 +3.87	+57.0 +200.23 -14.91 (-21.06) -5.42 +257.96 +3.90	+57.0 +200.23 -14.91 (-21.06) -5.42 +257.96 +3.90
7.75 \$/lb—9.0 \$/lb	+150.4 +66.60 +217.0 +4.44	+225.0 +72.33 +297.33 +5.08	+283.50 +111.69 +395.19 +5.48	+281.4 +93.97 +375.37 +5.69	+281.4 +95.26 +376.66 +5.70	+281.4 +95.26 +376.66 +5.70
119—129 \$/kg 104—114 \$/kg	+160 +20.60 +180.60 +3.70	+160 +26.79 +186.79 +3.19	+160 +33.41 +193.41 +2.68	+160 +27.02 +187.02 +2.84	+160 +27.41 +187.41 +2.84	+160 +27.41 +187.41 +2.84
14,000—20,000 \$/T	+87.67 +1.79	+84.36 1.44	+81.42 1.12	+82.33 1.24	+82.19 1.24	+82.19 1.24
31.5—33.0 \$/kgU	+23.5 +0.48	+23.1 +0.39	+23.0 +0.31	+23.0 +0.34	+23.0 +0.34	+23.0 +0.34
	0 +17.65 +17.65 +0.36	0 +21.35 +21.35 +0.36	0 +28.47 +28.47 +0.39	10.40 +27.55 +37.95 +0.58	10.41 +27.55 +37.96 +0.57	10.41 +27.55 +37.96 +0.57
4—5 mo	+5.79 -2.86 (-2.85) +1.12	+3.53 -2.62 (-3.34) +1.04	+5.18 -2.44 (-3.45) +1.13	+3.40 -2.90 (-4.11) +0.98	+3.40 -2.48 (-3.50) +0.98	+3.40 -2.48 (-3.50) +0.98

4. Computed Number (Continued)

Item	Change Region	Better					
		1	2	3	4	5	6
Sub Total		-5.23	-3.22	-5.22	-4.48	-4.64	-4.64
Ratio to Total Cost		-0.10	-0.05	-0.07	-0.06	-0.07	-0.07
9. Ship to Reprocessing Site	3—2 mo						
GG. Deviation from the Normal		Same as 8					
HH. Deviation from the Normal		Same as 8					
II. Deviation from the Normal		Same as 8					
KK. Deviation from the Normal		Same as 8.					
Sub Total							
Ratio to Total Cost							
10. Reprocessing	3—2 mo						
GG. Deviation from the Normal		Same as 8. GG					
HH. Deviation from the Normal		Same as 8. HH					
II. Deviation from the Normal		Same as 8. II					
Sub Total		-5.79	-4.26	-6.18	-5.64	-5.63	-5.63
Ratio to Total Cost		-0.11	-0.07	-0.08	-0.08	-0.08	-0.08
11. Losses	Pu 1.0—0.8 w/o U 1.3—1.0 w/o						
T. Deviation from the Normal		-3.98	-3.19	-4.14	-3.86	-3.86	-3.86
Ratio to Total Cost		-0.08	-0.05	-0.05	-0.05	-0.05	-0.05
12. Plutonium Credit (Fissile)	8—10 \$/gm						
II. Deviation from the Normal		(133.45)	(162.15)	(173.12)	(174.66)	(174.12)	(174.12)
Ratio to Total Cost		(+2.73)	(+2.77)	(+2.40)	(2.64)	(+2.63)	(+2.63)

5. Results

Item	Region		1		2		3		4		5		6		Total (p)	P
	R	P	R	P	R	P	R	P	R	P	R	P	R	P		
1. Plant Capacity Factor	1.12	6	1.66	5	2.42	4	2.22	5	2.26	5	2.26	5	30		4	
2. Interest Rate	3.52	3	3.54	3	4.43	3	3.86	3	3.90	3	3.90	3	18		2	
3. U ₃ O ₈ Price	3.77	2	4.71	2	4.80	2	4.98	1	4.98	1	4.98	1	9		1	
4. Fabrication Cost	7.40	1	6.39	1	5.37	1	4.26	2	4.25	2	4.25	2	9		1	
5. Ship Spent Fuel and Cask	1.19	5	0.96	6	0.75	7	0.83	6	0.82	6	0.82	6	36		5	
6. Reprocessing Cost	0.48	8	0.39	8	0.31	8	0.34	8	0.34	8	0.34	8	48		7	
7. Ship to Site, Storage and Testing	0.72	7	0.73	7	0.79	6	0.58	7	0.57	7	0.57	7	41		6	
8. Cooling	0.10	10	0.05	10	0.07	10	0.06	10	0.07	10	0.07	10	60		9	
9. Ship to Reprocessing Site	0.10	10	0.05	10	0.07	10	0.06	10	0.07	10	0.07	10	60		9	
10. Reprocessing	0.11	9	0.07	9	0.08	9	0.08	9	0.08	9	0.08	9	54		8	
11. Losses	0.08	11	0.05	10	0.05	11	0.05	11	0.05	11	0.05	11	65		10	
12. Plutonium Credit	2.73	4	2.77	4	2.40	5	2.64	4	2.63	4	2.63	4	25		3	

Item 7, 8, 9, 10: Terms

R: Rate to Total Cost in Percentage

P: Priority Order

Change	Region	Worse					
		1	2	3	4	5	6
3—4 mo		+4.66	+3.21	+5.06	+3.63	+3.44	+3.44
		+0.09	+0.05	+0.07	+0.05	+0.05	+0.05
		Same as 8.					
3—4 mo		Same as 8. GG					
		Same as 8. HH					
		Same as 8. II					
		+5.78	+4.25	+6.19	+4.61	+4.42	+4.42
		+0.11	+0.07	+0.08	+0.06	+0.06	+0.06
Pu 1.0—2.0 w/o							
U 1.3—2.0 w/o		+12.46	+11.46	+14.09	+13.42	+13.42	+13.42
		+0.25	+0.19	+0.19	+0.20	+0.20	+0.20
8—6 \$/gm		(-133.45)	(-162.14)	(-173.12)	(-174.66)	(-174.22)	(-174.22)
		(-2.73)	(-2.77)	(-2.40)	(-2.64)	(-2.63)	(-2.63)

6. NOTE

- The symbols and nomenclature used in the calculation were adopted from Westinghouse's quotation for our convenience's sake.
- In all computation, the normal condition was set forth as the standard price. We have deduced, from this standardized normal price, the percentage of influence of each component, which gives effect to the total fuel cycle cost, with the arbitrary but quite reasonable assumption of better and worse conditions.
- "+" marked in the table means increase in price, while "-" means decrease in price. (Computed numbers in better and worse conditions)
- Prices in Item 9 (Ship to Reprocessing Site) are same as those in Item 8. (Computed numbers in better and worse conditions)
- GG, HH, II in Item 10 (Reprocessing) are also same as those in Item 8, respectively. (Computed numbers in better and worse conditions)
- Fuel carrying charge for core fabrication was applied in the calculation being based upon progressive payment (installment) schedule.
- Other Estimated Charges
The time period which is a function of fuel carrying charge was assumed as follows:
Ore Purchase—Conversion to UF_6 : 2 months
Enrichment : 3 months
Fabrication : 6 months
- In all fabrication cost, \$4.00/KgU for the freight and insurance from the vender to Pusan was included.
- With the assumption of better and worse conditions, the priority order in number (the most dominant factor in the total fuel cycle cost was placed as number one, and the least factor as the last) is Uranium Ore Price and Fabrication are both the first, Interest Rate the second, Plutonium Credit the third, Plant Capacity Factor the fourth, etc.