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NUCLEAR POWER COSTS

Note by the Director General

1. In order to provide the General Conference with the latest data available to the Secretariat on the costs of nuclear power, the Director General has arranged for the preparation of the attached paper which contains information supplementing that already submitted to the General Conference at its fourth and fifth regular sessions[1].

2. Information is given on the cost of construction of a number of plants already built or being constructed, as well as on some the construction of which is planned for the near future. In addition, data available to the Secretariat up to 15 August 1962 on the operating costs of nuclear stations now in service has also been provided.

[1] GC(IV)/123 and GC(V)/INF/38.

LIST OF ABBREVIATIONS

g	gram
kg	kilogram
t	metric ton
kW	kilowatt
kWe	kilowatt electrical
kWh	kilowatt-hour
MW	megawatt
MWd	megawatt-day
MWe	megawatt electrical
Pu	plutonium
U	uranium
mill	one-thousandth of a dollar

All sums of money are expressed in United States dollars.

NUCLEAR POWER COSTS

New data obtained by the Secretariat up to 15 August 1962

1. In the past two years, the Secretariat has submitted to the General Conference two rather broad and general reviews of information on nuclear power costs[1]. In both of these papers the total cost of generating electricity was broken down into its various components, each of which was then discussed in detail. In addition information useful for the proper understanding of nuclear cost data was also given. Although all this information is still relevant, it has not been considered necessary to repeat it, and only current and up-to-date cost data on existing reactors and those under construction or being planned are presented here. Operating costs whenever available to the Secretariat have also been shown. The information thus provided is more specific than that contained in the reports referred to above, in that the costs relate to particular nuclear power stations rather than reactor types.

2. Even for reactors already in operation and under construction, such fundamental parameters as unit investment costs and total fuel costs may be substantially changed by technological developments. With regard to the former, more power may be obtained in some cases with improved cores with a corresponding lowering of the capital cost per unit. As to the latter, higher future burn-ups and lower fabrication costs may have to be balanced against lower credits for plutonium. Hence, the present figures should be regarded as indications rather than as final data.

3. The economic and technical assumptions on which generating costs have been calculated have been stated in each case. To evaluate the comparative merits of different reactor systems in relation to the requirements of, and the conditions obtaining in, any country, it would be necessary to compute generating costs on a normalized basis, using for all reactor systems the economic parameters which are considered applicable to that particular case.

4. The capital costs given in Table I are presented graphically in Figures 1 to 4. Each of these figures relates to a different reactor type. Actual costs of individual plants of a given type are shown as specific points on the graph concerned. The curves represent estimates of the cost for various sizes of that type of reactor, if built in the United States of America. These estimates, which are based on the studies made by USAEC in 1959 and 1960 in connection with the civilian power-reactor programme, were communicated to the General Conference last September in document GC(V)/INF/38. Now, for the first time, it has been possible to compare some of the estimates made earlier with actual costs in the case of a large number of plants. However, no trends in construction costs should be inferred, or other broad comparisons and extrapolations made, based on these figures. Many of the plants are types that have been built for the first time or incorporate experimental features which would not be typical of future plants built solely as commercial power stations.

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[1] GC(IV)/123 and GC(V)/INF/38.

TABLE I

CAPITAL COSTS[a]

Station	Location	Net electrical output in MWe	Capital investment in millions of $	Unit capital investment in $/net kWe	Remarks
Pressurized light water					
YANKEE	Rowe, Mass., United States	141	39.2	278	
INDIAN POINT	Indian Point, N.Y., United States	255	110	431	Oil-fired superheater contributes 104 of the 255 MWe.
SELNI	Trino, Italy	175	56.4	320	
SOUTHERN CALIFORNIA EDISON	California, United States	355	78	220	
Boiling light water					
DRESDEN	Morris, Ill., United States	184	51.3	279	
KAHL	Kahl am Main, Germany	16	8.75	550	
ELK RIVER	Elk River, Minn., United States	20.5	10.9	534	Coal-fired superheater contributes about 7 of the 20.5 MWe.
PATHFINDER	Sioux Falls, S. Dak., United States	62	22.5	363	Nuclear superheat.
BIG ROCK POINT	Big Rock Point, Mich., United States	48.5[b]	27.4	565	
HUMBOLDT BAY	Eureka, Calif., United States	48.5[b]	20.6	425	
SENN[c]	Near Naples, Italy	150	64	425	
BONUS	Punta Higuera, Puerto Rico	16.5	12	730	Nuclear superheat.
JPDR	Tokai Mura, Japan	11.7	11.5	985	
BODEGA BAY	Bodega Head, Calif., United States	313	61.5	197	
Gas-cooled					
BERKELEY[d]	Berkeley, Gloucester, United Kingdom	275	129	470	
BRADWELL[d]	Bradwell, Essex, United Kingdom	300	140	465	
HINCKLEY POINT "A"[d]	Bridgewater, Somerset, United Kingdom	500	192	384	
TRAWSFYNYDD[d]	Trawsfynydd, Wales, United Kingdom	500	180	361	
DUNGENESS "A"[d]	Dungeness, Kent, United Kingdom	550	166	302	
SIZEWELL "A"[d]	Sizewell, Suffolk, United Kingdom	580	169	291	
OLDBURY "A"[d]	Oldbury, Gloucester, United Kingdom	560	169	302	

Station	Location	Net electrical output in MWe	Capital investment in millions of $	Unit capital investment in $/net kWe	Remarks
EDF-1[e]	Chinon, France	60	51.4	856	Preliminary design cost, interest during construction, start-up costs and contingency are not included.
EDF-2[e]	Chinon, France	200	71.4	357	
EDF-3[e]	Chinon, France	480	118	246	
EL-4[e]	France	78.5	48	612	
LATINA[c]	Latina, Italy	200	75.8	379	
GCR-TOKAI MURA	Tokai Mura, Japan	157	85.6	546	
EGCR	Oak Ridge, Tenn., United States	22	40.6	1 850	Cost of four in-reactor loops included.
PEACH BOTTOM	Peach Bottom, Pa., United States	40	28.5	712	
Pressurized heavy water					
NPD-2[b]	Rolphton, Ont., Canada	20	30	1 500	
CAROLINAS-VIRGINIA	Parr, S.C., United States	17	19.4	1 140	
R-3	Agesta, Sweden	9	25		Reactor initially furnishes 55 MW of steam plus 9 MW (net) of electricity.
CANDU[f]	Douglas Point, Ont., Canada	202	81.5	403	
R-4	Marviken, Sweden	105	63.5	600	
UP-RATED NPD[g]	Rolphton, Ont., Canada	73	36.3	500	
Organic					
PIQUA	Piqua, Ohio, United States	11.4	7.59	665	
Sodium graphite					
SHELDON	Hallam, Nebr., United States	76	51.2	675	
Fast					
EBR-II	Idaho Falls, Idaho, United States	17.4	25.3	1 450	
FERMI	Lagoona Beach, Mich., United States	90	65	723	

a/ Unless designated otherwise, the cost figures given in this table were taken from: FELSEN, W.L., "7th Report on Nuclear Power", Electrical World, Vol. 157, No. 21, New York, N.Y. (21 May 1962), p. 92-100; the data which were obtained from utilities and USAEC proved to be in excellent accord with the information made available to the Agency.

b/ Source: Costs of Nuclear Power, TID-8531 (Rev.), USAEC, Washington, D.C. (January 1961), p. 8.

c/ Source: Communication of the Italian Comitato Regionale per l'Energia Nucleare, Rome.

d/ Source: Communication of the United Kingdom Atomic Energy Authority, London.

e/ Source: Communication of the French Commissariat à l'Energie Atomique, Paris.

f/ Source: Communication of the Atomic Energy of Canada Limited, Chalk River, Ontario.

g/ Source: Preliminary results of a study made by Canadian General Electric Company Ltd., Toronto (hence this reactor is not in the same category as the others) and communications of Canadian General Electric Company Ltd. and Atomic Energy of Canada Limited, Chalk River, Ontario.

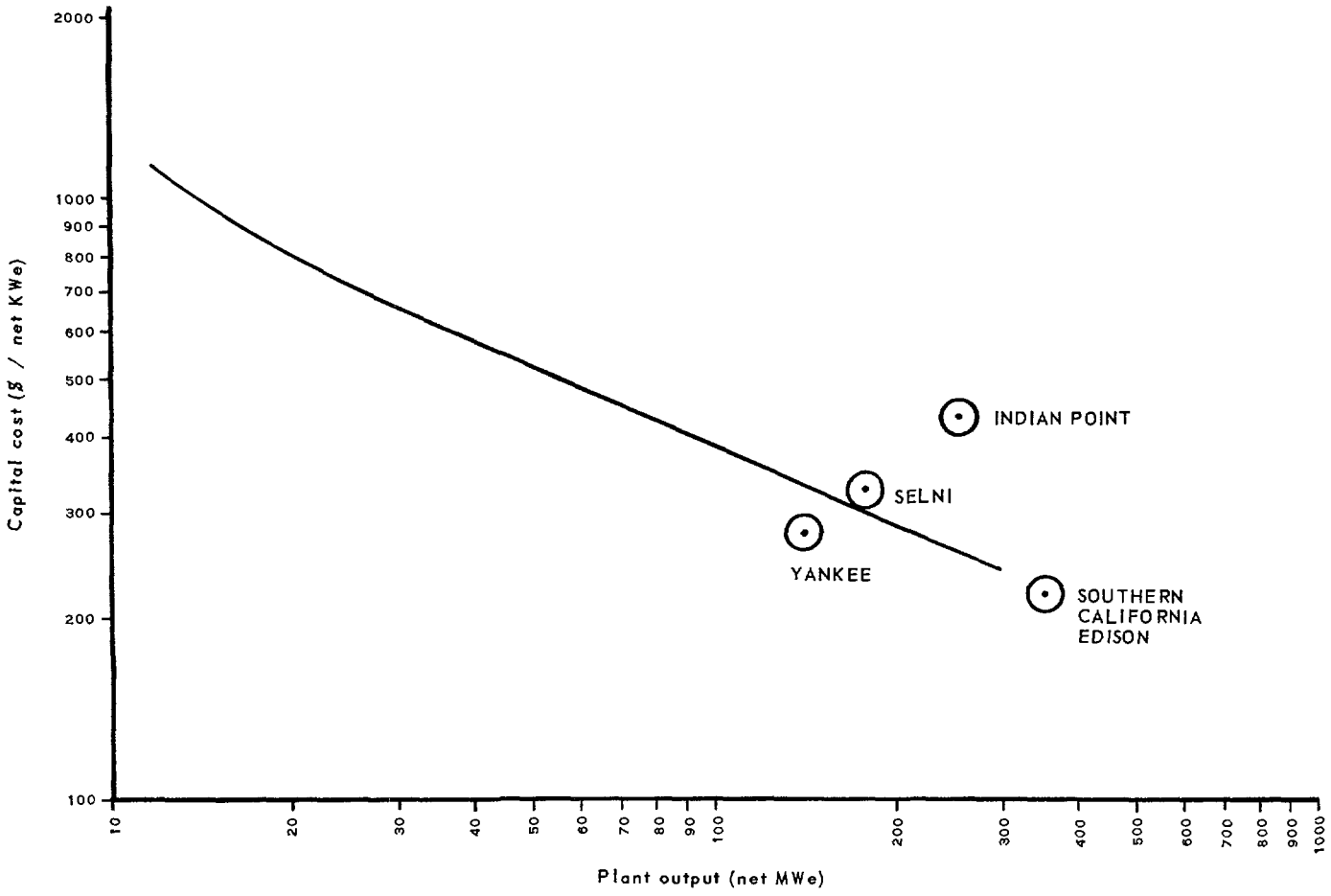

Figure 1

Capital Costs of Nuclear Power Plants

for Pressurized-Water Reactors

○ Actual costs

Costs estimated in 1959-60, as given in USAEC reports TID-8516 and TID-8535

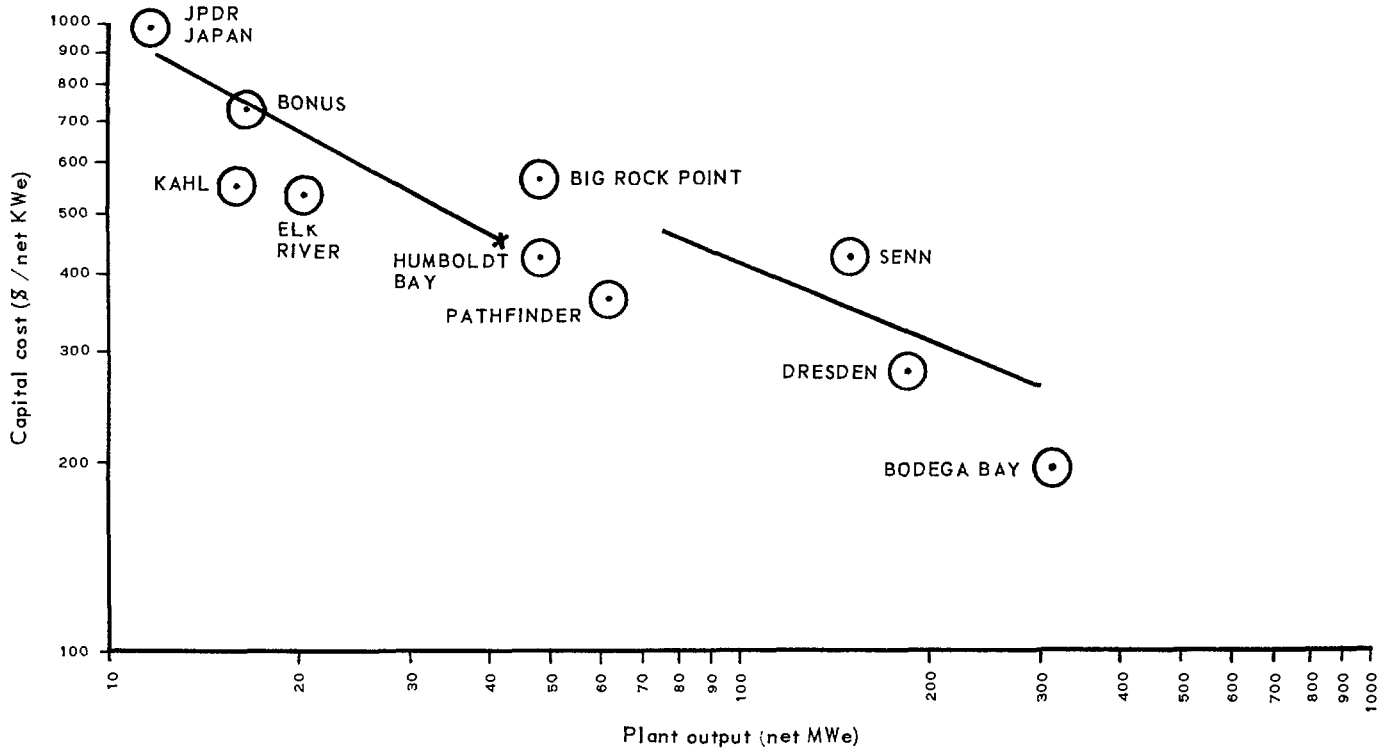

Figure 2

Capital Costs of Nuclear Power Plants for Boiling-Water Reactors

○ Actual costs

——— Costs estimated in 1959-60, as indicated in USAEC reports TID-8516 and TID-8535

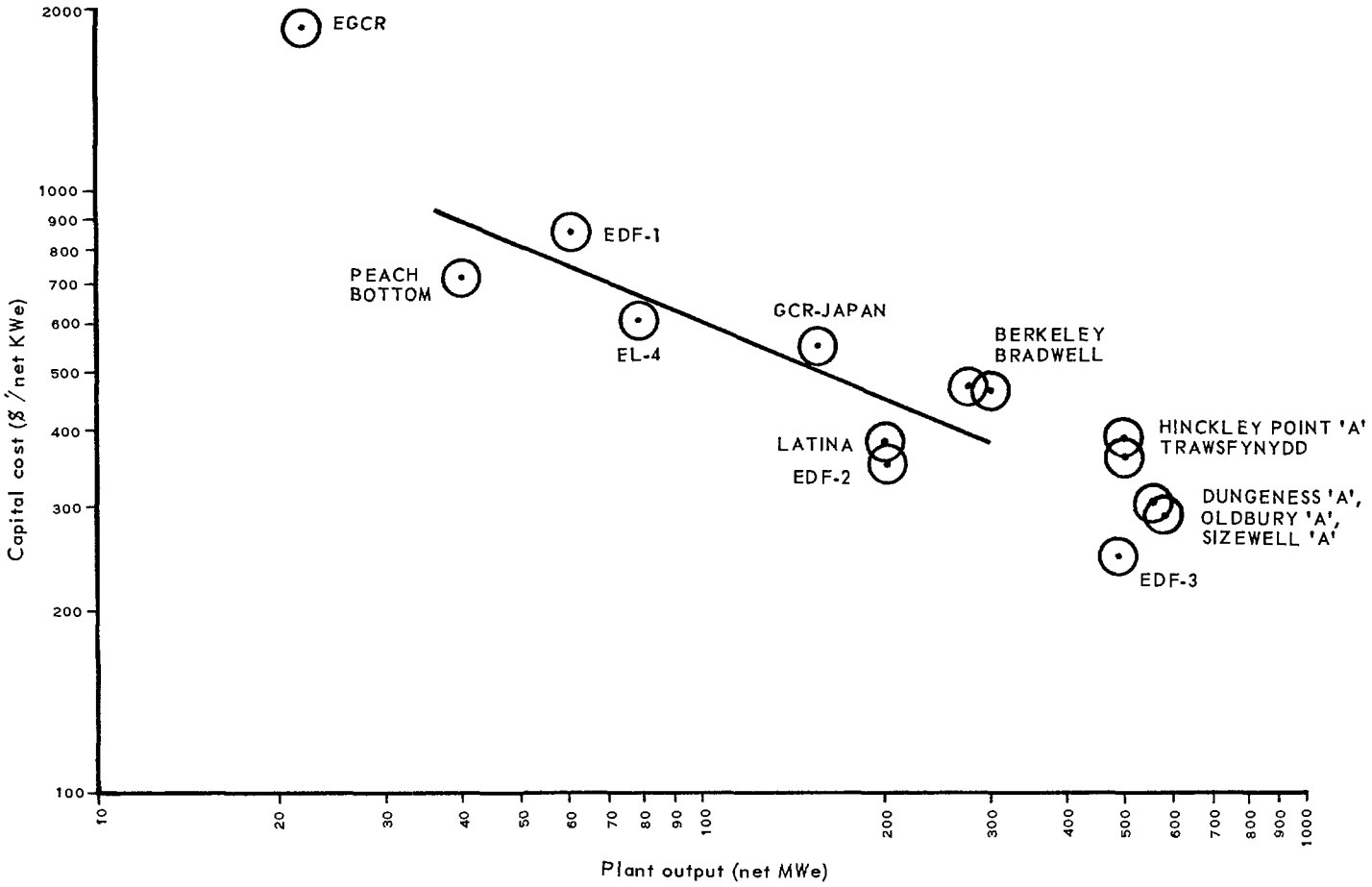

Figure 3

Capital Costs of Nuclear Power Plants for Gas-Cooled Reactors

○ Actual costs

——— Costs estimated in 1959-60, as indicated in USAEC reports TID-8516 and TID-8535

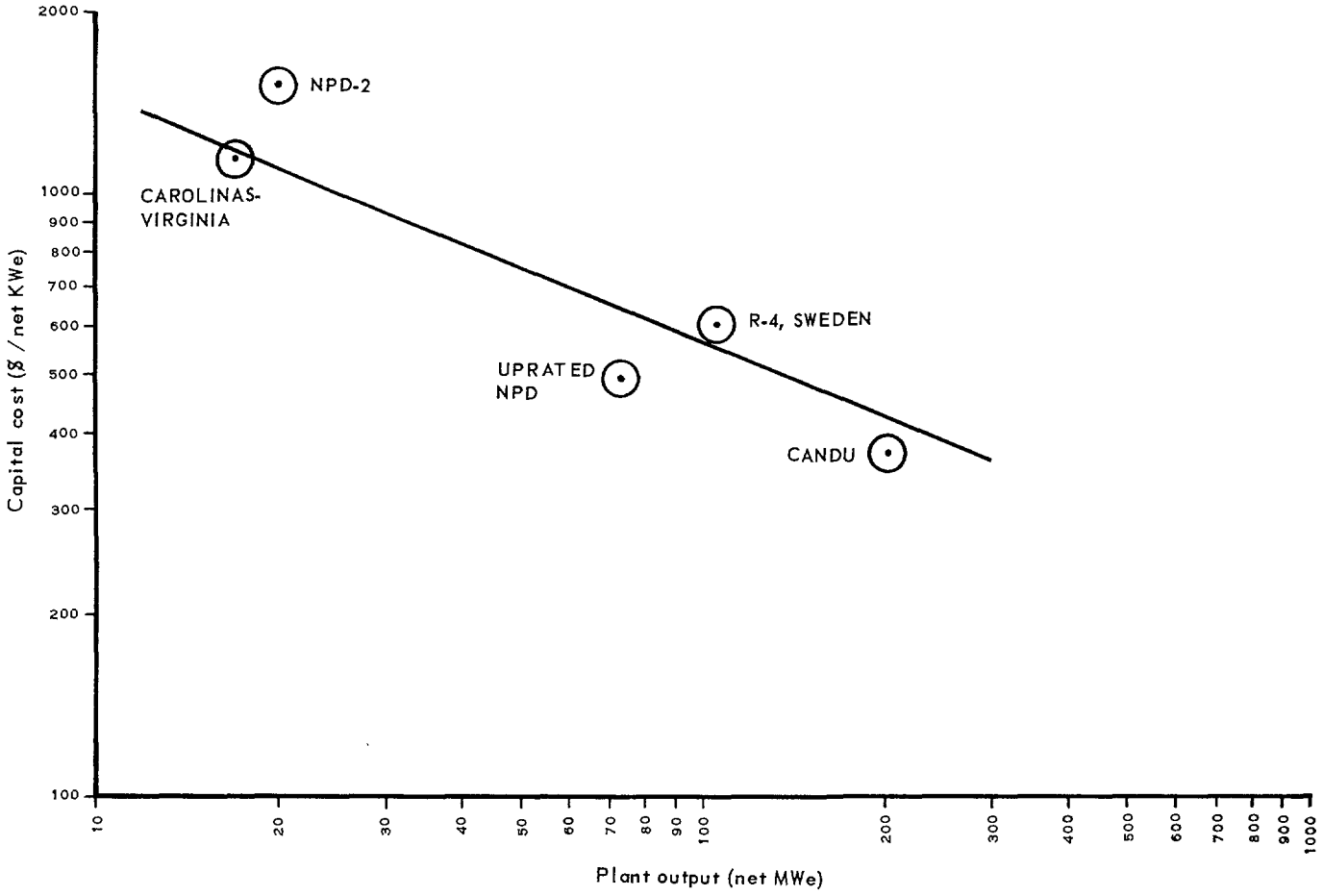

Figure 4

Capital Costs of Nuclear Power Plants for Heavy-Water Reactors

○ Actual costs

—— Costs estimated in 1959-60, as indicated in USAEC reports TID-8516 and 8535

TABLE II

FUELLING COSTS

A. Reactors in the United States

	BONUS[a]		YANKEE		DRESDEN[d]	BODEGA BAY[e]
	Boiler	Super-heater	Core 1[b]	Core 2[c]		
Fabrication						
$/kgU	178.30	373.70	143[f]	124[f]	188	101.70
mills/kWh	1.53	1.13	2.24	2.50	3.03	0.83
Shipping, mills/kWh	0.16	0.06	0.16	0.20	0.21	- [g]
Burn-up, mills/kWh	0.94[g]	0.48[g]	1.80[h]	1.68[g]	1.05[h]	0.96[g]
Chemical processing, mills/kWh	0.42	0.15	0.68	0.66	0.56	0.25
Plutonium credit						
$/g Pu	8[i]	8[i]	30[j]	8[i]	30[j]	8[i]
mills/kWh	0.29	0.07	2.46	0.69	2.16	0.43
Inventory charge, mill/kWh	0.26	0.29	0[k]	0.40	0.21	0.18
	3.02	2.04				
Net cost of fuel cycle, mills/kWh	5.06		2.42	4.75	2.90	1.79

B. Reactor in the United Kingdom

	BRADWELL[l]
Amortization of first core, plus inventory charge, mills/kWh	0.7
Fuel replacement, mills/kWh	2.1
Net cost of fuel cycle, mills/kWh	2.8

C. Reactors in Canada

	CANDU[m]	UP-RATED NPD[n]
Amortization of fuel, mills/kWh	0.02	0.02
Fuel inventory charge, mills/kWh	0.08	0.10
Fuel replacement, mills/kWh	1.11	2.13
Net cost of fuel cycle, mills/kWh	1.21	2.25

D. Reactors in France[o]

	EDF-1	EDF-2	EDF-3	EL-4
Fuel replacement, mills/kWh	4.8	3.2	2 - 2.4	1.6 - 2

E. Reactor in Japan

	GCR-TOKAI MURA[p/]
Amortization of fuel, mills/kWh	0.88
Fuel replacement, mills/kWh	2.65
Net cost of fuel cycle, mills/kWh	3.53

a/ Source: Communication of Oak Ridge Office, United States Atomic Energy Commission (USAEC), Washington, D.C.

b/ Irradiation level estimated to be 9150 thermal MWd/t U (average for first core).

c/ Irradiation level taken to be 7100 thermal MWd/t U (average); Source: FELSEN, W.L., "7th Report on Nuclear Power", Electrical World, Vol. 157, No. 21, New York, N.Y. (21 May 1962), p. 92.

d/ Source: Fuel Cycle Costs for Specific Power Reactors, TID-13293, USAEC, Washington, D.C. (July 1961), p. 9 - 10, except for plutonium credit.

e/ Source: Data presented by Pacific Gas and Electric Co. at hearing before California Public Utilities Commission in March 1962.

f/ Source: FELSEN, W.L., "7th Report on Nuclear Power", Electrical World, Vol. 157, No. 21, New York, N.Y. (21 May 1962), p. 92; weight of uranium in one core taken to be 20840 kgU, as in Fuel Cycle Costs for Specific Power Reactors, TID-13293, USAEC, Washington, D.C. (July 1961), p. 15.

g/ Source: Latest USAEC schedule of charges for enriched uranium, effective 1 July 1962.

h/ Source: USAEC schedule of charges for enriched uranium in effect from 1 July 1961 to 30 June 1962.

i/ This is $8/g of contained plutonium, in a nitrate solution. The cost of chemical processing in this case does not include a charge for conversion of plutonium to metal.

j/ This is $30/g Pu as metal. The chemical processing cost in this case includes a charge of $1.50/g Pu for conversion to metal.

k/ Use charge waived by USAEC for the first five years of operation. The use charge, if made, would be 0.43 mill/kWh.

l/ Source: Directory of Nuclear Reactors, STI/PUB/4, IAEA, Vienna (1959), p. 124.

m/ Source: Introduction to the Methods of Estimating Nuclear Power Generating Costs, Technical Reports Series No. 5, STI/DOC/10, IAEA, Vienna (1961), p. 56.

n/ Source: Communication of Canadian General Electric Company Ltd., Toronto.

o/ Source: Communication of the French Commissariat à l'Energie Atomique, Paris. The figures do not include any inventory or amortization charge for the reactor fuel. No allowance is made for the possible value of spent fuel.

p/ Source: Directory of Nuclear Reactors, STI/PUB/53, IAEA, Vienna (1962).

TABLE III

OPERATION AND MAINTENANCE COSTS

Station	Mills/kWh
YANKEE	1.15[a/]
INDIAN POINT	0.9[a/]
BODEGA BAY	0.72[b/]
GCR-TOKAI MURA	1.19[c/]
BRADWELL	0.6[d/]
CANDU	1.14[e/]
UP-RATED NPD	1.91[f/]

a/ Source: FELSEN, W.L., "7th Report on Nuclear Power", Electrical World, Vol. 157, No. 21, New York, N.Y. (21 May 1962), pp. 92-93.

b/ 0.34 mill/kWh is for additional insurance, the remaining 0.38 mill/kWh for operation, maintenance and general expenses. Source: Data presented by Pacific Gas and Electricity Co. at hearing before California Public Utilities Commission in March 1962.

c/ Source: Directory of Nuclear Reactors, STI/PUB/53, IAEA, Vienna (1962).

d/ Source: Directory of Nuclear Reactors, STI/PUB/4, IAEA, Vienna (1959), p. 124.

e/ Source: Introduction to the Methods of Estimating Nuclear Power Generating Costs, Technical Reports Series No. 5, STI/DOC/10, IAEA, Vienna (1961), p. 56.

f/ Source: Communication of Canadian General Electric Company Ltd., Toronto.

TABLE IV

TOTAL GENERATING COSTS

Station	Mills/kWh			
	Fixed charges	Fuel	Operation, maintenance and general	Total
YANKEE				
First core	5.50[a]	2.42[b]	1.15	9.1
Second core	5.50	4.75[c]	1.15	11.4
INDIAN POINT				
First core	8.0[d]	5.2[e]	0.9	14.1
Second core	8.0[d]	3.3[e]	0.9	12.2
BRADWELL	5.6[f]	2.8	0.6	9.0
GCR-TOKAI MURA	9.36[g]	3.53	1.19	14.1
BODEGA BAY	3.71[h]	1.79[c]	0.72	6.2
CANDU	3.41[i]	1.21	1.14	5.8
UP-RATED NPD	4.52[j]	2.25	1.91	8.7

a/ Based on annual fixed charge rate of 14.6%, 84% plant factor, and a capital investment of $278/kW.

b/ Includes credit for plutonium at $30/g Pu, in the form of metal. No use charge included. Burn-up based on USAEC schedule of charges for enriched uranium in effect from 1 July 1961 to 30 June 1962.

c/ Includes credit for plutonium at $8/g Pu, in the form of nitrate. Use charge is included. Burn-up of enriched uranium is charged based on the USAEC schedule of charges in effect as of 1 July 1962.

d/ Based on annual fixed charge rate of 13%, 80% plant factor, and a capital investment of $431/kW. Source: FELSEN, W.L., "7th Report on Nuclear Power", Electrical World, Vol. 157, No. 21, New York, N.Y. (21 May 1962), p. 93.

e/ Source: FELSEN, W.L., "7th Report on Nuclear Power", Electrical World, Vol. 157, No. 21, New York, N.Y. (21 May 1962), p. 93.

f/ Based on an interest rate of 5.5% per annum, 20 year plant life, leading to an annual fixed charge rate of 8.37%. Also assumed a plant factor of 80%, and a capital investment of $465/kW.

g/ Based on annual fixed charge rate of 12%, 80% plant factor, and a capital investment of $546/kW.

h/ Based on annual fixed charge rate of 13.2%, 80% plant factor, and a capital investment of $197/kW.

i/ Based on an interest rate of 4.5% per annum, amortization of heavy water in 40 years, of reactor portion of plant in 15 years, and of remainder of plant in 30 years, leading to an average annual fixed charge rate of 6.48%. Also assumed a plant factor of 80% and a capital investment of $373/kW.

j/ Based on an interest rate of 4.5% per annum, amortization of heavy water in 40 years, of reactor portion of plant in 15 years, and of remainder of plant in 30 years, leading to an average annual fixed charge rate of 6.37%. Also assumed a plant factor of 80% and a capital investment of $497/kW.