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Cost Estimating Relationships for Nuclear Power Plant Operation and Maintenance

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OPERATED BY
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This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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COST ESTIMATING RELATIONSHIPS FOR NUCLEAR POWER PLANT OPERATION AND MAINTENANCE

H. I. Bowers
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ABSTRACT

Revised cost estimating relationships for 1987 are presented for estimating annual nonfuel operation and maintenance (O&M) costs for light-water reactor (LWR) nuclear power plants, which update guidelines published previously in 1982. The purpose of these cost estimating relationships is for use in long range planning and evaluations of the economics of nuclear energy for electric power generation. A listing of a computer program, LWROM, implementing the cost estimating relationships and written in advanced BASIC for IBM personal computers, is included.

1. INTRODUCTION

The purpose of this report is to provide revised and updated cost estimating relationships for annual nonfuel operation and maintenance (O&M) costs for light-water reactor (LWR) nuclear power plants for electric power generation. The cost estimating relationships apply to today's commercial pressurized-water reactor (PWR) and boiling-water reactor (BWR) plants with units ranging in size from 400 to 1300 MW(e) operating base-loaded at capacity factors greater than 0.40. The application is for use in evaluations and projections of the economics of nuclear energy for long range planning purposes. These relationships are not substitutes for detailed analyses of specific nuclear power projects.

Table 1.1 shows a comparison of O&M cost estimates produced using the revised and updated 1987 cost estimating relationships reported in

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[a]Consultant.

Table 1.1 Comparison of 1982 and 1987 annual O&M cost estimates for a 1 x 1150-MW(e) PWR plant at 0.65 capacity factor

(millions of 1987 dollars)

	1982[a]	1987
Onsite staff	17.6	32.4
Maintenance materials	5.1	7.8
Supplies and expenses	6.5	14.8
Offsite technical support	4.4	13.3
Pensions and benefits	[b]	9.3
Nuclear regulatory fees	0.6	1.3
Nuclear insurance premiums	7.1	6.3
Other administrative and general expenses	10.2	10.2
Total	51.5	95.4

[a]From Table 1.1 of Ref. 1 adjusted to 1987 dollars using the Implicit Price Deflator for Gross National Product.

[b]Included in onsite staff, offsite technical support, and other administrative and general expenses.

the current study and the 1982 cost estimating relationships reported in Ref. 1. This comparison indicates that these nuclear power plant O&M cost projections have almost doubled in real terms from 1982 to 1987. The increase is principally due to the approximately doubling of staffing and staffing-related costs.

The accounting system utilized and its relationship to the Uniform System of Accounts[2] is discussed in Sect. 2.

The recommended cost estimating relationships are discussed in Sects. 3–10.

The results of using these cost estimating relationships and a comparison with reported O&M costs for nuclear power plants are discussed in Sect. 11.

A computer code, LWROM, implementing the cost estimating relationships is listed in Appendix A. The computer code is written in advanced BASIC for IBM personal computers. Since the input variables are menu driven and all variables are defined in the listing, the code is essentially self-contained without need for additional documentation.

2. OPERATION AND MAINTENANCE EXPENSE ACCOUNTS

In the earlier study for large nuclear plants,[1] a cost accounting breakdown similar to that shown in Table 2.1 was developed, which facilitates the derivation of costs related to expenditures for personnel, consumable materials and supplies, and administrative and general (A&G) expenses. This accounting breakdown encompasses approximately the same expenses as shown in Table 2.2 for the Uniform System of Accounts prescribed for public utilities subject to provisions of the Federal Power Act for nuclear power generation and A&G expenses.[2]

Table 2.1. O&M expense accounts

Nuclear Power Generation
Onsite staff
Maintenance materials
Fixed
Variable
Supplies and expenses
Fixed
Variable
Offsite technical support
Administrative and General
Pensions and benefits
Nuclear regulatory fees
Nuclear insurance premiums
Other administrative and general expenses

The power generation cost accounts in Table 2.1 include the nuclear power generation accounts from Table 2.2 with the exception of 518 Nuclear Fuel Expense, 521 Steam From Other Sources, 522 Steam Transferred, and 525 Rents. Nuclear fuel expense is considered separately in economic evaluations, and Accounts 521, 522, and 525 are considered to be

Table 2.2. Uniform system of accounts for nuclear power generation and administrative and general expenses[a]

	Nuclear Power Generation
	Operation
517	Operation supervision and engineering
518	Nuclear fuel expense
519	Coolants and water
520	Steam expenses
521	Steam from other sources
522	Steam transferred (credit)
523	Electric expenses
524	Miscellaneous nuclear power expenses
525	Rents
	Maintenance
528	Maintenance supervision and engineering
529	Maintenance of structures
530	Maintenance of reactor plant equipment
531	Maintenance of electric plant
532	Maintenance of miscellaneous nuclear plant
	Administrative and General Expenses
	Operation
920	Administrative and general salaries
921	Office supplies and expenses
922	Administrative expenses transferred (credit)
923	Outside services employed
924	Property insurance
925	Injuries and damages
926	Employee pensions and benefits
927	Franchise requirements
928	Regulatory commission expenses
929	Duplicate charges (credit)
930.1	General advertising expenses
930.2	Miscellaneous general expenses
931	Rents
932	Transportation expenses (minor)
	Maintenance
935	Maintenance of general plant

[a]Reference 2, pages 409–410.

zero for evaluation purposes. In addition to direct salaries the cost accounts for onsite staff and offsite technical support include payroll tax and insurance (social security tax and unemployment insurance premiums). In the earlier study they also included expenses for pensions and benefits from 926 Employee Pensions and Benefits, which are now itemized separately under A&G expenses.

The A&G cost accounts in Table 2.1 include A&G expense accounts from Table 2.2 as allocated to electric power generation. The pensions and benefits account includes an allocation of 926 Employee Benefits and Pensions and also as a cost estimating convenience an allowance for workers' compensation insurance, which is a part of 925 Injuries and Damages. Nuclear regulatory fees are a part of 928 Regulatory Commission Expenses; plant property damage insurance premiums are a part of 924 Property Insurance; and nuclear liability insurance premiums are a part of 925 Injuries and Damages. Other A&G expenses are an allocation of all other A&G accounts from Table 2.2.

In making comparisons it is important to be aware that most studies of empirical O&M cost data do not include any of the A&G expenses included in Accounts 920—932 and 935 and many include the fuel expense included in Account 518.

3. ONSITE STAFF

The evaluation of staffing requirements is an important first step in estimating annual O&M costs for nuclear power plants. Unfortunately, for cost estimating purposes there is no standardized organizational structure or approach to the staffing of nuclear power plants. Examination of the data reported by utilities on Form 1 to the Federal government shows a wide variation in onsite staffing, ranging from less than 300 to more than 1000 for large single-unit plants and from less than 500 to more than 2000 for large two-unit plants. The analysis is complicated by two factors: (1) many utilities contract activities such as security, peak maintenance, health physics, and quality control, while others perform all activities with their own employees; and (2) the distribution of onsite and offsite staff varies depending on management philosophy, which may include consideration of the number of nuclear plants in the utility system and distances between plants and central offices.

One disadvantage of the Form 1 data is that it identifies only the number of onsite utility personnel on the payroll. It does not identify offsite staff and contractor personnel. The Institute for Nuclear Power Operations (INPO) performs annual surveys of both onsite and offsite staffing, including contractor personnel, and the Edison Electric Institute (EEI) makes annual surveys of wages and salaries. However, in both cases the information is proprietary and not currently available for analysis. A 1983 analysis of the INPO data,[3] which examined total employment requirements for nuclear utilities, has been useful in identifying types of personnel, the requirements for offsite support, and size-scaling relationships. Wage schedules published by the International Brotherhood of Electrical Workers (IBEW)[4] have been very helpful in establishing salaries.

The estimated annual salaries and onsite staffing recommended for cost estimating purposes are shown in Table 3.1. The position titles and distribution of personnel are a synthesis using judgment following discussions with knowledgeable utility personnel, who have requested anonymity. This staffing arrangement has been developed solely for cost

Table 3.1. Estimated annual salaries and onsite staffing for 1100-Mw(e) nuclear units

(January 1987 dollars)

Job title	Salary ($/year)	Number of units in plant			
		1	2	3	4
Plant Manager's Office					
Plant Manager	$100,000	1	1		
Assistant manager	70,000	1	2		
Public relations	44,000	2	2		
Environmental control	44,000	2	2		
Quality assurance	51,000	6	8		
Training	49,000	48	58		
Safety and fire protect engr.	41,000	7	10		
Administrative services	27,000	80	120		
Fire brigade	24,000	27	27		
Security	24,000	126	173		
Subtotal		300	403		
Operations					
Supervision	51,000	4	6		
Shift operations	43,000	103	190		
Engineering	47,000	20	40		
Subtotal		127	236		
Maintenance					
Supervision	48,000	7	13		
Crafts	34,000	140	210		
Annualized peak maintenance	34,000	55	83		
Engineering	44,000	12	17		
Quality control	37,000	7	12		
Storekeepers	31,000	9	16		
Subtotal		230	351		
Technical Support					
Reactor engineering	51,000	5	8		
Radiochem. and water chem.	48,000	12	22		
Engineering	44,000	30	45		
Technicians	36,000	60	85		
Health physics	36,000	36	63		
Subtotal		143	223		
Total onsite staff		800	1,213	1,547	1,838
Total onsite annual salary (10^6 dollars)		$28.3	$43.5		
Average annual salary (dollars)		$35,400	$35,900		

estimating purposes and is not a recommendation for standardized staffing. However, it does reflect the management philosophy of staffing all positions with utility employees.

The following scaling relationship is recommended for estimating typical staffing as a function of unit size and number of units:

$$\text{Onsite staff} = 800 \left[\frac{\text{MW(e) per unit}}{1100}\right]^{0.5} (\text{No. of units})^{0.6} .$$

This is an empirical relationship based on judgment. There is considerable uncertainty in the form of the equation and the values of the scaling exponents. Reference 3 reports an exponent of approximately 0.5 for scaling staffing as a function of total megawatts capacity in the plant. Reference 5 reports an exponent of approximately 0.4 for scaling annual O&M cost as a function of unit size times number of units raised to approximately the 0.7 power.

The total onsite payroll is increased by 10% to allow for the expense of payroll tax and insurance (i.e., social security tax and unemployment insurance premiums).

4. MAINTENANCE MATERIALS

Maintenance materials are defined as expensed replacement items, expendable materials, and services that are utilized in maintaining the plant throughout its lifetime. They do not include large replacement items and improvements that are capitalized and amortized over a period of years. In practice these expenses may vary considerably from year-to-year due to unanticipated problems and the scheduling of maintenance of major equipment such as turbine-generator units.

The cost estimating factors shown in Table 4.1 are based on the recommendation presented in Ref. 1, which relates costs of materials to the number of positions on the maintenance staff (i.e., supervision, crafts, and annualized peak). The total annual expense for maintenance materials is estimated to be equal to the annual expense for maintenance staff at 0.80 capacity factor. There is estimated to be a fixed component (0.75), which does not vary with plant output, and a smaller variable component (0.25 at 0.80 capacity factor), which is directly proportional to energy generation.

Table 4.1 Maintenance materials cost estimating factors[a]

Fixed component	0.75
Variable component	0.25[b]
Total	1.00

[a] Fraction of maintenance onsite staff cost (supervision, crafts, and annualized peak).

[b] At 0.80 capacity factor.

The following relationship is recommended for adjusting maintenance materials costs for unit size and number of units

$$\text{Maintenance materials cost} = 202\ (\$36{,}000/\text{year}) \left[\frac{\text{MW(e) per unit}}{1100}\right]^{0.5} (\text{No. of units})^{0.6} .$$

5. SUPPLIES AND EXPENSES

The supplies and expenses account includes consumable materials that are unrecoverable after use and contract services for nonmaintenance activities. These include makeup materials, chemicals, gases, lubricants, office and personnel supplies, monitoring and record supplies, training, data processing, rents, and waste management.

Although consumption of water, such as that lost by evaporation from condenser cooling water systems, is significant [about 15,000,000 gpd for a 1000-MW(e) unit], no cost allowance is included for water not returned to the system or aquifer from which it was withdrawn. Water rights in some parts of the United States, however, are highly appropriated, and siting of power plants in these areas may require the purchase of existing water rights. The actual form and amount of such payments, which may be made annually, are not part of these procedures.

Fuel oil for standby and emergency diesel-engine generators and for auxiliary steam for building heating is not a nonfuel O&M expense but is defined in 18CFR101 as belonging in the fuel expense account for both nuclear and fossil-fueled plants. In most evaluations, however, this expense is overlooked in the fuel charges. An estimated allowance for a large LWR unit, which is not included here, is $1 million/year ($1 \times 10^6$ gal of No. 2 fuel oil at $1.00/gal). The major portion of fuel oil requirements is for use in auxiliary steam boilers that are operated during start-up and shutdown periods. Standby diesel-engine generators normally use little fuel because they operate only a few hours each month.

The expense associated with the handling of radioactive wastes requiring long term storage includes resins, filters and filter agents, materials for processing evaporator concentrates, and disposal, which depends on the costs of shielded containers, transportation, and burial. Section II.D of Appendix I to 10CFR50 requires that radioactive waste systems be designed to effect reductions in dose to the population within 80 km (50 miles) of the reactor to meet the as-low-as-reasonably-achievable (ALARA) criterion. Therefore, significant variations can be expected because of differences in designs for site location, fuel performance, and operating procedures.

The expenses for nonradioactive wastes are principally those related to treatment of various wastewater streams. The higher cooling tower blowdown for nuclear plants tends to balance waste streams from air pollution control systems and ash ponds for coal-fired plants. Both LWR and coal-fired plants require the treatment of an estimated 1500 gpd/MW(e) of installed capacity.

The guidelines for estimating costs of supplies and expenses, summarized in Table 5.1, apply to the first unit in a plant. The variation with plant load is judged to be small over the range of operation covered in this report and is highly uncertain because the fixed and variable components are not identified in published data.

Table 5.1. Estimated annual costs for supplies and expenses for a 1 x 1100-MW(e) plant

(January 1987 dollars)

Fixed costs, $/year	
Miscellaneous supplies (potable water, lubricants, communications, security, transportation, laboratory chemicals, clothing, lamping, gases, office supplies)	$ 2,000,000
Makeup materials and chemicals	2,000,000
Steam from other sources	0
Rents	500,000
Training	2,000,000
Data processing	2,000,000
Radioactive waste management	3,000,000
Nonradioactive waste management	1,000,000
Total fixed costs, $/year	$12,500,000
Variable costs, mills/kWh	0.3

The following relationship is recommended for adjusting the fixed supplies and expenses for unit size and number of units:

Supplies and expenses =

$$(\$12{,}500{,}000/\text{year}) \left[\frac{\text{MW(e) per unit}}{1100}\right]^{0.5} (\text{No. of units})^{0.6} .$$

6. OFFSITE TECHNICAL SUPPORT

The offsite technical support staff provides support to the nuclear power plants operated by the utility in areas of nuclear design, engineering, quality assurance, fuels, and research and development on specific problems. As with onsite staffing the size of the offsite technical support staff can vary significantly with management philosophy (e.g., the degree of contracting for support personnel and the distances between plants and central offices). For cost estimating purposes the staffing and costs shown in Table 6.1 for 1100-MW(e) units are judged to be required. Payroll tax and insurance are added to the direct salaries, along with an overhead allowance to account for office space, utilities, and miscellaneous expenses associated with the technical staff.

Table 6.1. Estimated staffing and costs for offsite technical support for 1100-MW(e) units

(January 1987 dollars)

	Number of 1100-MW(e) units in plant			
	1	2	3	4
Number on staff	150	200	250	300
Average annual salary	$ 51,000	$ 51,000	$ 51,000	$ 51,000
Total annual salaries	7,650,000	10,200,000	12,750,000	15,750,000
Payroll tax and insurance[a]	765,000	1,020,000	1,275,000	1,530,000
Overhead[b]	4,590,000	6,120,000	7,650,000	9,180,000
Total annual cost	$13,005,000	$17,340,000	$21,675,000	$26,010,000

[a] 10% of total salaries.

[b] 60% of total salaries.

The following relationship is recommended for estimating offsite staffing as a function of unit size and number of units:

$$\text{Offsite staff} = [100 + 50\ (\text{No. of units})] \left[\frac{\text{MW(e) per unit}}{1100}\right]^{0.5}.$$

This is also an empirical relationship based on judgment, and there is considerable uncertainty in the form of the equation and the scaling exponents.

7. PENSIONS AND BENEFITS

The pensions and benefits account includes (1) pensions paid to retired employees, accruals to provide for pensions, and payments for the purchase of annuities for pensions; (2) payment for employee accident, sickness, hospital, and death benefits; (3) expenses incurred in medical, educational, and recreational activities; (4) administrative expenses in connection with employee pensions and benefits; and (5) premiums for workers' compensation insurance.

An analysis was performed for the year 1984 of 33 investor-owned utilities operating nuclear power plants, based on data published in Ref. 6. The mean value of employee benefits and pensions was calculated to be 17.1% of total utility company salaries and wages with a standard deviation of 6.4% and a minimum value of 1.0% and a maximum value of 30.8%. The average values for all investor-owned utilities reported in Refs. 6 and 7 were calculated to range from 17% in 1975 and 1976 gradually increasing to 20% in 1982—1984.

The cost of workers' compensation insurance is estimated to be approximately 6% of the payroll.

For evaluation purposes it is recommended that employee pensions and benefits, including workers' compensation insurance, be estimated as 25% of the total of salaries and wages (not including payroll tax and insurance) for onsite and offsite staff.

8. NUCLEAR REGULATORY FEES

The Nuclear Regulatory Commission (NRC) amended its licensee fee schedule in 1984 to provide for a more complete recovery of costs incurred in providing inspections and the review of applications and requests for permits, licenses, approvals, amendments, renewals, and special projects,[8] and again in 1986 in response to a Congressional mandate to recover approximately one-third of its budgeted costs.[9] The 1984 fee schedule is covered in 10CFR170 and the 1986 fee schedule in 10CFR171.

Billings to utilities for the first full year's experience with the Part 170 fee schedule for operating nuclear plants averaged $233,000 per power reactor.[10] The frequency of inspections and reviews (and resulting fees) depends on the activities underway, the perceived potential safety hazards, and the problems experienced by the plants in previous inspections and reviews. Thus there is wide variation in the Part 170 fees for current operating nuclear plants.

The Part 171 fee for FY 1987 has been set at $950,000 per power reactor unit based on the recovery of one-third of NRC's FY 1987 budget of $405,000,000 less estimated Part 170 fees of $37 million apportioned among 101 licensed power reactors.[9] It is estimated that approximately $30 million of the Part 170 fees will come from power reactors. Plants such as Dresden 1, Humboldt Bay, Peach Bottom 1, and Indian Point 1 whose authority to operate have been permanently revoked are not subject to the Part 171 fee, although they remain subject to any applicable fees under Part 170. The annual fee for FY 1987 will be charged to every power reactor unit licensed to operate as of October 1, 1986, (assumed to be 101 reactors) and on a pro rata basis to any power reactor receiving a new operating license during the year.

The NRC states that they have been unable to correlate licensing and regulatory costs with reactor size. However, the NRC may grant upon application an exemption in part from the full Part 171 annual fee taking into consideration age and size of the reactor, effect on rates, and any other relevant matter.[9]

The fee schedule shown in Table 8.1 is recommended for cost estimating purposes for each nuclear power unit in both single-unit and multiple-unit plants.

Table 8.1. Estimated annual nuclear regulatory fees for each nuclear power unit

(January 1987 dollars)

10 CFR Part 170	$ 300,000
10 CFR Part 171	950,000
Total annual fee	$ 1,250,000

9. NUCLEAR INSURANCE PREMIUMS

From the time that a construction permit is issued for a nuclear power plant a utility is required to carry insurance to protect itself from public liability claims, which may arise from a nuclear accident, and to provide funds for plant cleanup and decommissioning following an accident. Amendments to the insurance policies are issued at various stages (e.g., operating permit, fuel delivery, fuel loading, and commercial operation). The following discussion applies to an operating plant.

Liability insurance is provided through a two-layer combination of commercial insurance and self insurance defined by the Price-Anderson Act, which first became law in 1957 (Refs. 11 and 12). Under the first layer the maximum coverage currently available from commercial insurers is $160 million, although this is likely to increase to $200 million. The second layer is a mandatory industry wide program of self insurance under which nuclear power plant licensees can be assessed an amount not to exceed $5 million in any one year for each operational reactor owned for each nuclear accident and not to exceed $10 million in the event of more than one accident. For 108 reactors licensed for commercial operation in the United States in early 1987 this self insurance program provided $540 million annual coverage based on one accident and $1.08 billion coverage based on two or more accidents. This second layer coverage increases as more nuclear power plants are placed in operation. There are no requirements for annual payments or premiums to cover this second layer liability, and to date no assessments have been made, including payments of claims from the Three Mile Island accident.

The Price-Anderson Act is due to expire in 1987, and there is a bill before Congress that will extend the Act and increase the liability cap to almost $7 billion, which would require utilities to pay deferred premiums of no more than $10 million/year.[13] The NRC would be authorized to set the maximum aggregate of deferred premiums. Again, it appears there will be no requirements for annual premiums. If the Act is not extended, all current operating nuclear power plants and those under construction will continue to be insured under the present law.

The legal requirements for property damage insurance to provide funds for plant clean-up following a nuclear accident are derived from NRC's mandate to provide for the public safety. This protection is provided in two layers of commercial insurance. The minimum amount of insurance currently required by NRC is $500 million primary coverage and $85 million excess, or secondary, coverage for a total of $585 million, although the maximum excess coverage currently available is approximately $600 million for a total of $1.1 billion. The NRC has issued a proposed rule requiring a minimum of $1.02 billion property damage insurance,[14,15] which is expected to be adopted in 1987. The rule makes no special provisions for smaller reactors, but they can be considered through individual exemptions.

So-called "extra expense" insurance is also available for nuclear power plants, which protects against replacement power costs for outages resulting from nuclear accidents exceeding six months and as long as two years.

The estimated annual premiums, shown in Table 9.1, are typical values based on information collected by the NRC[12,16,17] and in discussions with representatives of nuclear insurers. The actual premiums for specific plants are subject to site specific risk evaluations and options relating to deductibles.

Table 9.1. Estimated annual premiums for nuclear power plant insurance

(January 1987 dollars)

	Number of units in plant			
	1	2	3	4
Public liability				
Commercial ($160 million)	$ 600,000	$ 900,000	$ 1,200,000	$ 1,500,000
Self insurance[a]	0	0	0	0
Plant property damage				
Primary ($500 million)	3,000,000	4,600,000	6,200,000	7,800,000
Secondary ($600 million)	1,100,000	1,300,000	1,500,000	1,700,000
Replacement power	1,600,000	3,200,000	4,800,000	6,400,000
Total	$ 6,300,000	$ 10,000,000	$13,700,000	$17,400,000

[a]See text for discussion of self insurance and deferred premiums.

10. OTHER ADMINISTRATIVE AND GENERAL EXPENSES

Other A&G expenses as defined here include those expenses collected in Accounts 920—933 and 935 less nuclear insurance premiums, workers' compensation insurance premiums, employee benefits and pensions, and nuclear regulatory fees. Total power production expenses include the sum of all expenses (exclusive of amortization of capital investment) incurred for operating and maintaining electric utilities and producing electric power[6] (i.e., fossil power generation, nuclear power generation, hydraulic power generation, other power generation, other power supply, transmission, distribution, customer accounts, customer service and information, sales, and administrative and general). There are no standard cost accounting rules for allocating overhead costs to production costs other than where specific expenses can be clearly identified (e.g., nuclear insurance premiums, nuclear regulatory fees, and pensions and benefits). It is recommended here that other A&G expenses as defined above be allocated to the total power production expenses less fuel and total A&G. Thus generation, transmission, distribution, customer accounts, customer service and information, and sales all bear pro rata shares of other A&G. However, because of wide differences of opinion among analysts regarding rules for allocation, there is also difference of opinion as to whether the other A&G expenses should be considered in long range evaluations.

Based on data reported in Ref. 6, the mean value of other A&G expenses as defined above for 33 investor-owned utilities operating nuclear plants in 1984 was calculated to be 12.5% of total power production expenses less fuel and total A&G. However, there is a very wide spread in the calculated values for individual nuclear utilities; the standard deviation was 11.7% with the minimum value approaching zero and a maximum value of 41.1%. Based on summaries[6] of all reporting utilities for the years 1981—1984, the calculated average value was 13.1%, with a slight increase from 1981 to 1984. This indicates little difference between nuclear and non-nuclear utilities.

For evaluation purposes it is recommended that other A&G expenses be estimated as 15% of the sum of the power generation cost accounts (i.e., onsite staff, maintenance materials, supplies and expenses, and offsite technical support).

11. RESULTS AND COMPARISON WITH REPORTED O&M COSTS

The cost estimating relationships developed and recommended in Sects. 3—10 have been incorporated into a computer program, called LWROM, which is summarized and listed in Appendix A. The LWROM model was used to produce the cost estimate shown in Table 11.1 for a single-unit 1100-MW(e) LWR nuclear power plant operating at 0.70 capacity factor for the year 1987.

The first page of Table 11.1 shows the input data required for running a case. These are the default values that are listed on the input menu when running the code with the exception that annual net generation is calculated by the code using the specified unit rating, number of units, and capacity factor. The user has the option of using the default values of input data or of specifying new values. The user is cautioned that the base year average salaries for onsite and offsite staff must be in 1987 dollars, the base year for the cost estimating relationships developed in this study. The code uses either the default or user specified escalation rates to adjust the cost estimates to other years.

Table 11.1. Example O&M cost estimate

SUMMARY OF ANNUAL NONFUEL O&M COST FOR LWR POWER PLANT

Version 10-15-87 Run Date 10-15-1987

Example Case

UNIT NET RATING, MWe		1100
NUMBER OF UNITS PER PLANT		1
CAPACITY FACTOR		.70
ESCALATION RATES, percent		
WAGES AND SALARIES	5	
MATERIALS AND SUPPLIES	5	
NUCLEAR REGULATORY FEES	5	
NUCLEAR INSURANCE	5	
BASE YEAR AVE. ONSITE STAFF COST $/year before payroll taxes & insurance		36000
BASE YEAR AVE. OFFSITE STAFF COST $/year before payroll taxes, insurance, and overhead		51000
OTHER A&G, percent		15
ANNUAL NET GENERATION, million kWh		6745
YEAR OF ESTIMATE		1987.0

Table 11.1. (continued)

SUMMARY OF ANNUAL NONFUEL O&M COST FOR LWR POWER PLANT

Version 10-15-87 Run Date 10-15-1987

Example Case

POWER GENERATION COSTS ($million/year)	
ONSITE STAFF (800 persons)	31.68
MAINTENANCE MATERIALS	
FIXED	6.00
VARIABLE	1.75
SUBTOTAL	7.75
SUPPLIES AND EXPENSES	
FIXED	12.50
VARIABLE	2.02
SUBTOTAL	14.52
OFFSITE TECHNICAL SUPPORT (150 persons)	13.01
SUBTOTAL, POWER GENERATION COSTS	
FIXED	63.18
VARIABLE	3.77
SUBTOTAL	66.96

ADMINISTRATIVE AND GENERAL COSTS ($million/year)	
PENSIONS AND BENEFITS	9.11
NUCLEAR REGULATORY FEES	1.25
LIABILITY INSURANCE	0.60
PROPERTY INSURANCE	4.10
REPLACEMENT POWER INSURANCE	1.60
OTHER ADMINISTRATIVE & GENERAL EXPENSES	10.04
SUBTOTAL	26.71

TOTAL O&M COSTS ($million/year)	
FIXED	89.9
VARIABLE	3.8
TOTAL NONFUEL O&M	93.7
mills/kWh (with A&G)	13.89
mills/kWh (without A&G)	9.93

The second page of Table 11.1 shows the cost estimate produced by the computer code. In this illustration the various cost accounts are reproductions of the costs produced by each of the cost estimating relationships discussed earlier in this report at the reference unit size of 1100 MW(e) and 0.70 capacity factor. It can be seen that staffing costs are the major cost component, contributing approximately two-thirds of the direct power generation costs, and that administrative and general costs are an important factor in cost evaluations, contributing an additional 40% of the direct power generation costs.

Figures 11.1 and 11.2 show comparisons of cost estimates produced by the LWROM computer code, using the cost estimating relationships developed in this study, with selected O&M costs for 1985 as reported by utilities on Form 1 and summarized in Ref. 18. The scatter plots show the reported data, which are tabulated in Table 11.2 along with the adjustment to 0.70 capacity factor; the numbers on the plots indicate the number of units in each plant. Because the cost estimating relationships were developed for base-loaded plants, only those nuclear plants

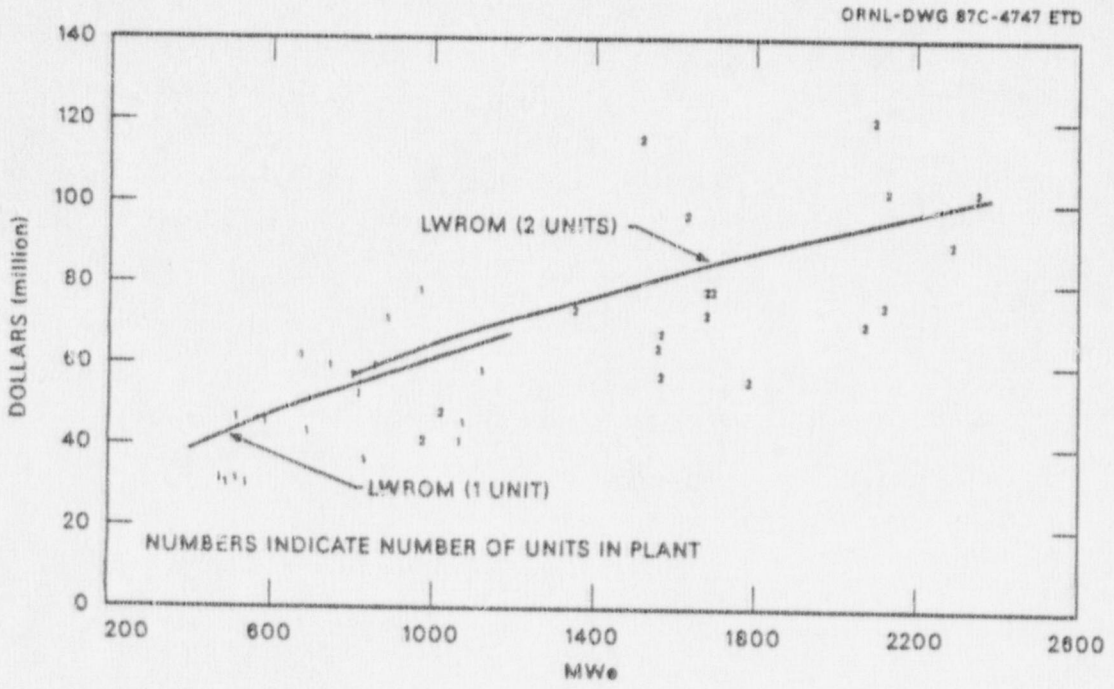

Fig. 11.1. Comparison of LWROM cost estimates (without A&G) at 0.70 capacity factor with 1985 costs for selected nuclear power plants (not adjusted for capacity factor).

Table 11.2. Selected nuclear power plant O&M cost data for 1985[a]

Plant	Units	MW(e)	Capacity factor	Million dollars	Mills/kWh	
					Reported	Adjusted to 0.70 capacity factor[b]
Beaver Valley	1	810	0.845	52.9	8.8	10.6
Calloway	1	1122	0.817	57.6	7.2	8.4
Connecticut Yankee	1	576	0.918	45.6	9.8	12.9
Diablo Canyon	1	1073	0.695	41.2	6.3	6.3
Fitzpatrick	1	800	0.595	57.0	13.7	11.6
Fort Calhoun	1	484	0.723	30.5	10.0	10.3
Ginna	1	470	0.878	31.6	8.7	11.0
Indian Point 2	1	856	0.887	58.9	8.9	11.2
Indian Point 3	1	965	0.560	78.3	16.6	13.2
Kewaunee	1	518	0.815	31.6	8.6	10.0
Maine Yankee	1	836	0.731	35.8	6.7	7.0
Monticello	1	538	0.910	30.3	7.1	9.2
Palisades	1	741	0.815	58.9	11.1	12.9
Pilgrim	1	668	0.846	61.2	12.4	15.0
Robinson	1	683	0.876	42.6	8.1	10.2
Trojan	1	1080	0.730	46.2	6.7	7.0
Summer	1	887	0.646	70.7	14.1	13.0
Vermont Yankee	1	512	0.669	46.4	15.5	14.8
Arkansas Nuclear One	2	1694	0.666	77.8	7.9	7.5
Calvert Cliffs	2	1685	0.672	72.2	7.3	7.0
Cook	2	2130	0.418	102.6	13.2	7.9
Dresden	2	1567	0.545	67.5	9.0	7.0
Farley	2	1631	0.794	97.1	8.6	9.7
LaSalle	2	2126	0.442	74.8	9.1	5.7
McGuire	2	2360	0.598	102.5	8.3	7.1
Millstone	2	1516	0.609	115.3	14.3	12.4
North Anna	2	1786	0.806	55.6	4.4	5.1
Point Beach	2	970	0.819	41.3	5.9	7.0
Prairie Island	2	1035	0.804	49.0	6.7	7.7
Quad Cities	2	1558	0.779	64.3	6.1	6.7
Sequoyah	2	2296	0.605	89.1	7.3	6.3
St. Lucie	2	1681	0.860	77.3	6.1	7.5
Surry	2	1562	0.708	56.9	5.9	5.9
Susquehanna	2	2100	0.664	119.7	9.8	9.3
Turkey Point	2	1354	0.721	73.2	8.6	8.8
Zion	2	2080	0.545	69.8	7.0	5.5

[a] Plants with greater than 0.40 capacity factor.

[b] Assuming all O&M costs are fixed [e.g., 8.8 (0.845/0.70) = 10.6].

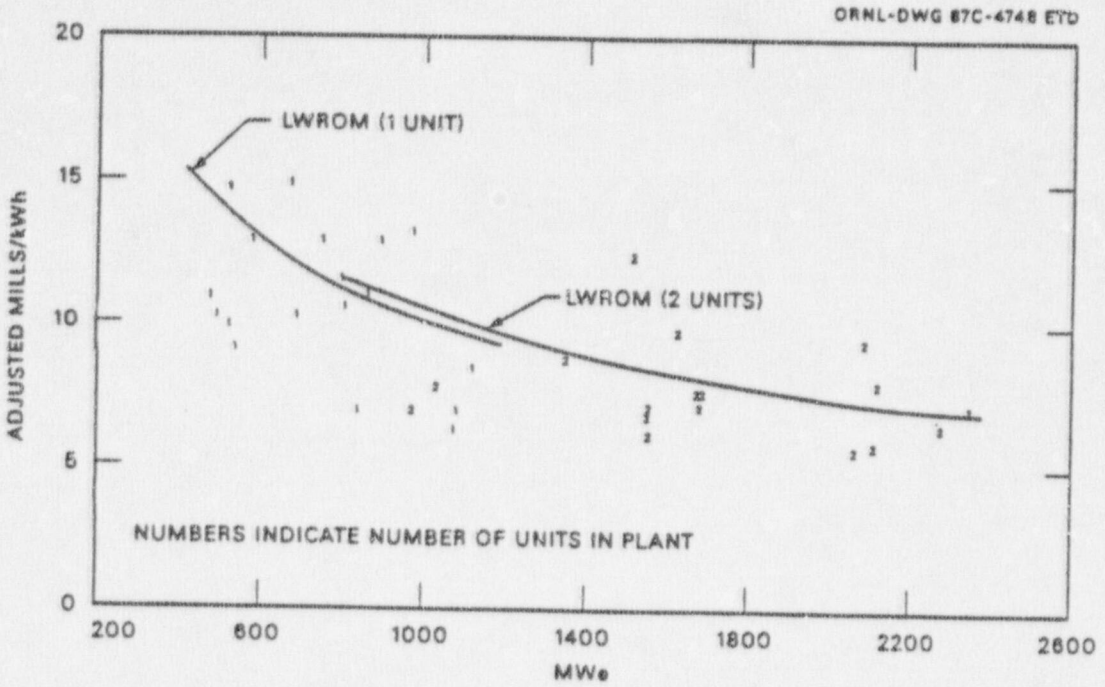

Fig. 11.2. Comparison of LWROM cost estimates (without A&G) at 0.70 capacity factor with 1985 costs for selected nuclear power plants (adjusted to 0.70 capacity factor).

with capacity factors greater than 0.40 in 1985 are included in the comparison. Two additional plants, one with questionably very low O&M costs and the other with questionably very high O&M costs, also are not included in the comparison. The reasons for the wide range of reported O&M costs for any specific year are not apparent. However, they may include variations in annual maintenance requirements, utility practices, plant utilization (capacity factor), unit size, number of units, and regional wage rates.

The continuous curves in Figs. 11.1 and 11.2, which were produced by the LWROM computer code, do not include A&G expenses because these expenses are not allocated to the direct power generation O&M expense accounts in 18CFR101 and on Form 1. The LWROM cost estimates were deflated to 1985 by using the Implicit Price Deflator for Gross National Product.

The principal conclusion that can be made in examining Figs. 11.1 and 11.2 is that the procedures developed in this study provide reasonable cost estimates that fall within the range of reported costs for 1985.

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Appendix A

LWROM COMPUTER CODE

The LWROM.BAS computer code calculates estimated annual nonfuel operation and maintenance (O&M) costs for light-water reactor (LWR) plants based on the early 1987 cost estimating relationships developed in Sects. 3–10 of this report. Escalation rates are included for wages and salaries, materials and supplies, nuclear regulatory fees, and nuclear insurance. Variables are assigned default values within the program to permit the calculation of an example case. This affords the new user an opportunity to run the program with an incomplete set of input data. The user may elect to change any of the menu driven input variables. These include: (1) net rating of each unit in MW(e), (2) number of units per plant, (3) base load capacity factor, (4) year of operation, (5) either individual escalation rates or a general escalation rate to replace the individual escalation rates, (6) onsite and offsite average annual salaries, and (7) other administrative and general (A&G) costs. The user may specify one, two, three, or four units per plant with O&M costs for all units escalated to a single specified year.

LWROM.BAS was written using the IBM Advanced BASIC Interpreter. The user is prompted to select an output destination of printer, screen, or disk file. A variable dictionary is included within the program. Initial values of variables are set through either assignment statements or data statements. Default values of input data items appear with the menu.

The user has the option of using either four individual escalation rates or a general escalation rate applied to all cost categories. If a general escalation rate is input, the individual escalation rates are reset to the general rate.

A test is made to ensure that the number of units per plant is in the range of 1 to 4. If it is out of range, a message is printed and input of number of units per plant is prompted.

Annual net power generation is calculate using the net rating of each unit, the number of units, and the capacity factor.

The number of onsite plant staff is calculated using a scaling equation, which is a function of unit size and number of units in the plant. The annual cost of onsite staff is the total number of staff times the average annual salary plus payroll tax and insurance.

Annual cost of maintenance materials at 0.80 capacity factor is estimated to be proportional to the sum of maintenance staff costs for crafts and annualized peak maintenance. The number of onsite maintenance staff is calculated using a scaling equation, which is a function of unit size and number of units in the plant. Annual maintenance staff cost is calculated as the number of maintenance staff times the sum of average annual onsite staff salary without payroll tax and insurance. Fixed maintenance materials costs are estimated to be 75% of the total, and variable maintenance materials costs are estimated to be 25% of the total at 0.80 capacity factor adjusted for the capacity factor used for the run. Output includes fixed, variable, and total maintenance materials costs.

Supplies and expenses are also shown as fixed, variable, and total. Fixed supplies and expenses are calculated as a function of unit size and number of units in the plant. Variable supplies and expenses are calculated from an estimated mill/kWh cost and the annual net generation.

The size of the offsite support staff is calculated as a function of unit size and number of units in the plant. The offsite technical support costs are calculated as the number of the staff times an average annual salary plus the sum of payroll tax and insurance and overhead.

Administrative and general costs include pensions and benefits, nuclear regulatory fees, commercial liability insurance, primary and secondary property insurance, replacement power insurance, and other A&G. Pensions and benefits are estimated to be 25% of the sum of onsite and offsite staff costs before payroll tax and insurance. The cost of nuclear regulatory fees is a constant times the number of units. Liability insurance and primary and secondary property insurance are straight line functions of the number of units. Replacement power

insurance is a constant times the number of units. In addition to the A&G costs mentioned above, a category called "other administrative and general" is calculated as 15% of the total power generation costs before the addition of any A&G costs.

Annual fixed, variable, and total power generation costs must be calculated before the other A&G costs can be calculated. Fixed power generation costs include costs of onsite staff, fixed maintenance materials, fixed supplies and expenses, and offsite technical support. Variable power generation costs include variable maintenance materials and variable supplies and expenses. Other A&G costs are added to pensions and benefits, nuclear regulatory fees, commercial liability insurance, property insurance, and replacement power insurance to obtain total A&G costs. At this point fixed, variable, and total annual O&M costs, including A&G, are determined, which are divided by the annual net generation to obtain unit costs in mills/kWh. Unit costs are output with and without A&G costs included.

At the completion of these calculations the input data are printed followed by the O&M cost summary. The output destination will have been previously selected by the user. The program returns to the menu until the user specifies 99 for "exit program" at which time the computer is still in BASICA.

```
10 '    LWROM.BAS
20 '    Nonfuel O&M Cost for LWR Plants
30 CLS
40 COLOR 11,9,10
50 '
60 'Select output destination
70 PRINT "     Select output destination as follows:"
80 PRINT "          1 - printer"
90 PRINT "          2 - screen"
100 PRINT "          3 - A:LWROM.DAT"
110 PRINT "          4 - B:LWROM.DAT"
120 PRINT "          5 - C:LWROM.DAT"
130 INPUT DEVICEOUT
140 IF DEVICEOUT=1 GOTO 190
150 IF DEVICEOUT=2 GOTO 230
160 IF DEVICEOUT=3 GOTO 250
170 IF DEVICEOUT=4 GOTO 270
180 IF DEVICEOUT=5 GOTO 290
190 WIDTH "LPT1:",80
200 OPEN "LPT1:" FOR OUTPUT AS #1
210 PRINT #1, CHR$(27)"l"CHR$(10)   'set left margin to 10
220 GOTO 300
230 OPEN "SCRN:" FOR OUTPUT AS #1
240 GOTO 300
250 OPEN "A:LWROM.DAT" FOR OUTPUT AS #1
260 GOTO 300
270 OPEN "B:LWROM.DAT" FOR OUTPUT AS #1
280 GOTO 300
290 OPEN "C:LWROM.DAT" FOR OUTPUT AS #1
300 '  ANNGEN  annual net generation, million kWh
310 '  ADMGEN  administrative and general, $millions/year
320 '  ANSWER$  yes or no answer to question (Y, y, N, or n)
330 '  BASECF  reference capacity factor for variable maintenance
340 '          material cost
350 '  BASELIABIL  liability insurance at base year for cost model,
360 '              $million/year
370 '  BASEMWN  base net rating at which staff was assigned
380 '  BASEPRIMARY  primary property insurance at base year for cost model,
390 '               $million/year
400 '  BASERPOWER  cost of replacement power insurance
410 '              at base year for cost model, $million/year
420 '  BASESECONDARY  secondary property insurance at base year for
430 '                 cost model, $million/year
440 '  BASEYR  base year for cost model
450 '  BASM  annual cost of maintenance material at reference
460 '        capacity factor, $million/year
470 '  COMINS  commercial liability insurance, $millions/year
480 '  COSTAF  onsite staff cost, $million/year
490 '  DATAPROC  data processing, $thousand/year
500 '  DATE$  date
510 '  DEVICEOUT  output destination (printer, screen, disk)
520 '  ESCGEN  general escalation rate, pct/year
530 '  ESCINS  escalation rate for nuclear insurance, pct/year
540 '  ESFEES  escalation rate for cost of inspection fees, pct/year
```

```
550 '  ESMATL  escalation rate for materials and supplies, pct/year
560 '  ESWAGE  escalation rate for wages and salaries, pct/year
570 '  EXCESS  escess property insurance, $million/year
580 '  FEEINS  nuclear regulatory fees, $millions/year
590 '  FIXFAC  fixed portion of plant maintenance material costs
600 '  FIXMIL  fixed nonfuel O&M, mills/kWh
610 '  FIXMNT  fixed maintenance material cost, $millions/year
620 '  FIXPOWER  fixed power generation costs, $million/year
630 '  FIXS  fixed annual costs of supplies and expenses before escalation
640 '        $million/year
650 '  FIXSE  fixed annual costs of supplies and expenses, $million/year
660 '  FULLYR  total hours in a year
670 '  IESC  -1 individual escalation rates used, -2 general escalation rate
680 '  MAKEUP  makeup materials and chemicals, $thousand/year
690 '  MANCOS  average cost of an onsite staff member at year of operation,
700 '          $/year
710 '  MISCSUPPLIES  potable water, lubricants, communications,
720 '                 security, transportation, laboratory chemicals,
730 '                 clothing, lamping, gases, office supplies, $thousand/year
740 '  MWN  net rating of each unit, MWe
750 '  NONRADIOWASTE  nonradioactive waste management, $thousand/year
760 '  NUM  menu item number
770 '  OFFANNUAL  total annual cost of offsite technical support
780 '             including payroll taxes and insurance, before
790 '             escalation, $/year
800 '  OFFOVERHEAD  overhead factor for offsite technical support
810 '  OFFSALARY  annual salary for offsite technical support at base year
820 '             for cost model before payroll taxes, insurance,
830 '             and overhead, $/year
840 '  OFFSTAFF  number of staff members for offsite technical support
850 '  OTHERAG  other A&G, $million/year
860 '  OTHERAGFAC factor relating other A&G to total power generation cost
870 '  PAYTAXINSUR  payroll taxes & insurance as fraction of staff cost
880 '  PENFACT  factor relating pensions to staff cost
890 '  PENSION  onsite and offsite staff pension costs, $million/year
900 '  PEOPLE  number of onsite staff members
910 '  PLTFAC  base load capacity factor
920 '  PRIMAR  primary property insurance, $million/year
930 '  PROPIN  property insurance, $million/year
940 '  RADIOWASTE  radioactive waste management, $thousand/year
950 '  RENTS  rents, $thousand/year
960 '  RPOWER  replacement power insurance cost, $million/year
970 '  RUNID$  run identification
980 '  SIZESCALE  exponent for size scaling
990 '  STAFCOS  average cost of an onsite staff member in base year dollars
1000 '          before payroll taxes and insurance, $/year
1010 '  SUPEXF  cost of makeup materials, office,
1020 '          security, personnel, supplies, training, LWR radwaste
1030 '          in base year for cost model, $thousand/year
1040 '  SUPEXP  supplies and expenses, $millions/year
1050 '  SUPORT  offsite support services, $millions/year
1060 '  TOTAL  total nonfuel O&M
1070 '  TOTALLESSAG  total costs less A&G
1080 '  TOTFIX  total fixed directs and indirects
```

```
1090 '  TOTLESSAGMIL  total mills/kWh less A&G
1100 '  TOTMIL  total nonfuel O&M, mills/kWh
1110 '  TOTMNT  maintenance material cost, $millions/year
1120 '  TOTPOWER  total power generation costs, $million/year
1130 '  TOTVAR  total variable directs and indirects
1140 '  TRAINING  training, $thousand/year
1150 '  U$  formats for USING
1160 '  UNITS  number of units per plant
1170 '  UNITSCALE  exponent for unit scaling
1180 '  V$  5 blanks
1190 '  VARFAC  variable portion of plant maint matl costs
1200 '  VARMIL  variable nonfuel O&M, mills/kWh
1210 '  VARMNT  variable maintenance material cost, $million/year
1220 '  VARPOWER  variable power generation costs, $million/year
1230 '  VSEBAS  variable cost of supplies and expenses, $million/year
1240 '  VSEMIL  base year var cost of S&E
1250 '  YEAR  year of estimate (operation)
1260 '  Z$  ampersand symbol "&"
1270 DIM U$(33)
1280 DIM BASELIABIL(4)
1290 DIM BASEPRIMARY(4)
1300 DIM BASESECONDARY(4)
1310 DIM BASERPOWER(4)
1320 DEF FNI(BASEYR,YEAR,ESWAGE)=(1+ESWAGE/100)^(YEAR-BASEYR)
1330 FOR I=1 TO 4 : PRINT : NEXT
1340 PRINT TAB(20) "NONFUEL O&M COST FOR LWR PLANTS"
1350 PRINT TAB(20) "base year for cost model is 1987" : PRINT
1360 FOR I=1 TO 4 : PRINT : NEXT
1370 GOSUB 4800
1380 '
1390 'Define initial values of variables and arrays
1400 U$(1)="     UNIT NET RATING, MWe                                  ####."
1410 U$(2)="     NUMBER OF UNITS PER PLANT                               #."
1420 U$(3)="     CAPACITY FACTOR                                       .##"
1430 U$(4)="     ESCALATION RATE (percent/year)                       ##.##"
1440 U$(6)="     SUBTOTAL, POWER GENERATION COSTS"
1450 U$(7)="     BASE YEAR AVE. ONSITE STAFF COST $/year          ######."
1460 U$(8)="     ANNUAL NET GENERATION, million kWh               ######."
1470 U$(9)="     YEAR OF ESTIMATE                                 ####.#"
1480 U$(10)="     ONSITE STAFF (####. persons)                      ###.##"
1490 U$(11)="     BASE YEAR AVE. OFFSITE STAFF COST $/year         ######."
1500 U$(12)="     MAINTENANCE MATERIALS"
1510 U$(13)="          FIXED"
1520 U$(14)="          VARIABLE                                    ###.##"
1530 U$(15)="     SUPPLIES AND EXPENSES"                           ###.##"
1540 U$(17)="     OFFSITE TECHNICAL SUPPORT (####. persons)          ###.##"
1550 U$(5)="                                                        -----"
1560 U$(18)="               SUBTOTAL                                ###.##"
1570 U$(32)="     PENSIONS AND BENEFITS                            ###.##"
1580 U$(16)="     NUCLEAR REGULATORY FEES                          ###.##"
1590 U$(19)="     LIABILITY INSURANCE                              ###.##"
1600 U$(20)="     before payroll taxes & insurance"
1610 U$(21)="     OTHER A&G, percent                                  ##"
1620 U$(22)="     PROPERTY INSURANCE                               ###.##"
```

```
1630 U$(23)="     before payroll taxes, insurance, and overhead"
1640 U$(24)="     REPLACEMENT POWER INSURANCE                          ###.##"
1650 U$(25)="     OTHER ADMINISTRATIVE & GENERAL EXPENSES              ###.##"
1660 U$(26)="     FIXED                                                ####.#"
1670 U$(27)="     VARIABLE                                             ####.#"
1680 U$(28)="          TOTAL NONFUEL O&M                               ####.#"
1690 U$(31)="          mills/kWh (with A&G)                            ###.##"
1700 U$(33)="          mills/kWh (without A&G)                         ###.##"
1710 V$="     "
1720 BASECF=.8
1730 BASEYR=1987
1740 FIXFAC=.75
1750 FULLYR=8760
1760 MISCSUPPLIES=2000 : MAKEUP=2000 : RENTS=500 : TRAINING=2000
1770 DATAPROC=2000 : RADIOWASTE=3000 : NONRADIOWASTE=1000
1780 SUPEXF=MISCSUPPLIES+MAKEUP+RENTS+TRAINING
1790 SUPEXF=SUPEXF+DATAPROC+RADIOWASTE+NONRADIOWASTE
1800 VARFAC=.25
1810 VSEMIL=.3
1820 SIZESCALE=.5
1830 UNITSCALE=.6
1840 Z$="&"
1850 OFFSALARY=51000!
1860 PAYTAXINSUR=.1
1870 OFFOVERHEAD=.6
1880 PENFACT=.25
1890 OTHERAGFAC=15
1900 FOR I=1 TO 4
1910 READ BASELIABIL(I)
1920 DATA .60,.90,1.20,1.50
1930 NEXT I
1940 FOR I=1 TO 4
1950 READ BASEPRIMARY(I)
1960 DATA 3.,4.6,6.2,7.8
1970 NEXT I
1980 FOR I=1 TO 4
1990 READ BASESECONDARY(I)
2000 DATA 1.1,1.3,1.5,1.7
2010 NEXT I
2020 FOR I=1 TO 4
2030 READ BASERPOWER(I)
2040 DATA 1.6,3.2,4.8,6.4
2050 NEXT I
2060 IESC=1
2070 MWN=1100
2080 BASEMWN=1100
2090 STAFCOS=36000!
2100 UNITS=1
2110 PLTFAC=.7
2120 YEAR=1987
2130 ESWAGE=5
2140 ESMATL=5
2150 ESFEES=5
2160 ESCINS=5
```

```
2170 ESCGEN=5
2180 '
2190 'Print current values of menu variables
2200 PRINT "     THE AVAILABLE MENU OPTIONS AND THEIR VALUES AT THIS TIME
2210 PRINT
2220 PRINT "     0 = RUN CASE, DATA ENTRY COMPLETE"
2230 PRINT "     1 = NET RATING OF EACH UNIT (MWe)    ";MWN
2240 PRINT "     2 = NUMBER OF UNITS PER PLANT        ";UNITS
2250 PRINT "     3 = BASE LOAD CAPACITY FACTOR        ";PLTFAC
2260 PRINT "     4 = YEAR OF OPERATION                ";YEAR
2270 IF IESC=1 GOTO 2290
2280 IF IESC=2 GOTO 2350
2290 PRINT "     5 = ESCALATION RATES"
2300 PRINT "         WAGES AND SALARIES               ";ESWAGE
2310 PRINT "         MATERIALS AND SUPPLIES           ";ESMATL
2320 PRINT "         NUCLEAR REGULATORY FEES          ";ESFEES
2330 PRINT "         NUCLEAR INSURANCE                ";ESCINS
2340 GOTO 2360
2350 PRINT "     5 = ESCALATION RATE (percent)        ";ESCGEN
2360 PRINT "     6 = AVERAGE ONSITE STAFF COST        ";STAFCOS
2370 PRINT "         before payroll taxes & insurance"
2380 PRINT "         AVERAGE OFFSITE STAFF COST       ";OFFSALARY
2390 PRINT "         before payroll taxes, insurance, and overhead"
2400 PRINT "     7 = OTHER A&G (percent)              ";OTHERAGFAC
2410 PRINT "    99 = EXIT PROGRAM"
2420 PRINT
2430 '
2440 'Read menu-driven input values
2450 PRINT "     ENTER A NUMBER FROM THE MENU"
2460 INPUT NUM
2470 IF NUM=0 GOTO 3200
2480 IF NUM=1 GOTO 2560
2490 IF NUM=2 GOTO 2590
2500 IF NUM=3 GOTO 2650
2510 IF NUM=4 GOTO 2680
2520 IF NUM=5 GOTO 2880
2530 IF NUM=6 GOTO 2720
2540 IF NUM=7 GOTO 2830
2550 IF NUM > 7 GOTO 4920
2560 PRINT "     INPUT MWE NET RATING PER UNIT"
2570 INPUT MWN
2580 GOTO 2200
2590 PRINT "     INPUT NUMBER OF UNITS PER PLANT"
2600 INPUT UNITS
2610 IF UNITS < 1 OR UNITS > 4 GOTO 2620 ELSE GOTO 2640
2620 PRINT "     UNITS < 1 or UNITS > 4"
2630 GOTO 2590
2640 GOTO 2200
2650 PRINT "     INPUT BASE LOAD CAPACITY FACTOR AS A DECIMAL"
2660 INPUT PLTFAC
2670 GOTO 2200
2680 PRINT "     INPUT YEAR OF OPERATION"
2690 INPUT YEAR
2700 GOTO 2200
```

```
2710 '
2720 'Staffing average cost per person input
2730 PRINT "     INPUT AVERAGE COST PER ONSITE STAFF MEMBER, $/YEAR"
2740 PRINT "     IN " BASEYR " DOLLARS"
2750 PRINT "     before payroll taxes and insurance"
2760 INPUT STAFCOS
2770 PRINT "     INPUT AVERAGE COST PER OFFSITE STAFF MEMBER, $/YEAR"
2780 PRINT "     IN " BASEYR " DOLLARS"
2790 PRINT "     before payroll taxes, insurance, and overhead"
2800 INPUT OFFSALARY
2810 GOTO 2200
2820 '
2830 'Other A&G input
2840 PRINT "     INPUT OTHER A&G AS PCT. OF TOTAL POWER GENERATION COST"
2850 INPUT OTHERAGFAC
2860 GOTO 2200
2870 'Escalation input
2880 PRINT "     DO YOU WANT TO USE THE DEFAULT GENERAL ESCALATION RATE?"
2890 PRINT "     (Y OR N)"
2900 INPUT ANSWER$
2910 IF ANSWER$="Y" GOTO 2940
2920 IF ANSWER$="y" GOTO 2940
2930 GOTO 2960
2940 GOSUB 4710
2950 GOTO 3190
2960 PRINT "     DO YOU WANT TO INPUT A GENERAL ESCALATION RATE? (Y OR N)"
2970 INPUT ANSWER$
2980 IF ANSWER$="Y" GOTO 3160
2990 IF ANSWER$="y" GOTO 3160
3000 IESC=1
3010 PRINT "     DO YOU WANT TO INPUT INDIVIDUAL ESCALATION RATES? (Y OR N)"
3020 INPUT ANSWER$
3030 IF ANSWER$="Y" GOTO 3060
3040 IF ANSWER$="y" GOTO 3060
3050 GOTO 3190
3060 PRINT "     INPUT ESCALATION RATES (PERCENT)"
3070 PRINT "          WAGES AND SALARIES"
3080 INPUT ESWAGE
3090 PRINT "          MATERIALS AND SUPPLIES"
3100 INPUT ESMATL
3110 PRINT "          NUCLEAR REGULATORY FEES"
3120 INPUT ESFEES
3130 PRINT "          NUCLEAR INSURANCE"
3140 INPUT ESCINS
3150 GOTO 3190
3160 PRINT "     INPUT ESCALATION RATE (PERCENT)"
3170 INPUT ESCGEN
3180 GOSUB 4710
3190 GOTO 2200
3200 PRINT "     ENTER RUN IDENTIFICATION (OR NULL LINE)"
3210 INPUT RUNID$
3220 '
3230 'Calculate annual net power generation
3240 ANNGEN=MWN*FULLYR*PLTFAC*UNITS/1000
```

```
3250 '
3260 'Calculate onsite staff cost
3270 PEOPLE=CINT(300*((MWN/BASEMWN)^SIZESCALE)*(UNITS^UNITSCALE))
3280 MANCOS=(1!+PAYTAXINSUR)*STAFCOS*FNI(BASEYR,YEAR,ESWAGE)
3290 COSTAF=PEOPLE*MANCOS/1000000!
3300 MAINTSTAF=CINT(202*((MWN/BASEMWN)^SIZESCALE)*(UNITS^UNITSCALE))
3310 '
3320 'Calculate fixed, variable, and total maintenance material cost
3330 BASM=MAINTSTAF*MANCOS/1000000!
3340 FIXMNT=FIXFAC*BASM
3350 VARMNT=VARFAC*BASM*PLTFAC/BASECF
3360 TOTMNT=FIXMNT+VARMNT
3370 '
3380 'Calculate fixed, variable, and total supplies and expenses
3390 VSEBAS=VSEMIL*(ANNGEN/1000)*FNI(BASEYR,YEAR,ESMATL)
3400 FIXS=(SUPEXF/1000)*((MWN/BASEMWN)^SIZESCALE)*(UNITS^UNITSCALE)
3410 FIXSE=FIXS*FNI(BASEYR,YEAR,ESMATL)
3420 SUPEXP=FIXSE+VSEBAS
3430 '
3440 'Calculate cost of offsite support services
3450 OFFSTAFF=CINT((100+50*UNITS)*((MWN/BASEMWN)^SIZESCALE))
3460 OFFANNUAL=(1+PAYTAXINSUR+OFFOVERHEAD)*OFFSALARY*OFFSTAFF
3470 SUPORT=OFFANNUAL*FNI(BASEYR,YEAR,ESWAGE)/1000000!
3480 '
3490 'Calculate Administrative and General costs including:
3500 '     pensions
3510 '     nuclear regulatory fees
3520 '     commercial liability insurance
3530 '     primary and secondary property insurance
3540 '     replacement power insurance
3550 BASEONOFF=PEOPLE*STAFCOS+OFFSTAFF*OFFSALARY
3560 PENSION=PENFACT*BASEONOFF*FNI(BASEYR,YEAR,ESWAGE)/1000000!
3570 FEEINS=(300000!+950000!)*UNITS*FNI(BASEYR,YEAR,ESFEES)/1000000!
3580 COMINS=BASELIABIL(UNITS)*FNI(BASEYR,YEAR,ESCINS)
3590 PRIMAR=BASEPRIMARY(UNITS)*FNI(BASEYR,YEAR,ESCINC)
3600 EXCESS=BASESECONDARY(UNITS)*FNI(BASEYR,YEAR,ESCINS)
3610 PROPIN=PRIMAR+EXCESS
3620 RPOWER=BASERPOWER(UNITS)*FNI(BASEYR,YEAR,ESCINS)
3630 '
3640 'Calculate fixed, variable, and total power generation costs
3650 FIXPOWER=COSTAF+FIXMNT+FIXSE+SUPORT
3660 VARPOWER=VARMNT+VSEBAS
3670 TOTPOWER=FIXPOWER+VARPOWER
3680 '
3690 'Calculate other A&G costs
3700 OTHERAG=OTHERAGFAC*TOTPOWER/100
3710 '
3720 'Calculate total A&G costs
3730 ADMGEN=PENSION+FEEINS+COMINS+PROPIN+RPOWER+OTHERAG
3740 '
3750 'Sum fixed, variable, and total annual costs
3760 TOTFIX=FIXPOWER+ADMGEN
3770 TOTVAR=VARMNT+VSEBAS
3780 TOTAL=TOTFIX+TOTVAR
```

```
3790 '
3800 'Calculate total annual and total unit costs less A&G
3810 TOTALLESSAG=TOTAL-ADMGEN
3820 TOTLESSAGMIL=1000*TOTALLESSAG/ANNGEN
3830 '
3840 'Convert fixed, variable, and total annual costs to unit costs
3850 FIXMIL=1000*TOTFIX/ANNGEN
3860 VARMIL=1000*TOTVAR/ANNGEN
3870 TOTMIL=1000*TOTAL/ANNGEN
3880 '
3890 'Print input data
3900 GOSUB 4860
3910 PRINT #1,V$
3920 PRINT #1, USING U$(1); MWN
3930 PRINT #1, USING U$(2); UNITS
3940 PRINT #1, USING U$(3); PLTFAC
3950 IF IESC=1 GOTO 3970
3960 IF IESC=2 GOTO 4030
3970 PRINT #1,"     ESCALATION RATES, percent"
3980 PRINT #1,"         WAGES AND SALARIES                  ";ESWAGE
3990 PRINT #1,"         MATERIALS AND SUPPLIES              ";ESMATL
4000 PRINT #1,"         NUCLEAR REGULATORY FEES             ";ESFEES
4010 PRINT #1,"         NUCLEAR INSURANCE                   ";ESCINS
4020 GOTO 4040
4030 PRINT #1, USING U$(4); ESCGEN
4040 '
4050 PRINT #1, USING U$(7); STAFCOS
4060 PRINT #1, U$(20)
4070 PRINT #1, USING U$(11); OFFSALARY
4080 PRINT #1, U$(23)
4090 PRINT #1, USING U$(21);Z$;OTHERAGFAC
4100 PRINT #1, USING U$(8); ANNGEN
4110 PRINT #1, USING U$(9); YEAR
4120 IF DEVICEOUT=2 THEN GOSUB 4800
4130 PRINT #1, CHR$(12)
4140 '
4150 'Print O&M cost summary
4160 GOSUB 4860
4170 PRINT #1,V$
4180 PRINT #1,"            POWER GENERATION COSTS ($million/year) "
4190 PRINT #1,"            ---------------------------------------- "
4200 PRINT #1,V$
4210 PRINT #1, USING U$(10);PEOPLE,COSTAF
4220 PRINT #1,V$
4230 PRINT #1, U$(12)
4240 PRINT #1, USING U$(13);FIXMNT
4250 PRINT #1, USING U$(14);VARMNT
4260 PRINT #1, U$(5)
4270 PRINT #1, USING U$(18);TOTMNT
4280 PRINT #1,V$
4290 PRINT #1, U$(15)
4300 PRINT #1, USING U$(13);FIXSE
4310 PRINT #1, USING U$(14);VSEBAS
4320 PRINT #1, U$(5)
```

```
4330 PRINT #1, USING U$(18);SUPEXP
4340 PRINT #1,V$
4350 PRINT #1, USING U$(17);OFFSTAFF,SUPORT
4360 IF DEVICEOUT=2 THEN GOSUB 4800
4370 PRINT #1,V$
4380 PRINT #1, U$(6)
4390 PRINT #1, USING U$(13);FIXPOWER
4400 PRINT #1, USING U$(14);VARPOWER
4410 PRINT #1, U$(5)
4420 PRINT #1, USING U$(18);TOTPOWER
4430 PRINT #1,V$
4440 PRINT #1,"       ADMINISTRATIVE AND GENERAL COSTS ($million/year)"
4450 PRINT #1,"       ------------------------------------------------"
4460 PRINT #1,V$
4470 PRINT #1, USING U$(32);PENSION
4480 PRINT #1, USING U$(16);FEEINS
4490 PRINT #1, USING U$(19);COMINS
4500 PRINT #1, USING U$(22);PROPIN
4510 PRINT #1, USING U$(24);RPOWER
4520 PRINT #1, USING U$(25);Z$;OTHERAG
4530 PRINT #1, U$(5)
4540 PRINT #1, USING U$(18);ADMGEN
4550 IF DEVICEOUT=2 THEN GOSUB 4800
4560 PRINT #1,V$
4570 PRINT #1,"            TOTAL O&M COSTS ($million/year)"
4580 PRINT #1,"            -------------------------------"
4590 PRINT #1,V$
4600 PRINT #1, USING U$(26);TOTFIX
4610 PRINT #1, USING U$(27);TOTVAR
4620 PRINT #1, U$(5)
4630 PRINT #1, USING U$(28);Z$;TOTAL
4640 PRINT #1,V$
4650 PRINT #1, USING U$(31);Z$;TOTMIL
4660 PRINT #1, USING U$(33);Z$;TOTLESSAGMIL
4670 IF DEVICEOUT=2 THEN GOSUB 4800
4680 PRINT #1, CHR$(12)
4690 GOTO 2200
4700 '-----------------------------------------------------------------
4710 'OPTIONAL Reset individual escalation rates to general escalation rate
4720 IESC=2
4730 ESWAGE=ESCGEN
4740 ESMATL=ESCGEN
4750 ESFEES=ESCGEN
4760 ESCINS=ESCGEN
4770 RETURN
4780 '-----------------------------------------------------------------
4790 'pause for screen output
4800 PRINT "Press any key to continue"
4810 A$=INKEY$
4820 IF A$="" THEN 4810
4830 RETURN
4840 '-----------------------------------------------------------------
4850 'print page heading
4860 PRINT #1,"     SUMMARY OF ANNUAL NONFUEL O&M COST FOR LWR POWER PLANT
```

```
4870 PRINT #1,V$
4880 PRINT #1,"                Version 10-15-87  Run Date "; DATE$
4890 PRINT #1,V$
4900 PRINT #1,V$;RUNID$
4910 RETURN
4920 END
```

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