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Estimation of Nonfuel Operation and Maintenance Costs for Advanced Circulating Fluidized-Bed and Advanced Natural Gas-Fired Combined Cycle Power Plants

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CONTENTS

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ESTIMATION OF NONFUEL OPERATION AND MAINTENANCE COSTS FOR ADVANCED CIRCULATING FLUIDIZED-BED AND ADVANCED NATURAL GAS-FIRED COMBINED CYCLE POWER PLANTS

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ABSTRACT

Operation and maintenance cost estimating methodologies for advanced coal-fired atmospheric circulating fluidized-bed and advanced natural gas-fired combined cycle electric power plants are presented. The purpose of these cost estimating relationships is for use in long range planning and evaluation of the economics of use of these technologies for electric power generation. Projected annual costs of reference plants at ten different sites in the United States, one in each of the ten DOE regions, are given as of 1989, and comparisons are made with existing technologies. A listing of a computer program implementing the methodologies is included.

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1. INTRODUCTION

The purpose of this report is to present the results of an investigation into the nonfuel operation and maintenance (O&M) costs for two advanced fossil fuel technologies which could be used for baseload electric power generation beginning in or near the year 2000. The estimate applies to future atmospheric circulating fluidized-bed (ACFB) power plants, with units ranging in size from 300 to 600 MW(e), and advanced natural gas-fired combined cycle (AGCC) power plants, also with units ranging in size from 300 to 600 MW(e). The methodologies and results presented herein are to be used in the evaluation of the economics of these technologies for long range planning purposes and are not meant to be substitutes for detailed analyses of specific projects.

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*Consultant

One reference plant for each of the two technologies was used in order to give some basis for required assumptions. The reference ACFB plant is a single-unit 500 MW(e) plant based on a combination of a previous reference pulverized coal plant[1] and a Combustion Engineering Power Systems atmospheric circulating fluidized-bed steam generator.[2] The plant consists of two circulating fluidized-bed boilers supplying a single 493 MW(e) steam turbine-generator as shown in Fig. 1.1.

The reference AGCC plant is a single-unit, 500 MW(e) plant based on a combination of the same previous reference pulverized coal plant, a recent United Engineers & Constructors in-house combined cycle design, and a General Electric Company advanced concept gas turbine. The plant consists of two natural gas-fired combustion turbine-generator modules, each combined with its own heat recovery steam generator and steam turbine-generator, as shown in Fig. 1.2. Each combined cycle module is rated at 248 MW(e) for a total output of 496 MW(e). About two-thirds of the electrical capacity is from the combustion turbines and about one-third from the steam turbines.

Both of these reference plants were developed as part of the Energy Economic Data Base Program (EEDB) and are documented extensively in other publications.[3,4]

Since no large ACFB plants have been constructed or operated to date, the approach taken in developing O&M cost estimates has been to assume that the staffing and costs for the ACFB plant (excluding limestone costs and additional ash disposal costs) are approximately the same as for an equivalent size pulverized coal-fired plant without scrubbers. For the AGCC plant, significant reductions in costs and staffing, relative to coal-fired plants, are assumed because of the absence of the operating conditions related to coal preparation and combustion and ash handling and disposal.

The cost accounting system used in tracking expenses is shown in Table 1.1. This system is similar to those used in previous studies[5,6] by Oak Ridge National Laboratory (ORNL) and encompasses approximately the same expenses as the Uniform System of Accounts, excerpts of which are shown in Table 1.2, prescribed for public utilities subject to provisions of the Federal Power Act.[7]

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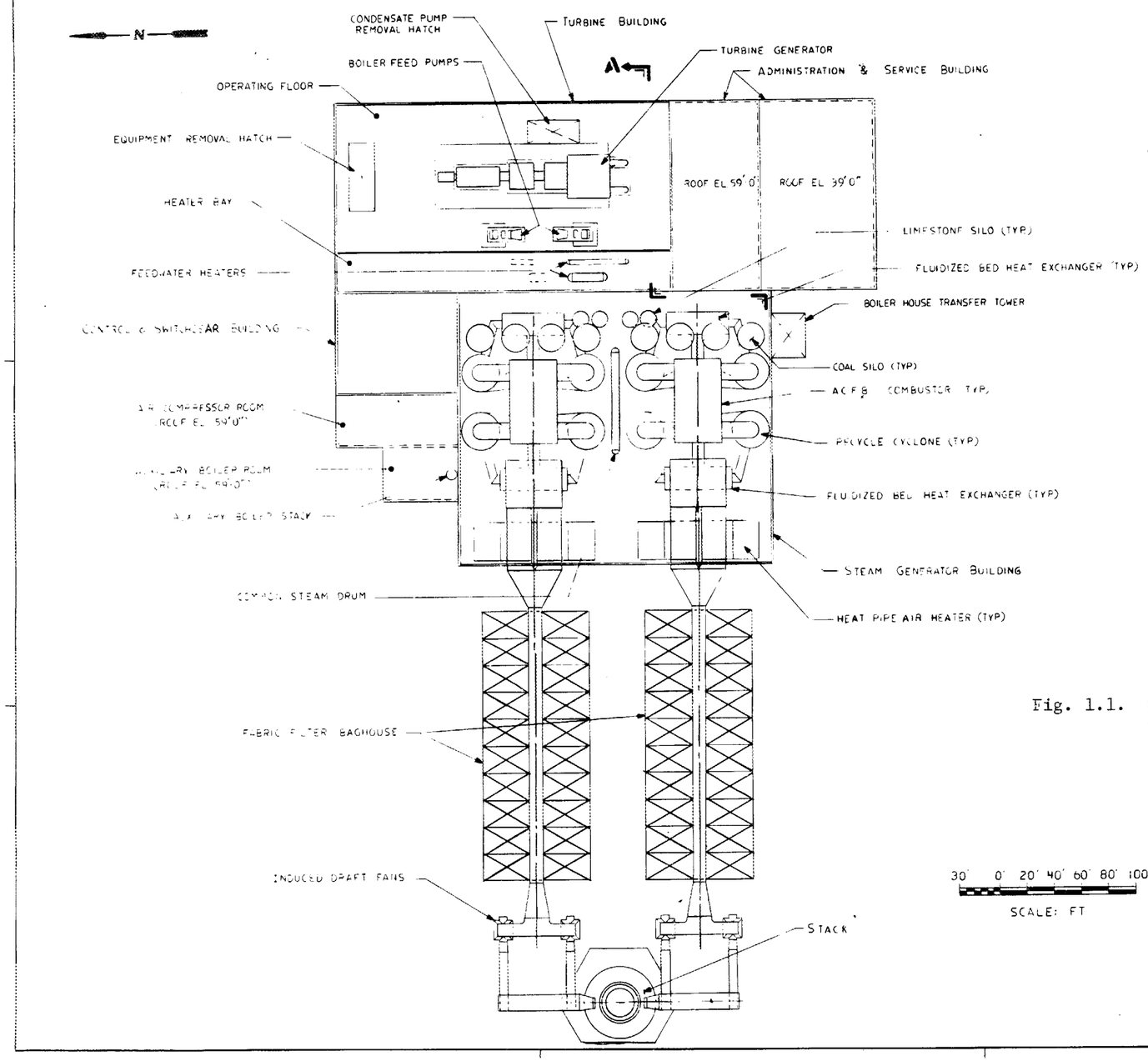

Fig. 1.1. General arrangement of reference ACFB plant (Reference 3).

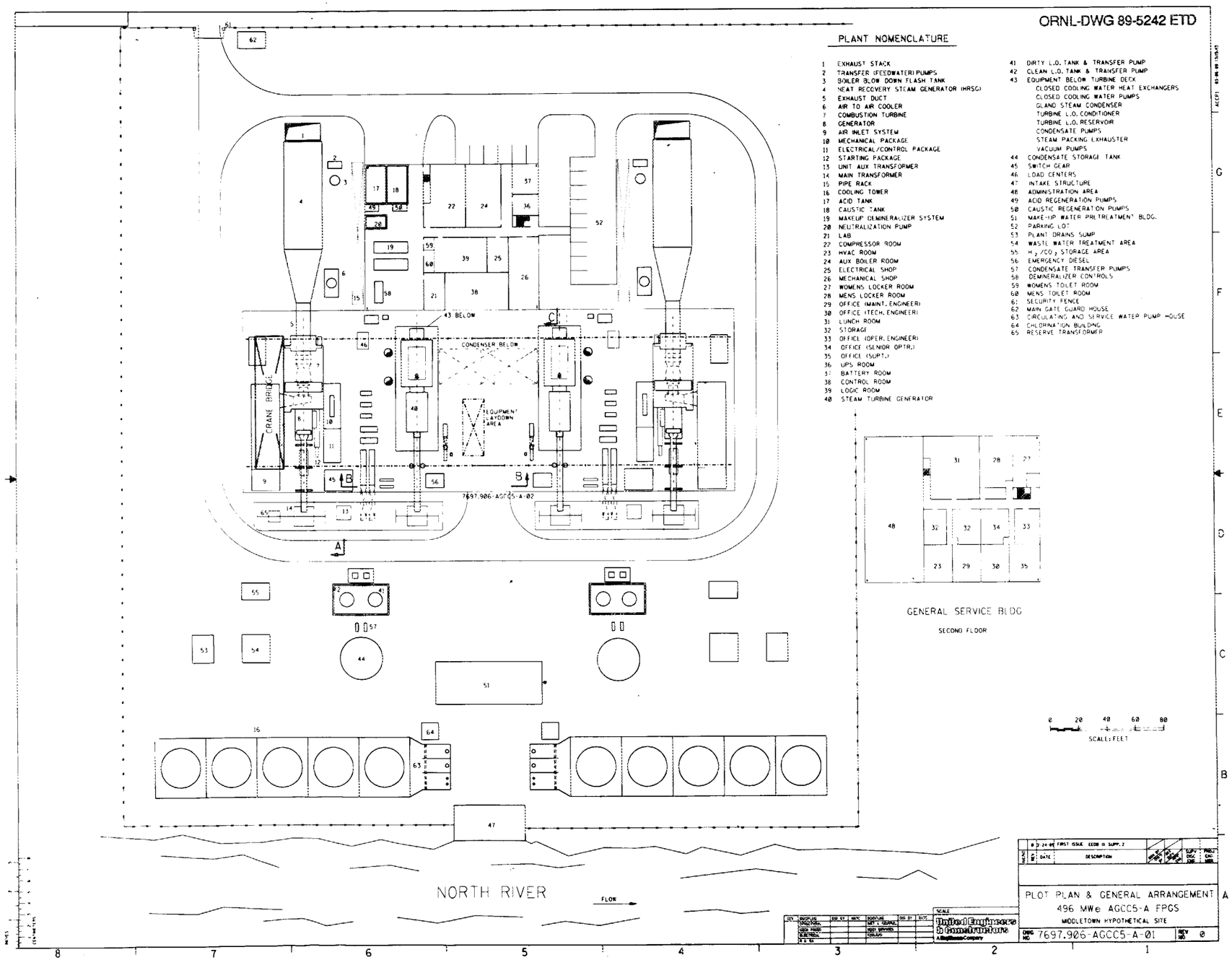

Fig. 1.2. General arrangement of reference AGCC Plant (Ref. 4).

Table 1.1 O&M expense accounts

Power Generation Costs
Onsite staff
Maintenance materials
Fixed
Variable
Supplies and expenses
Fixed
Variable – Plant
– Limestone
– Ash Disposal
Offsite technical support
Administrative and General Costs
Pensions, benefits, and Workers' compensation
Other general expenses

The accounts in Table 1.1 include all accounts in Table 1.2, with the exceptions of 501 Fuel, 503 Steam from other sources, and 504 Steam transferred. Fuel expenses are not considered in this report, and 503 and 504 are assumed to be zero for evaluation purposes. Administrative and general (A&G) expenses are usually not given in reports of operation and maintenance costs by utilities, but they are included here for completeness. Care should be taken in making comparisons with reported costs to insure consistency in regards to A&G costs.

The cost account for onsite staff includes direct salaries along with payroll tax and insurance (social security tax and unemployment insurance premiums). For the offsite technical support account, in addition to this payroll tax and insurance, an overhead burden is applied to the direct salaries. Although uniformity dictates that AGCC plants have accounts for limestone and ash disposal, these costs are zero in the AGCC case. The pensions, benefits, and workers' compensation account in Table 1.1 includes an allocation of 926 Employee pensions and benefits and an allocation of a portion of 925 Injuries and damages, which contains workers' compensation insurance. Other general expenses in Table 1.1 are an allocation of the remaining A&G accounts in Table 1.2.

Table 1.2. Uniform system of accounts for steam power generation and administrative and general expenses

	Steam Power Generation
	Operation
500	Operation supervision and engineering
501	Fuel
502	Steam expenses
503	Steam from other sources
504	Steam transferred – Credit
505	Electric expenses
506	Miscellaneous steam power expenses
507	Rents
508	Operation supplies and expenses
	Maintenance
510	Maintenance supervision and engineering
511	Maintenance of structures
512	Maintenance of boiler plant
513	Maintenance of electric plant
514	Maintenance of miscellaneous steam plant
515	Maintenance of steam production plant
	Administrative and General Expense
	Operation
920	Administrative and general
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
933	Transportation expenses
	Maintenance
935	Maintenance of general plant

In general, the cost estimating relationships presented in this report are for developing annual costs. The computer code listed in Appendix A contains the optional capability to produce levelized costs in addition to annual costs. Constant dollar annual costs are equivalent to constant dollar levelized costs, assuming constant capacity factor, unless some real (excluding inflation) escalation is used for the labor and commodities in the estimate. A complete discussion of levelized costs is available in another report prepared by ORNL.[8]

Equations appearing in the text are applicable, in general, for any site in one of the ten DOE regions of the United States. The DOE regions are displayed in Fig. 1.3. A reference city in each region was chosen, based on locations of DOE regional offices and availability of labor wage rate data. Regional differences in labor wage rates are discussed in Section 2. Also, for each region, a reference coal was chosen, as seen in Table 1.3, to give some idea of the different coals used

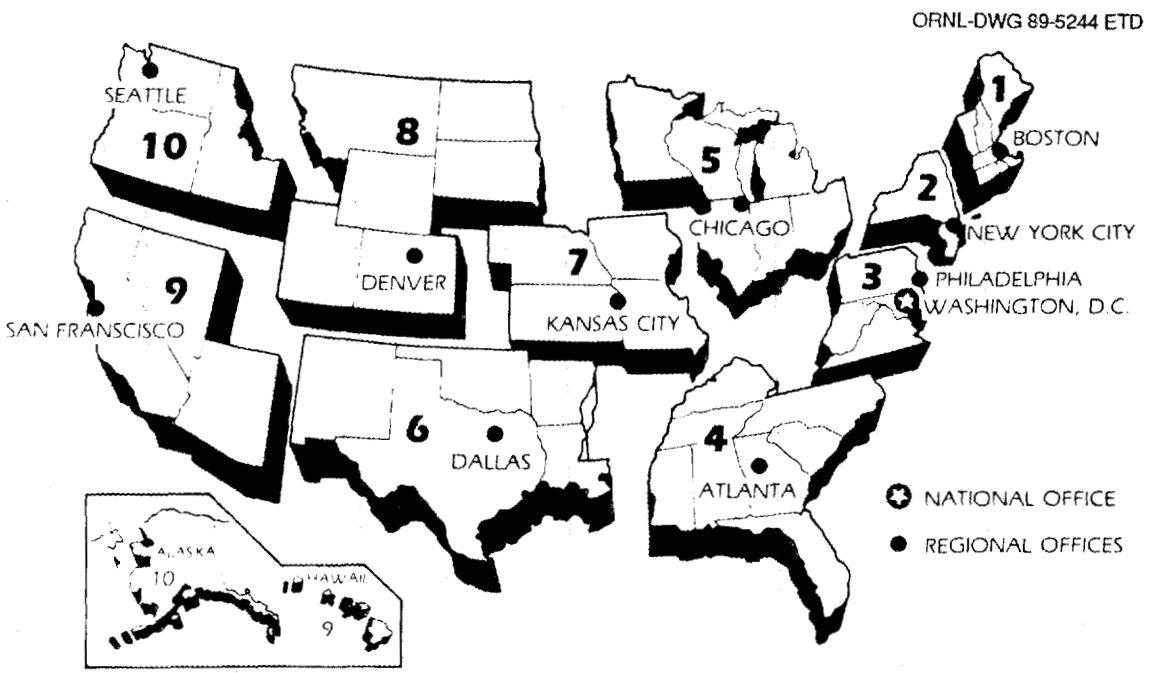

Fig. 1.3. The United States as subdivided into ten federal regions. (Source: Energy Information Administration, "Inventory of Power Plants in the United States 1987," DOE/EIA-0095/87, U.S. Department of Energy, August 1988, p. 282).

Table 1.3. Reference coals for geographic regions

DOE region	Reference city	Producing state	Type[a]	Btu/lb	Sulfur (%)	Ash (%)
1	Boston	WV	Bit.	13100	2.6	9.1
2	New York	PA	Bit.	13700	1.3	9.6
3	Philadelphia	WV	Bit.	13100	2.6	9.1
4	Atlanta	KY	Bit.	12300	1.1	13.8
5	Chicago	IL	Bit.	10100	4.0	16.0
6	Dallas	TX	Lig.	6825	1.0	9.3
7	Kansas City	WY	Sub.	8020	0.5	6.4
8	Denver	WY	Sub.	8220	0.5	6.0
9	San Francisco	AZ	Bit.	12350	0.4	9.6
10	Seattle	WA	Bit.	13170	0.8	7.3
-	Middletown	IL	Bit.	11026	3.6	11.6

[a]Bit. = Bituminous

Lig. = Lignite

Sub. = Subbituminous

throughout the country. In choosing these coals, an analysis was performed to determine the state of origin of all coal received at electric power plants in each of the various regions. Generally, the state of origin contributing the greatest amount to a region's receipts was chosen as the producing state for that region, and a representative coal[9] from the producing state was chosen. Exceptions were made in Regions 2 and 6 (where, in both cases, the second largest contributing state was chosen) to allow a wider range of coals to be included in the task. For the hypothetical Middletown site, the design coal of the reference plant[3] was used.

The cost estimating relationships are discussed in Sections 2–5. Results using these relationships and comparisons to reported costs are found in Section 6. A listing of a computer code incorporating the relationships is given in Appendix A. Because it is written in BASIC with variables defined in the listing and because it is menu driven and user friendly, the code is essentially self-contained and does not require additional documentation. An algorithm for determining ACFB ash flow rate is presented in Appendix B.

2. STAFFING COSTS

Plant staffing can be segregated into two types, onsite and offsite. As used in this report, onsite staff refers to full time employees of the plant's operator who are located physically at the site year round and who are involved either in direct operation of the plant, maintenance of the plant, or in one of several support functions. The offsite staff provides technical support in areas of design, engineering, quality assurance, fuels, and research and development on special problems. They are located offsite and in general perform work at the plant site only during periods of special need, such as outages. Onsite staffing levels are a function of unit size and number of units and are usually independent of actual electric generation during a given year. Onsite staff levels for the two reference plants have been developed and are shown in Tables 2.1 and 2.2. These staff sizes are applicable only for base-loaded plants.

The estimation of staff sizes involves predicting the number of employees involved in each of the major job functions, including administration, operations, maintenance, and technical support.

In the single unit ACFB case, a total of 58 people are assigned to the operations category and 77 are assigned to maintenance. The operations staff is composed of 1 manager (non-shift), 40 operators (5 shifts of 7 plus 5 shift supervisors), 12 fuel and limestone handling personnel, and 5 waste systems personnel. The maintenance staff is composed of 1 manager, 1 planning engineer, 1 mechanical supervisor, 1 electrical supervisor, 4 crews of mechanics (10 persons per crew including foreman), 2 crews of electricians (8 persons per crew including foreman), the equivalent of 15 slots for peak maintenance (annualized), and 2 storekeepers.

In the single unit AGCC case, 26 people are assigned to operations and 43 to maintenance. The operations staff is composed of 1 manager (non-shift), and 25 operators (5 shifts of 4 plus 5 shift supervisors). The maintenance staff is composed of 1 manager, 1 mechanical supervisor, 1 electrical supervisor, 2 crews of mechanics (10 per crew including foreman), 1 crew of electricians (8 per crew including foreman), the

Table 2.1. Estimated onsite staff size for reference ACFB plant[a]

Job title	Salary[b]	Number of units[c]	
		1	2
Plant manager's office			
Plant manager	$74000/y	1	1
Assistant plant manager	59000	1	2
Environmental control	46000	1	1
Training and safety	46000	1	1
Administrative services	23000	10	12
Security	23000	7	7
Operations			
Supervision (Excluding shift)	46000	1	2
Shifts	37000	40	60
Fuel & limestone handling	25000	12	16
Waste systems	25000	5	7
Maintenance			
Supervision	46000	4	5
Crafts	37000	56	75
Peak maint. annualized	40000	15	30
Storekeepers	30000	2	2
Technical support			
Engineering	46000	4	6
Technicians	37000	4	6
Chemistry	40000	2	3
Instr. & Control	40000	8	10
TOTAL STAFF SIZE		174	246
AVERAGE STAFF SALARY[a]		$35600/y	$36000/y

[a]Middletown site.

[b]1989$.

[c]500 MW(e) unit size.

equivalent of 10 persons for peak maintenance (annualized), and 2 storekeepers. The assistant plant manager is to be responsible for environmental control and, in conjunction with the maintenance manager, for outage planning.

Table 2.2. Estimated onsite staff size for reference AGCC plant[a]

Job title	Salary[b]	Number of units[c]	
		1	2
Plant manager's office			
Plant manager	$74000/y	1	1
Assistant plant manager	59000	1	2
Training and safety	46000	1	1
Administrative services	23000	8	11
Security	23000	6	6
Operations			
Supervision (Excluding shift)	46000	1	2
Shifts	37000	25	35
Maintenance			
Supervision	46000	3	4
Crafts	37000	28	38
Peak maint. annualized	40000	10	20
Storekeepers	30000	2	2
Technical support			
Engineering	46000	2	3
Technicians	37000	2	3
Chemistry	40000	1	2
Instr. & Control	40000	8	10
TOTAL STAFF SIZE		99	140
AVERAGE STAFF SALARY[a]		$36600/y	$37100/y

[a]Middletown site.

[b]1989$.

[c]500 MW(e) unit size.

The smaller crew size used for the electricians in both the ACFB and AGCC cases reflects the use of a relatively large amount of equipment utilizing microelectronics in comparison with older plants. Therefore, the electrician crew was reduced in size while the instrument and control staff under technical support was increased above the amount appropriate for plants without the emphasis on microelectronics.

These predictions were made using judgement following discussions with knowledgeable people in the industry. The staff sizes and allocations are for cost estimating purposes only and are not meant to be recommendations for standardized staffing.

As previously stated, onsite staff size is a function of both unit size and number of units. The following empirical relationship has been developed for estimating staff sizes for plants of unit size different than 500 MW(e) and/or with more than two units:

$$\text{Onsite Staff} = (\text{Reference Staff}) \left(\frac{\text{Unit Size}}{500}\right)^{0.4} (\text{No. Units})^{0.5}$$

where,

Reference staff = 174 for ACFB plants, 99 for AGCC plants, per Tables 2.1 and 2.2

Unit Size = Net unit rating in MW(e)

No. Units = Number of units in plant.

Salary levels were established using data from the International Brotherhood of Electrical Workers (IBEW).[10] Salaries for individual positions, seen in Tables 2.1 and 2.2, were developed for the Middletown site only. A labor rate index was then developed based on regional IBEW line labor rate data. When multiplied by the average Middletown onsite staff salary discussed in the next paragraph, the factors in Table 2.3 yield an average salary for each of the ten geographic regions.

Table 2.3. Regional salary adjustment factors

Region no.	Reference city	Factor
1	Boston	0.94
2	New York	1.08
3	Philadelphia	0.98
4	Atlanta	0.96
5	Chicago	1.08
6	Dallas	0.89
7	Kansas City	0.98
8	Denver	0.98
9	San Francisco	1.07
10	Seattle	1.02
-	Middletown	1.00

Total onsite payroll can be determined by multiplying the staff size by the average staff salary. Tables 2.1 and 2.2 indicate that there is little difference (less than 5 %) in the average salary for one- or two-unit plants for ACFB or AGCC plants. Therefore, $36,000 per year (1989$) is recommended as the average staff salary for single- and multi-unit ACFB and AGCC plants. The total onsite payroll should be increased by 10% to allow for the expense of payroll social security tax and unemployment insurance premiums to complete the total onsite staff cost.

Estimates of offsite support staff sizes were made in much the same way as those for onsite staff. Results are tabulated in Table 2.4. The following relationship is recommended for scaling offsite staff sizes:

$$\text{Offsite Staff} = [\text{Base} + \text{Incr.}\ (\text{No. Units})] \left(\frac{\text{Unit Size}}{500}\right)^{0.5}$$

where,

Base = 8 for ACFB, 4 for AGCC
Incr. = 2 for ACFB, 2 for AGCC
No. Units = Number of units in plant
Unit Size = Net unit rating in MW(e)

$46,000 per year is the recommended annual salary for offsite personnel. The total cost of offsite technical support is the annual offsite payroll with an added burden of 70% (10% for payroll taxes and insurances, as in onsite staff, and 60% for overhead).

Table 2.4. Estimated offsite staff sizes for reference plants[a]

Type of plant	Number of units	
	1	2
ACFB	10	12
AGCC	6	8

[a]500 MW(e) unit size.

3. MAINTENANCE MATERIALS COSTS

Maintenance materials expense includes costs for replacement items and expendable materials that are utilized in maintaining the plant during its lifetime. Capital improvements which are amortized over more than one year are not included.

Maintenance materials costs are assumed to be proportional to maintenance staff costs. At 75% capacity factor, the annual maintenance materials expense was estimated to be equal to the total cost of the maintenance staff at the reference Middletown site. Sixty percent of the maintenance materials cost was allocated to fixed charges while the remaining 40% was allocated to variable charges. Projected expenses for single-unit plants are shown in Table 3.1. The fixed portion of the cost is independent of actual electrical generation (capacity factor). Since the variable portion is dependent on actual generation, the 60%-40% breakdown is valid only at 75% capacity factor. At other capacity factors, the breakdown will change.

In scaling the maintenance materials costs, no additional relationship beyond a size scaling for the size of the maintenance staff is

Table 3.1. Projected annual maintenance materials costs for single-unit plants at 75% capacity factor[a]

	ACFB	AGCC
Maintenance Staff Size	77	43
Annual Salary (@ Middletown)	$36000	$36000
Annual Maint. Payroll ($M)	2.772	1.548
Payroll Tax & Insurance ($M)	0.277	0.155
Annual Maint. Staff Cost ($M)	3.049	1.703
Annual Maint. Materials Costs ($M)	3.049	1.703
- fixed portion	1.830	1.022
- variable portion	1.219	0.681

[a]1989$ for 500 MW(e) unit size.

necessary. It is recommended that the size scaling relationship for maintenance staff take the same form as for total onsite staff. Thus:

$$\text{Maint. Staff} = \left(\text{Reference Main Staff}\right)\left(\frac{\text{Unit Size}}{500}\right)^{0.4} (\text{No. Units})^{0.5}$$

where,

Reference Maint. Staff = 77 for ACFB, 43 for AGCC

Unit Size = Net unit rating in MW(e)

No. Units = Number of units in plant.

It is assumed that there is no significant regional variation in maintenance materials costs. Care must be taken to avoid unintentionally incorporating regional adjustment into maintenance materials cost estimates. The estimate of maintenance staff cost is, indeed, a function of region, since salaries incorporate regional adjustment. However, when estimating maintenance materials expense, it is recommened that only the Middletown maintenance staff cost be used to avoid this unintentional adjustment.

4. SUPPLIES AND EXPENSES

The supplies and expenses account includes consumables and some non-maintenance contracts. Allowances for makeup materials and chemicals, steam from other sources, rents, training, data processing, computer maintenance and services, waste management, and miscellaneous expenses are included in the fixed portion of supplies and expenses for both ACFB and AGCC plants. Also, a variable expense to cover general plant consumables is recommended for both types of plants.

In the ACFB case, additional variable costs are incurred for limestone and ash disposal. Process flows for the reference plant at Middletown indicate approximately 70 tons per hour of limestone injected and a sum total of approximately 85 tons per hour of ash (dry solid waste) collected at the bottom of the boiler and the baghouse. More information on calculation of ash flow rates is given in Appendix B. No sludge or wet waste is created from the reference ACFB plant. A unit cost (1989$) of $9/ton was used for determining the variable cost for ash disposal, and a unit cost (1989$) of $16/ton was used in determining variable limestone costs. Both of these unit costs were determined by escalating a previously reported value[11] to 1989$ using the Producer Price Index.[12] The AGCC plant does not use any limestone, and ash disposal costs for the AGCC plant are also assumed to be zero.

Some investigation into the regional variation in the unit cost of limestone was made. A quoted price, including an FOB mine component and a delivery component based on an assumed 100 mile rail journey, was developed for each reference city using the Engineering News Record[13] and telephone contacts. The results of this exercise showed a wide difference form city to city in the delivered cost of limestone. For example, in two neighboring regions, the difference was greater than 160%. It was concluded that this difference was not due to geologic availability of limestone in the region. Instead, it was concluded that the reason for the large differences lies in temporary market conditions and not in long-term trends. Since this study involves a long time horizon, it is believed that temporary effects which could distort the final results should be ignored. Therefore, no regional adjustment in

the unit cost of limestone is recommended. However, total limestone and ash disposal expenses, which are functions of ash content, sulfur content, and other fuel properties, will vary from region to region since the reference coal varies from region to region (see Table 1.3). The limestone and ash disposal expenses are the only portion of supplies and expenses which show regional variation for ACFB plants; there is no variation in supplies and expenses for AGCC plants.

A tabulation of recommended allowances for supplies and expenses for single-unit plants is seen in Table 4.1.

Table 4.1. Estimated annual allowances for supplies and expenses for reference plants

	ACFB	AGCC
Fixed Costs (1989 $M)		
Makeup materials and chemicals	1.0	0.5
Steam from other sources	0.0	0.0
Rents	0.2	0.2
Training	0.3	0.2
Data processing	0.3	0.3
Computer services	0.2	0.2
Waste management	0.5	0.1
Miscellaneous	1.0	0.5
	3.5	2.0
Variable Costs (1989 mills/kWh)		
Plant	0.15	0.10
Limestone	2.2[a]	0.0
Ash disposal	1.5[a]	0.0
	3.85	0.1

[a]Based on reference coal for Middletown site.

The following relationship is recommended for size scaling of the fixed portion of supplies and expenses:

$$\text{Supplies \& expense} = \left(\frac{\text{Base}}{\text{S\&E}}\right)\left(\frac{\text{Unit Size}}{500}\right)^{0.4}(\text{No. Units})^{0.5}$$

where,

Base S&E = 3.5 for ACFB, 2.0 for AGCC, per Table 4.1

Unit Size = Net unit rating in MW(e)

No. Units = Number of units.

5. ADMINISTRATIVE AND GENERAL EXPENSES

Administrative and general expenses are power company overhead costs that are allocated to the plant. This category includes expenses in accounts 920-933 and 935 of the Uniform System of Accounts (see Table 1.2). In the recommended estimating methodology, only pensions, benefits, and workers' compensation are addressed specifically. The remaining expenses fall into the category of other general expenses. No attempt was made to estimate separately costs for insurance, since an operator often will have only one insurance policy to cover all of its fossil-fired plants.

In estimating the cost to a plant for pensions, benefits, and workers' compensation, an analysis was made for year 1987 of 51 non-nuclear utilities. Non-nuclear was defined to be any electric utility which did not operate or own a majority of a nuclear plant but did own or operate at least one coal-fired plant. A pensions and benefits factor, defined as the total utility expenses for pensions and benefits divided by the total utility expenses for salaries and wages, was computed for each of the 51 utilities. The mean value of these factors was found to be 0.15 with a standard deviation of 0.06. A similar procedure yielded an average injuries and damages factor of 0.06 with a standard deviation of 0.05. It is recommended that an allowance of 20% of total salaries and wages (before payroll tax and insurance) be applied to cover the cost of pensions, benefits, and workers' compensation.

In determining an allowance for other general expenses, a similar analysis was performed. An other A&G factor, defined as the ratio of total A&G expenses less pensions, benefits, and workers' compensation to the total operation and maintenance cost less A&G, was computed for each of the same 51 utilities. The mean value of this factor was found to be 0.21 with a standard deviation of 0.13. It is recommended that other general expenses be estimated as 20% of total operation and maintenance cost less A&G.

Data for the calculations described above were obtained from Utility Data Institute[14] which compiles information from reports to the Federal Energy Regulatory Commission by electric utilities.

Total O&M expense (less A&G) and total salaries are functions of geographic region. Pensions, benefits, and workers' compensation expense is a function of total salaries and therefore a function of geographic region. Likewise, the cost allocation for other general expenses is a function of total O&M expense less A&G and therefore assumed to be a function of geographic region. Analyses of regional variation in A&G costs are not possible since one utility may operate plants in more than one geographic region. Therefore, uncertainty concerning this regional variation exists.

6. RESULTS

The cost estimating relationships discussed in Sections 2-5 have been incorporated into a computer code, FOSSILOM, for execution on an IBM-type personal computer. FOSSILOM was used to produce annual nonfuel O&M costs for a single-unit 500 MW(e) ACFB plant and a single-unit 500 MW(e) AGCC plant. Both plants are specified in this case to be located at the hypothetical Middletown site and would begin operation in the year 2000. The results, which are taken directly from FOSSILOM output, are given in Tables 6.1 and 6.2. The first page of the output is a restatement of the input parameters listed in the data menu on the screen during program execution. The second page of the output gives the annual O&M cost estimate. All of the default values, except for the plant type value in the AGCC case, were used in producing these results. More information on FOSSILOM appears in Appendix A.

Costs for plants at any of the ten reference cities are easily produced using FOSSILOM. An O&M cost summary (including A&G) for each region is given in Table 6.3. Table 6.4 gives results of O&M cost less A&G.

Differences in estimated costs for various regions are driven by two factors, regional labor wage rate variations and differences in quality of coal burned in each region (recall Tables 2.3 and 1.3). Reference coals used in this analysis are by no means meant to be the only type of coal available in a particular region. Labor rates can also vary widely within a region, so for any particular site within a region, in practice there may be a wide range of O&M costs other than those reported in Tables 6.3 and 6.4.

Comparison of the results of FOSSILOM to existing plants is uncertain for two reasons. First, these reference plants are not expected to come on line until the year 2000, which leaves a decade for changes in plant operation and maintenance. Secondly, and most importantly, plants of this type and size have never been built before; true comparison data do not exist. Several small (less than 260 MW(e) net) combined cycle plants were built and began operation during the seventies. At present, some utilities are considering building larger scale AGCC and coal-fired

Table 6.1a. Estimated annual O&M costs for single-unit, 500 MW(e) ACFB plant at Middletown site

ANNUAL NONFUEL O&M COST FOR ADVANCED
CIRCULATING FLUIDIZED-BED POWER PLANT
FOR YEAR 2000

VERSION DATE 07-31-1989
RUN DATE 09-01-1989

Sample ACFB output	
O&M COST MODEL NAME	ACFB5
LOCATION	MIDDLETOWN
UNIT NET RATING, MWe	500
NUMBER OF UNITS PER PLANT	1
CAPACITY FACTOR (fraction)	0.75
ESCALATION RATE (fraction/year)	0.050
AVG. ONSITE STAFF SALARY 1989.00 $/year	36000
AVG. OFFSITE STAFF SALARY 1989.00 $/year	46000
FUEL QUALITY: HEATING VALUE (Btu/lb)	11026
SULFUR (wt. fraction)	0.036
ASH (wt. fraction)	0.116
LIMESTONE COST (1989.00 $/ton)	16.00
ASH DISPOSAL COST (1989.00 $/ton)	9.00
PLANT NET HEATRATE (Btu/kWh)	9690
OTHER A&G FACTOR	0.20
YEAR OF STARTUP	2000.00
BASE YEAR FOR COST MODEL	1989.00
REF. YEAR FOR CONSTANT DOLLAR	1989.00
INFLATION RATE	0.050
COST OF MONEY (Nominal fraction)	0.0957
PLANT ECONOMIC LIFE (Years)	30

Table 6.1b. Estimated annual O&M costs for single-unit, 500 MW(e) ACFB plant at Middletown site

CIRCULATING FLUIDIZED-BED POWER PLANT
YEAR 2000
POWER GENERATION COSTS (1989 $million/year)

ONSITE STAFF (174 persons)		6.89
MAINTENANCE MATERIALS		3.05
FIXED	1.83	
VARIABLE	1.22	
SUPPLIES AND EXPENSES		16.22
FIXED	3.50	
VARIABLE - PLANT	0.49	
- LIMESTONE	7.24	
- ASH DISPOSAL	4.99	
OFFSITE TECHNICAL SUPPORT (10 persons)		0.78
SUBTOTAL, DIRECT O&M COSTS		26.95
FIXED	13.00	
VARIABLE	13.94	
ADMINISTRATIVE AND GENERAL COSTS		6.73
PENSIONS, BENEFITS, AND		
WORKERS' COMPENSATION	1.34	
OTHER GENERAL EXPENSES	5.39	
TOTAL NONFUEL O&M COSTS		33.68
FIXED	19.7	
VARIABLE	13.9	
UNIT COSTS:		
mills/kWh (without A&G, 1989.00 $)		8.20
mills/kWh (with A&G, 1989.00 $)		10.25

Table 6.2a. Estimated annual O&M costs for single-unit, 500 MW(e) AGCC plant at Middletown site

ANNUAL NONFUEL O&M COST FOR ADVANCED
NATURAL GAS-FIRED COMBINED CYCLE POWER PLANT
FOR YEAR 2000

VERSION DATE 07-31-1989
RUN DATE 09-01-1989

Sample AGCC output	
O&M COST MODEL NAME	AGCC5
LOCATION	MIDDLETOWN
UNIT NET RATING, MWe	500
NUMBER OF UNITS PER PLANT	1
CAPACITY FACTOR (fraction)	0.75
ESCALATION RATE (fraction/year)	0.050
AVG. ONSITE STAFF SALARY 1989.00 $/year	36000
AVG. OFFSITE STAFF SALARY 1989.00 $/year	46000
FUEL QUALITY: HEATING VALUE (Btu/lb)	11026
SULFUR (wt. fraction)	0.000
ASH (wt. fraction)	0.000
LIMESTONE COST (1989.00 $/ton)	0.00
ASH DISPOSAL COST (1989.00 $/ton)	0.00
NET PLANT HEATRATE (Btu/kWh)	7293
OTHER A&G FACTOR	0.20
YEAR OF STARTUP	2000.00
BASE YEAR FOR COST MODEL	1989.00
REF. YEAR FOR CONSTANT DOLLAR	1989.00
INFLATION RATE	0.050
COST OF MONEY (Nominal fraction)	0.0957
PLANT ECONOMIC LIFE (Years)	30

Table 6.2b. Estimated annual O&M costs for single-unit, 500 MW(e) AGCC plant at Middletown site

NATURAL GAS-FIRED COMBINED CYCLE POWER PLANT

YEAR 2000

POWER GENERATION COSTS (1989 $million/year)

ONSITE STAFF (99 persons)		3.92
MAINTENANCE MATERIALS		1.70
FIXED	1.02	
VARIABLE	0.68	
SUPPLIES AND EXPENSES		2.33
FIXED	2.00	
VARIABLE - PLANT	0.33	
- LIMESTONE	0.00	
- ASH DISPOSAL	0.00	
OFFSITE TECHNICAL SUPPORT (8 persons)		0.47
SUBTOTAL, DIRECT O&M COSTS		8.42
FIXED	7.41	
VARIABLE	1.01	
ADMINISTRATIVE AND GENERAL COSTS		2.45
PENSIONS, BENEFITS, AND		
WORKER'S COMPENSATION	0.77	
OTHER GENERAL EXPENSES	1.68	
TOTAL NONFUEL O&M COSTS		10.87
FIXED	9.9	
VARIABLE	1.0	
UNIT COSTS:		
mills/kWh (without A&G, 1989.00 $)		2.56
mills/kWh (with A&G, 1989.00 $)		3.31

Table 6.3. Estimated annual nonfuel O&M costs (including A&G) by region

DOE region	Reference city	O&M cost – 1989 $M/year		O&M cost-mills/kWh	
		ACFB	AGCC	ACFB	AGCC
1	Boston	27.1	10.4	8.26	3.16
2	New York	24.6	11.2	7.47	3.41
3	Philadelphia	27.7	10.7	8.43	3.26
4	Atlanta	23.9	10.6	7.27	3.21
5	Chicago	37.9	11.2	11.53	3.41
6	Dallas	26.0	10.2	7.90	3.10
7	Kansas City	22.5	10.7	6.86	3.25
8	Denver	22.4	10.7	6.80	3.25
9	San Francisco	22.2	11.2	6.76	3.41
10	Seattle	22.4	10.9	6.80	3.31
-	Middletown	33.7	10.9	10.25	3.31

Table 6.4. Estimated annual nonfuel O&M costs (less A&G) by Region

DOE region	Reference city	O&M cost – 1989 $M/year		O&M cost-mills/kWh	
		ACFB	AGCC	ACFB	AGCC
1	Boston	21.6	8.1	6.57	2.45
2	New York	19.3	8.7	5.86	2.64
3	Philadelphia	22.0	8.3	6.69	2.53
4	Atlanta	18.9	8.2	5.74	2.49
5	Chicago	30.4	8.7	9.25	2.64
6	Dallas	20.7	7.9	6.28	2.41
7	Kansas City	17.7	8.3	5.38	2.52
8	Denver	17.6	8.3	5.34	2.52
9	San Francisco	17.4	8.7	5.28	2.64
10	Seattle	17.5	8.4	5.33	2.56
-	Middletown	27.0	8.4	8.20	2.56

ACFB plants, and at least three fluidized-bed plants in the 100 MW(e) size range are operating.

In keeping with the approach of developing ACFB and AGCC plant O&M costs from pulverized coal-fired plant costs, and because no large (300–600 MW(e) unit size) ACFB and AGCC plants are presently in operation, similar sized pulverized coal-fired plants without flue gas desulfurization (FGD) that are currently in operation were used for comparison. Data for year 1987 were obtained from Utility Data Institute.[14]

Data for year 1987 from coal-fired plants without FGD of one to four units with unit sizes ranging from 275–625 MW(e) were compared against results of FOSSILOM at the Middletown location. In multi-unit cases, FOSSILOM uses the same unit size for each unit in the plant, while in practice, unit sizes often vary. Results are displayed graphically in Fig. 6.1. FOSSILOM was executed several times to produce data used to develop smooth curves. For each execution, the plant type was

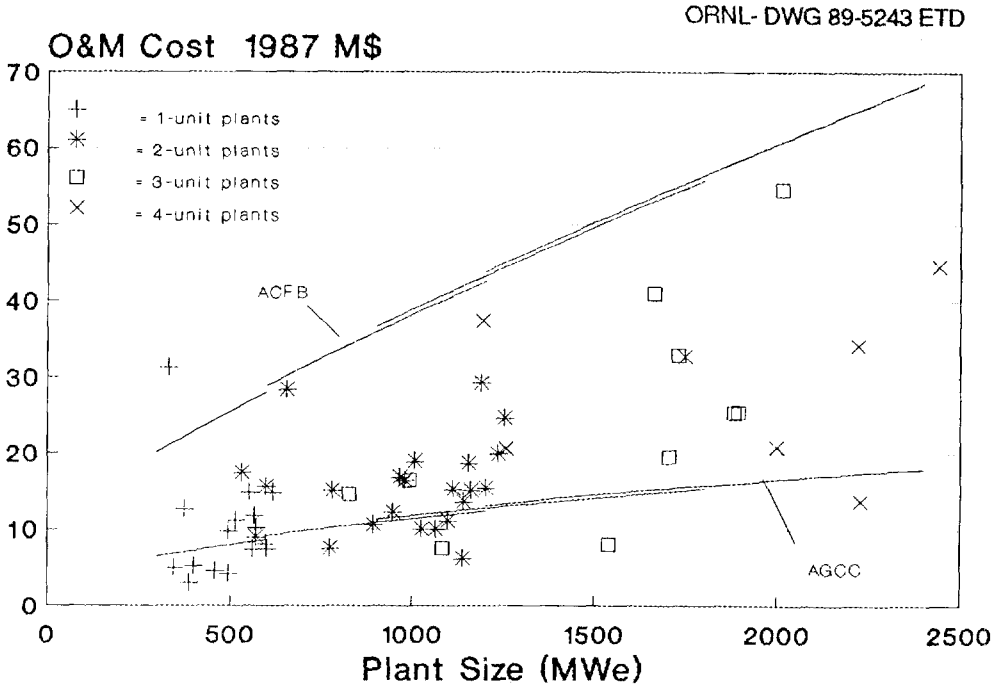

Fig. 6.1. ACFB and AGCC results of FOSSILOM compared to 1987 pulverized coal-fired plant (without flue gas desulfurization) data.

set to the appropriate model (ACFB or AGCC), the year of commercial operation was set to 1989, and both unit size and number of units were varied over ranges of 300-600 MW(e) and 1-4, respectively. All of the other input parameters in the data menu were left at their default setting. Costs were deflated to mid-1987$ using the gross national product implicit price deflator. FOSSILOM results shown are less A&G costs.

The principal conclusion that can be drawn from Fig. 6.1 is that the annual O&M costs (less A&G) for ACFB plants, using the cost estimating relationships developed in this study, are estimated to be somewhat higher than the median costs for similar sized pulverized coal-fired plants without FGD. The higher ACFB costs are principally due to limestone costs and the added costs due to the increased amount of ash handled. Including these limestone and ash costs also increases the slope of the ACFB curve, relative to the slope of the reported data, because these costs are linear functions of plant size. In the AGCC case, results show that O&M costs (less A&G) are estimated to be much less than average pulverized coal-fired plant costs. This result is expected due to the easier fuel handling requirements and cleaner combustion of the AGCC.

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Appendix A. FOSSILOM COMPUTER CODE

FOSSILOM calculates O&M costs for ACFB and AGCC plants using the methodologies recommended in Sections 2-5. Either annual or levelized costs can be produced, and output gives O&M cost both with and without A&G expenses.

FOSSILOM was written using Microsoft Corporation's Quick BASIC 4.0. It is designed to run on any IBM-type computer equipped with a BASIC interpreter, such as Quick BASIC, BASICA, or GW-BASIC. Input data is listed in a data menu which allows the user to alter any input parameters. At start-up, the data menu is equipped with default values to allow the user to execute an entire case without having to input any data. The default value for cost model is ACFB; thus, to produce an estimate for an AGCC plant, the user would have to change the value of the first item in the data menu, cost model, to AGCC from ACFB. Other default values which the user may change in the data menu are site location (must be either hypothetical Middletown site or one of ten reference cities seen in Table 6.3), net unit rating, number of units, average annual capacity factor, plant economic life, annual escalation rates, annual inflation rate, annual interest rate (cost of money), average onsite and offsite staff salaries, heating value of fuel, sulfur content of fuel, ash content of fuel, limestone unit cost, ash disposal unit cost, fraction of total O&M costs less A&G to be allocated to other A&G costs, year of startup, base year for cost models, and a reference year for expressing output in constant dollars.

The output destination can be specified by the user to be either the screen, the printer, or a disk file on one of two drives. The first page of output is a summary of the input parameters used in the analysis, and the second page is the actual cost estimate, which contains a breakdown by the accounting scheme displayed in Table 1.1. Program execution will continue until the user specifies the exit number in the data menu.

The execution of the code was designed to be user friendly, so a detailed user's manual is not provided. The program is written in BASIC to allow the user to modify the code easily. This would be necessary

should the user wish to develop a new cost model other than AGCC or ACFB. Also, a variable dictionary is included in the code to aid the user in understanding the flow of logic.

```
100 '*************************************************************************
110 '************************  F O S S I L O M  ******************************
120 '*************************************************************************
130 '***                                                                   ***
140 '***      FOSSILOM (FOSSIL POWER PLANTS OPERATION AND MAINTENANCE)     ***
150 '***                                                                   ***
160 '***     A computer code for evaluation of operating and maintenance   ***
170 '***     costs for advanced fossil fuel-fired electric power plants.   ***
180 '***     This version includes:                                        ***
190 '***                AGCC - Natural gas-fired combined cycle            ***
200 '***                ACFB - Circulating fluidized-bed                   ***
210 '***                                                                   ***
220 '***                     J. J. Coen                                    ***
230 '***                     Oak Ridge National Laboratory                 ***
240 '***                     P.O. Box 2009, Bldg 9104-1                    ***
250 '***                     Oak Ridge, TN  37831-8057                     ***
260 '***                     (615) 574-0315                                ***
270 '***                     (FTS) 624-0315                                ***
280 '***                                                                   ***
290 '*************************************************************************
300 '***                                                                   ***
310 '***                  Last Update:  07/31/89                           ***
320 '***                                                                   ***
330 '*************************************************************************
340 '
350 '
360 '
370 '*************************************************************************
380 '***                        Preliminary Statements                     ***
390 '*************************************************************************
400 VER$ = "07-31-1989"
410 KEY OFF
420 COLOR 14
430 DEVICEOUT = 2
440 OPEN "SCRN:" FOR OUTPUT AS #1
450 DIM U$(60)
460 DIM BASELIABIL(4)
470 DIM BASEPRIMARY(4)
480 DIM BASESECONDARY(4)
490 DIM BASERPOWER(4)
500 DIM LIMEFAC(11)
510 DIM CITY$(11)
520 DIM LABFAC(11)
530 DIM FUELREF(11, 3)
540 DIM COSTI(15)
550 DEF FNI (BASEYR, YEAR, ESWAGE) = (1 + ESWAGE) ^ (YEAR - BASEYR)
560 DEF FNC (P, I, N) = P * {(I * (1 + I) ^ N) / [(1 + I) ^ N - 1]}
570 CLS
580 FOR I = 1 TO 4: PRINT : NEXT
590 PRINT TAB(12); "NONFUEL O&M COST FOR ADVANCED FOSSIL POWER PLANTS"
600 PRINT TAB(20); "base year for cost model is 1989": PRINT
610 FOR I = 1 TO 4: PRINT : NEXT
```

```
620 GOSUB 6500  'Pause for screen
630 'Define arrays
640 U$(1) = "     UNIT NET RATING, MWe                                ###."
650 U$(2) = "     NUMBER OF UNITS PER PLANT                           #"
660 U$(3) = "     CAPACITY FACTOR (fraction)                          .##"
670 U$(4) = "     ESCALATION RATE (fraction/year)                     .###"
680 U$(5) = "                                                         -------"
690 U$(6) = "     SUBTOTAL, DIRECT O&M COSTS                          ###.##"
700 U$(7) = "     AVG. ONSITE STAFF SALARY ####.## $/year             #####."
710 U$(8) = "     FUEL QUALITY:  HEATING VALUE (Btu/lb)               #####"
720 U$(9) = "     YEAR OF STARTUP                                     ####.##"
730 U$(10) = "     ONSITE STAFF (###. persons)                         ##.##"
740 U$(11) = "     AVG. OFFSITE STAFF SALARY ####.## $/year           #####."
750 U$(12) = "     MAINTENANCE MATERIALS                               ##.##"
760 U$(13) = "          FIXED                              ###.##"
770 U$(14) = "          VARIABLE                            ##.##"
780 U$(15) = "     SUPPLIES AND EXPENSES                               ##.##"
790 U$(16) = "          REGULATORY FEES                     ##.##"
800 U$(17) = "     OFFSITE TECHNICAL SUPPORT (##. persons)             ##.##"
810 U$(18) = "               SUBTOTAL                                  ##.##"
820 U$(19) = "          INSURANCE                          ##.##"
830 U$(20) = "                    SULFUR (wt. fraction)               .###"
840 U$(21) = """
850 U$(22) = "          PROPERTY INSURANCE                 ##.##"
860 U$(23) = "                    ASH (wt. fraction)                  .###"
870 U$(24) = "          REPLACEMENT POWER INSURANCE        ##.##"
880 U$(25) = "          OTHER GENERAL EXPENSES             ##.##"
890 U$(26) = "          FIXED                             ###.#"
900 U$(27) = "          VARIABLE                          ###.#"
910 U$(28) = "          TOTAL NONFUEL O&M                         ###.#"
920 U$(29) = "     LIMESTONE COST (####.## $/ton)                      ##.##"
930 U$(30) = "     ASH DISPOSAL COST (####.## $/ton)                   ##.##"
940 U$(34) = """
950 U$(35) = "     BASE YEAR FOR COST MODEL                            ####.##"
960 U$(36) = "     REF. YEAR FOR CONSTANT DOLLAR                       ####.##"
970 U$(37) = "     INFLATION RATE                                      .### "
980 U$(38) = """
990 U$(39) = "          mills/kWh (with A&G, ####.## $)                ##.##"
1000 U$(40) = "     ADMINISTRATIVE AND GENERAL COSTS                    ##.##"
1010 U$(41) = "     TOTAL NONFUEL O&M COSTS                             ###.##"
1020 U$(42) = "     COST OF MONEY (Nominal fraction)                    .####"
1030 U$(43) = "     PLANT ECONOMIC LIFE (Years)                         ##"
1040 U$(44) = "     OTHER A/G FACTOR                                    .## "
1050 U$(45) = "     5 = OTHER A/G FACTOR (fraction)       .##"
1060 U$(46) = "          PENSIONS, BENEFITS, AND                  "
1070 U$(47) = "          WORKER'S COMPENSATION            ##.##"
1080 U$(48) = "          VARIABLE - PLANT                 ##.##"
1090 U$(49) = "                   - LIMESTONE             ##.##"
1100 U$(50) = "                   - ASH DISPOSAL          ##.##"
1110 U$(51) = "          mills/kWh (with A&G, ####.## $)                ##.##"
1120 U$(52) = "          mills/kWh (without A&G, ####.## $)             ##.##"
1130 U$(53) = "          mills/kWh (with A&G, as spent $)               ##.##"
```

```
1140 U$(54) = "          mills/kWh (without A&G, as spent $)      ##.##"
1150 U$(55) = "     LEVELIZED UNIT COSTS:"
1155 U$(56) = "     UNIT COSTS:"
1160 V$ = "     "
1170 GOSUB 7460 'Assign data values and default values
1180 '*************************************************************************
1190 '
1200 '
1210 '
1220 '*************************************************************************
1230 '***              Menu for Data Entry/Modification                     ***
1240 '*************************************************************************
1250 CLS
1260 PRINT "    THE AVAILABLE MENU OPTIONS AND THEIR VALUES AT THIS TIME ARE:"
1270 PRINT
1280 PRINT "    0 = RUN CASE, DATA ENTRY COMPLETE"
1290 PRINT "    1 = COST MODEL                          "; TMOD$
1300 PRINT "    2 = AVERAGE ONSITE STAFF COST          "; STAFCOS
1310 PRINT "        before payroll taxes and"
1320 PRINT "        insurance in"; BASEYR; "$"
1330 PRINT "        AVERAGE OFFSITE STAFF COST         "; OFFSALARY
1340 PRINT "        before payroll taxes and"
1350 PRINT "        insurance in"; BASEYR; "$"
1360 IF IESC = 2 GOTO 1390
1370 PRINT "    3 = ESCALATION RATES -- VARIOUS"
1380 GOTO 1400
1390 PRINT "    3 = ESCALATION RATE (fraction)         "; ESCGEN
1400 PRINT "    4 = PRICE AND FUEL QUALITY MENU        "
1410 REM   "    5 = OTHER A&G FACTOR                   "; OTHERAGFAC
1420 PRINT USING U$(45); OTHERAGFAC
1430 PRINT "    6 = BASE YEAR FOR FOR COST MODEL       "; BASEYR
1440 PRINT "        YEAR OF PLANT STARTUP              "; YEAR
1450 PRINT "        REF. YEAR FOR CONSTANT DOLLAR      "; TREF
1460 PRINT "    7 = INFLATION RATE                     "; RINF
1470 PRINT
1480 PRINT "     INPUT A NUMBER FROM ABOVE OR PRESS "
1490 PRINT "     RETURN TO SEE THE REST OF THE MENU"
1500 INPUT A$
1510 IF A$ = "" THEN A$ = "!"
1520 IF ASC[LEFT$(A$, 1)] > 47 AND ASC[LEFT$(A$, 1)] < 58 THEN 1530 ELSE 1550
1530 NUM = VAL(A$)
1540 GOTO 1770
1550 PRINT
1560 PRINT "    8 = NUMBER OF UNITS PER PLANT          "; UNITS
1570 PRINT "    9 = BASE LOAD CAPACITY FACTOR          "; PLTFAC
1580 PRINT "   10 = NET RATING OF EACH UNIT (MWe)      "; MWN
1590 PRINT "   11 = PLANT ECONOMIC LIFE (years)        "; LIFE
1600 PRINT "   12 = COST OF MONEY (nom. fraction)      "; INTRATE
1610 PRINT "   13 = LOCATION                           "; CITY$
1620 PRINT "   14 = TYPE OF OUTPUT                     "; OUTER$
1630 PRINT "   15 = OUTPUT DESTINATION";
1640 ON DEVICEOUT GOTO 1650, 1670, 1690, 1710
```

```
1650 PRINT "                Printer"
1660 GOTO 1720
1670 PRINT "                Screen"
1680 GOTO 1720
1690 PRINT "                A:FOSSILOM.DAT"
1700 GOTO 1720
1710 PRINT "                C:FOSSILOM.DAT"
1720 PRINT "    16 = RESET DEFAULT VALUES"
1730 PRINT "    99 = EXIT PROGRAM"
1740 PRINT
1750 PRINT "ENTER A NUMBER FROM THE MENU"
1760 INPUT NUM
1770 IF NUM = 0 GOTO 4430
1780 IF NUM = 99 THEN END
1790 IF NUM < 1 OR NUM > 16 THEN GOSUB 7370 ELSE 1810
1800 GOTO 1250
1810 ON NUM GOTO 2210, 3090, 3240, 3700, 2820, 3000, 3190, 2900, 2960, 2780,
2860, 1890, 3730, 1940, 2190, 1820
1820 'Default reset ********************************************
1830 PRINT "Are you sure (Y/N)?"                                  '*
1840 INPUT ANSW$: ANSW$ = LEFT$(ANSW$, 1)                         '*
1850 IF ANSW$ = "y" OR ANSW$ = "Y" THEN GOSUB 8110 ELSE 1870      '*
1860 GOTO 1250                                                    '*
1870 IF ANSW$ = "N" OR ANSW$ = "n" THEN 1250 ELSE GOSUB 7370      '*
1880 GOTO 1820 '*************************************************
1890 ' Change cost of money '*******************************************
1900 PRINT "     INPUT ANNUAL COST OF MONEY (nominal fraction) "      '*
1910 INPUT INTRATE                                                    '*
1920 RCOM = (1 + INTRATE) / (1 + RINF) - 1                            '*
1930 GOTO 1250  '*********************************************************
1940 'Change type of output ***********************************
1950 PRINT "SELECT TYPE OF OUTPUT"                              '*
1960 PRINT "     A = ANNUAL COSTS "                             '*
1970 PRINT "     L = LEVELIZED ANNUAL COSTS "                   '*
1980 PRINT                                                      '*
1990 PRINT "ENTER AN A OR L"                                    '*
2000 INPUT OUTER$                                               '*
2010 OUTB$ = LEFT$(OUTER$, 1)                                   '*
2020 IF OUTB$ = "a" OR OUTB$ = "A" THEN 2030 ELSE 2110          '*
2030 OUTER$ = "ANNUAL"                                          '*
2040 PRINT                                                      '*
2050 PRINT "OUTPUT FOR WHAT YEAR ?"                             '*
2060 INPUT AYEAR                                                '*
2070 IF AYEAR < YEAR OR AYEAR > (YEAR + LIFE) THEN 2080 ELSE 2100
2080 GOSUB 7370                                                 '*
2090 GOTO 2050                                                  '*
2100 GOTO 2160                                                  '*
2110 IF OUTB$ = "l" OR OUTB$ = "L" THEN 2120 ELSE 2140          '*
2120 OUTER$ = "LEVELIZED"                                       '*
2130 GOTO 2160                                                  '*
2140 GOSUB 7370                                                 '*
2150 GOTO 1940                                                  '*
```

```
2160 IF OUTB$ = "1" THEN OUTB$ = "L"                                    '*
2170 IF OUTB$ = "a" THEN OUTB$ = "A"                                    '*
2180 GOTO 1250 '*********************************************
2190 'Change output destination *****
2200 GOSUB 6580 '*******************
2210 'Change cost model ***************************************
2220 PRINT                                                              '*
2230 PRINT "MENU VALUES CHANGE IN ACCORDANCE WITH COST MODEL"'
2240 GOSUB 6500                                                         '*
2250 CLS                                                                '*
2260 PRINT "     INPUT COST MODEL DESIRED"                              '*
2270 PRINT "          1 = ACFB5 -- ATMOSPHERIC CIRCULATING"             '*
2280 PRINT "                       FLUIDIZED-BED PLANT    "            '*
2290 PRINT "          2 = AGCC5 -- NATURAL GAS-FIRED   "                '*
2300 PRINT "                       COMBINED CYCLE PLANT"              '*
2310 INPUT NTYP                                                         '*
2320 IF NTYP < 1 OR NTYP > 2 THEN GOSUB 7370 ELSE 2340                  '*
2330 GOTO 2260                                                          '*
2340 ON NTYP GOTO 2350, 2560                                            '*
2350 TMOD$ = "ACFB5" '**********************                            '*
2360 BASEMWN = 500                          '*                          '*
2370 HTRATE = 9690                          '*                          '*
2380 BTUVAL = FUELREF(CITYNUM, 1)           '*                          '*
2390 SULFUR = FUELREF(CITYNUM, 2)           '*                          '*
2400 ASH = FUELREF(CITYNUM, 3)              '*                          '*
2410 ASHCOST = 9                            '*                          '*
2420 LIMECOST = CINT(16 * LIMEFAC(CITYNUM) * 10) / 10                   '*
2430 RSTAF = 182                            '*                          '*
2440 RMSTAF = 81                            '*                          '*
2450 MATERFAC = 1!                          '*                          '*
2460 MISCSUPP = 1200                        '*                          '*
2470 MAKEUP = 1200                          '*                          '*
2480 OTSTEAM = 0                            '*                          '*
2490 RENTS = 300                            '*                          '*
2500 TRAINING = 500                         '*                          '*
2510 DATAPROC = 500                         '*                          '*
2520 COMPSERV = 200                         '*                          '*
2530 WASTE = 600                            '*                          '*
2540 VSEMIL = .15                           '*                          '*
2550 GOTO 1250 '*****************************                           '*
2560 TMOD$ = "AGCC5" '***************                                   '*
2570 BASEMWN = 500                  '*                                  '*
2580 HTRATE = 7293                  '*                                  '*
2590 SULFUR = 0                     '*                                  '*
2600 ASH = 0                        '*                                  '*
2610 ASHCOST = 0                    '*                                  '*
2620 LIMECOST = 0                   '*                                  '*
2630 BTUVALG = 1000                 '*                                  '*
2640 RSTAF = 99                     '*                                  '*
2650 RMSTAF = 41                    '*                                  '*
2660 MATERFAC = 1!                  '*                                  '*
2670 MISCSUPP = 600                 '*                                  '*
```

```
2680 MAKEUP = 600                    '*                          '*
2690 OTSTEAM = 0                     '*                          '*
2700 RENTS = 200                     '*                          '*
2710 TRAINING = 200                  '*                          '*
2720 DATAPROC = 500                  '*                          '*
2730 COMPSERV = 200                  '*                          '*
2740 WASTE = 100                     '*                          '*
2750 VSEMIL = .1                     '*                          '*
2760 REM '*************************                             '*
2770 GOTO 1250 '************************************************
2780 'Change net unit size '**********************
2790 PRINT "     INPUT MWE NET RATING PER UNIT" '*
2800 INPUT MWN                                  '*
2810 GOTO 1250 '*********************************
2820 'Change other A&G factor '***************************
2830 PRINT "     INPUT OTHER A&G FACTOR (fraction) "    '*
2840 INPUT OTHERAGFAC                                   '*
2850 GOTO 1250 '*****************************************
2860 'Change plant life '********************
2870 PRINT "     INPUT PLANT LIFE (years)" '*
2880 INPUT LIFE                            '*
2890 GOTO 1250 '*****************************
2900 'Change number of units '***************************
2910 PRINT "     INPUT NUMBER OF UNITS PER PLANT"       '*
2920 INPUT UNITS                                        '*
2930 IF UNITS < 1 OR UNITS > 4 THEN 2940 ELSE 1250      '*
2940 GOSUB 7370                                         '*
2950 GOTO 2900 '*************************************
2960 'Change capacity factor '************************************
2970 PRINT "     INPUT BASE LOAD CAPACITY FACTOR AS A DECIMAL"   '*
2980 INPUT PLTFAC                                                '*
2990 GOTO 1250 '*************************************************
3000 'Change timings '************************************
3010 PRINT "     INPUT BASE YEAR FOR COST MODEL"          '*
3020 INPUT BASEYR                                         '*
3030 PRINT "     INPUT YEAR OF PLANT STARTUP"             '*
3040 INPUT YEAR                                           '*
3050 AYEAR = YEAR                                         '*
3060 PRINT "     INPUT YEAR FOR CONSTANT DOLLAR OUTPUT"   '*
3070 INPUT TREF                                           '*
3080 GOTO 1250  '*************************************
3090 'Change average staffing cost '***********************************
3100 PRINT "     INPUT AVERAGE COST PER ONSITE STAFF MEMBER, $/YEAR" '*
3110 PRINT "     IN "; BASEYR; " DOLLARS"                            '*
3120 PRINT "     before payroll taxes and insurance"                 '*
3130 INPUT STAFCOS                                                   '*
3140 PRINT "     INPUT AVERAGE COST PER OFFSITE STAFF MEMBER, $/YEAR"'*
3150 PRINT "     IN "; BASEYR; " DOLLARS"                            '*
3160 PRINT "     before payroll taxes, insurance, and overhead"      '*
3170 INPUT OFFSALARY                                                 '*
3180 GOTO 1250 '*****************************************************
3190 'Change annual inflation rate ******************
```

```
3200 PRINT "     INPUT INFLATION RATE (decimal) "    '*
3210 INPUT RINF                                      '*
3220 GOTO 1250 '************************************
3230 'Change annual escalation data '*****************************************
3240 PRINT "     DO YOU WANT TO USE THE DEFAULT GENERAL ESCALATION RATE?"  '*
3250 PRINT "     (Y OR N)"                                                 '*
3260 INPUT ANSWER$: ANSWER$ = LEFT$(ANSWER$, 1)                           '*
3270 IF ANSWER$ = "Y" OR ANSWER$ = "y" THEN 3300                          '*
3280 IF ANSWER$ <> "N" AND ANSWER$ <> "n" THEN GOSUB 7370 ELSE 3320       '*
3290 GOTO 3240                                                            '*
3300 GOSUB 6390                                                           '*
3310 GOTO 3690                                                            '*
3320 PRINT "     DO YOU WANT TO INPUT A GENERAL ESCALATION RATE? (Y OR N)" '*
3330 INPUT ANSWER$                                                        '*
3340 IF ANSWER$ = "Y" OR ANSWER$ = "y" THEN 3660                          '*
3350 IF ANSWER$ <> "N" AND ANSWER$ <> "n" THEN GOSUB 7370 ELSE 3370       '*
3360 GOTO 3320                                                            '*
3370 IESC = 1                                                             '*
3380 PRINT "     DO YOU WANT TO INPUT INDIVIDUAL ESCALATION RATES? (Y/N)"  '*
3390 INPUT ANSWER$                                                        '*
3400 IF ANSWER$ = "Y" OR ANSWER$ = "y" THEN 3440                          '*
3410 IF ANSWER$ <> "N" AND ANSWER$ <> "n" THEN GOSUB 7370 ELSE 3430       '*
3420 GOTO 3380                                                            '*
3430 BEEP: GOSUB 7370: GOTO 3240                                          '*
3440 PRINT "    CURRENT VALUES ARE"                                       '*
3450 PRINT "            WAGES AND SALARIES              "; ESWAGE         '*
3460 PRINT "            MATERIALS AND SUPPLIES          "; ESMATL         '*
3470 PRINT "            LIMESTONE                       "; ESLIME         '*
3480 PRINT "            ASH DISPOSAL                    "; ESASH          '*
3490 'PRINT "            REGULATORY FEE                  "; ESFEES        '*
3500 'PRINT "            INSURANCE                       "; ESCINS        '*
3510 PRINT : PRINT                                                        '*
3520 PRINT "     INPUT ESCALATION RATES (fraction/year)"                  '*
3530 PRINT "          WAGES AND SALARIES"                                 '*
3540 INPUT ESWAGE                                                         '*
3550 PRINT "          MATERIALS AND SUPPLIES"                             '*
3560 INPUT ESMATL                                                         '*
3570 PRINT "          LIMESTONE"                                          '*
3580 INPUT ESLIME                                                         '*
3590 PRINT "          ASH DISPOSAL"                                       '*
3600 INPUT ESASH                                                          '*
3610 'PRINT "          REGULATORY FEES"                                    '*
3620 'INPUT ESFEES                                                        '*
3630 'PRINT "          INSURANCE"                                          '*
3640 'INPUT ESCINS                                                        '*
3650 GOTO 3690                                                            '*
3660 PRINT "     INPUT ESCALATION RATE (fraction/year)"                   '*
3670 INPUT ESCGEN                                                         '*
3680 GOSUB 6390                                                           '*
3690 GOTO 1250 '*************************************************************
3700 'Change fuel qualities '****
3710 GOSUB 6960                '*
```

```
3720 GOTO 1230 '*****************
3730 'Change location ******************************************
3740 PRINT                                                      '*
3750 PRINT "FUEL QUALITY AND SALARIES CHANGE "                  '*
3760 PRINT "WITH CHANGE IN LOCATION"                            '*
3770 GOSUB 6500                                                 '*
3780 CLS                                                        '*
3790 PRINT                                                      '*
3800 PRINT TAB(10); " 1 = BOSTON"                               '*
3810 PRINT TAB(10); " 2 = NEW YORK"                             '*
3820 PRINT TAB(10); " 3 = PHILADELPHIA"                         '*
3830 PRINT TAB(10); " 4 = ATLANTA"                              '*
3840 PRINT TAB(10); " 5 = CHICAGO"                              '*
3850 PRINT TAB(10); " 6 = DALLAS"                               '*
3860 PRINT TAB(10); " 7 = KANSAS CITY"                          '*
3870 PRINT TAB(10); " 8 = DENVER"                               '*
3880 PRINT TAB(10); " 9 = SAN FRANCISCO"                        '*
3890 PRINT TAB(10); "10 = SEATTLE"                              '*
3900 PRINT TAB(10); "11 = MIDDLETOWN"                           '*
3910 PRINT : PRINT                                              '*
3920 PRINT "TYPE THE NUMBER OF THE DESIRED CITY"                '*
3930 INPUT CITYNUM                                              '*
3940 IF CITYNUM < 1 OR CITYNUM > 11 THEN GOSUB 7370 ELSE 3960   '*
3950 GOTO 3780                                                  '*
3960 ON CITYNUM GOTO 3970, 3990, 4010, 4030, 4050, 4070, 4090, 4110, 4130,
   4150, 4170
3970 CITY$ = "BOSTON"                                           '*
3980 GOTO 4200                                                  '*
3990 CITY$ = "NEW YORK"                                         '*
4000 GOTO 4200                                                  '*
4010 CITY$ = "PHILADELPHIA"                                     '*
4020 GOTO 4200                                                  '*
4030 CITY$ = "ATLANTA"                                          '*
4040 GOTO 4200                                                  '*
4050 CITY$ = "CHICAGO"                                          '*
4060 GOTO 4200                                                  '*
4070 CITY$ = "DALLAS"                                           '*
4080 GOTO 4200                                                  '*
4090 CITY$ = "KANSAS CITY"                                      '*
4100 GOTO 4200                                                  '*
4110 CITY$ = "DENVER"                                           '*
4120 GOTO 4200                                                  '*
4130 CITY$ = "SAN FRANCISCO"                                    '*
4140 GOTO 4200                                                  '*
4150 CITY$ = "SEATTLE"                                          '*
4160 GOTO 4200                                                  '*
4170 CITY$ = "MIDDLETOWN"                                       '*
4180 GOTO 4200                                                  '*
4200 LABR = LABFAC(CITYNUM)                                     '*
4202 STAFCOS = INT(36000! * LABR / 1000) * 1000                 '*
4204 OFFSALARY = INT(46000! * LABR / 1000) * 1000               '*
4206 IF NTYP = 2 THEN 4270   'nat. gas doesn't change           '*
```

```
4210 SULFUR = FUELREF(CITYNUM, 2)                                    '*
4220 ASH = FUELREF(CITYNUM, 3)                                       '*
4230 BTUVAL = FUELREF(CITYNUM, 1)                                    '*
4260 LIMECOST = CINT(16! * LIMEFAC(CITYNUM) * 10) / 10               '*
4270 GOTO 1250 '*************************************************
4280 '*************************************************************************
4290 '
4300 '
4310 '
4320 '*************************************************************************
4330 '***                                                                   ***
4340 '***                        Main Program                               ***
4350 '***                                                                   ***
4360 '***     This portion of the code calculates the annual O&M costs      ***
4370 '***     for the first year of operation in TREF dollars.  This        ***
4380 '***     amount is then adjusted to another year of operation          ***
4390 '***     (still in TREF $) or is converted to a levelized basis        ***
4400 '***     in subroutines, per user specification.                       ***
4410 '***                                                                   ***
4420 '*************************************************************************
4430 PRINT "ENTER RUN IDENTIFICATION (OR NULL LINE)"
4440 INPUT RUNID$
4450 'Calculate annual net power generation
4460 ANNGEN = MWN * FULLYR * PLTFAC * UNITS / 1000
4470 'Calculate onsite staff cost
4480 PEOPLE = CINT(RSTAF * [(MWN / BASEMWN) ^ .4) * (UNITS ^ .5)]
4490 MANCOS = (1! + PAYTAXINSUR) * STAFCOS * FNI(BASEYR, YEAR, ESWAGE)
4495 MANCOSM = (1 + PAYTAXINSUR) * 36000 * FNI(BASEYR, YEAR, ESWAGE)
4500 COSTAF = PEOPLE * MANCOS / [1000000! * FNI(TREF, YEAR, RINF)]
4510 'Calculate fixed and variable maintenance material cost
4520 MAINTSTAF = CINT{RMSTAF * [(MWN / BASEMWN) ^ .4] * (UNITS ^ .5)}
4530 BASM = MATERFAC * MAINTSTAF * MANCOSM / [1000000! * FNI(TREF, YEAR,
   RINF)]
4540 FIXMNT = FIXFAC * BASM
4550 VARMNT = VARFAC * BASM * PLTFAC / BASECF
4560 'Calculate fixed and portions of variable supplies and expenses
4570 SUPEXF = MISCSUPP + MAKEUP + OTSTEAM + RENTS + TRAINING + DATAPROC +
   COMPSERV + WASTE
4580 SUPEXF = SUPEXF * FNI(BASEYR, YEAR, ESMATL) / FNI(TREF, YEAR, RINF)
4590 FIXSE = (SUPEXF / 1000) * [(MWN / BASEMWN) ^ .4] * (UNITS ^ .5)
4600 LIMEPD = (HTRATE / BTUVAL) * SULFUR * CASURAT * 2.5 * 40 / (LIMEPUR * 32)
4610 LIMVAR = LIMEPD * LIMECOST * FNI(BASEYR, YEAR, ESLIME) / FNI(TREF, YEAR,
   RINF) / 2
4620 ASHMULT = (11026 / BTUVAL) * [.31 * ASH / .116 + .69 * CASURAT ^ .7 *
   SULFUR * (1 + LINERT) / (2.5 ^ .7 * .0361 * 1.07)]
4630 ASHPD = ASHMULT * ASHBASE * 2 / (UNITS * MWN)
4640 ASHVAR = ASHPD * ASHCOST * FNI(BASEYR, YEAR, ESASH) / FNI(TREF, YEAR,
   RINF) / 2
4650 VSEMILREF = VSEMIL * FNI(BASEYR, YEAR, ESMATL) / FNI(TREF, YEAR, RINF)
4660 'Calculate offsite support services
4670 IF NTYP = 2 THEN 4680 ELSE 4710
4680 '-combined cycle:
```

```
4690 OFFSTAFF = CINT[(6 + 2 * UNITS) * (MWN / BASEMWN) ^ .5]
4700 GOTO 4730
4710 '-cfb:
4720 OFFSTAFF = CINT[(10 + 5 * UNITS) * (MWN / BASEMWN) ^ .5]
4730 OFFANNUAL = (1 + PAYTAXINSUR + OFFOVERHEAD) * OFFSALARY * OFFSTAFF
4740 SUPORT = OFFANNUAL * FNI(BASEYR, YEAR, ESWAGE) / [1000000! * FNI(TREF,
   YEAR, RINF)]
4750 'Calculate Administrative and General costs including:
4760 '     pensions (includes workman's compensation insurance)
4770 '     nuclear regulatory fees
4780 '     commercial liability insurance
4790 '     primary and secondary property insurance
4800 '     replacement power insurance
4810 PENSION = PENFACT * (PEOPLE * STAFCOS + OFFSTAFF * OFFSALARY) / 1000000!
4820 PENSION = PENSION * FNI(BASEYR, YEAR, ESWAGE) / FNI(TREF, YEAR, RINF)
4830 REGFEES = 0
4840 REGFEES = REGFEES * FNI(BASEYR, YEAR, ESFEES) / FNI(TREF, YEAR, RINF)
4850 COMINS = .1 * BASELIABIL(UNITS) * FNI(BASEYR, YEAR, ESCINS) / FNI(TREF,
   YEAR, RINF)
4860 PRIMAR = .1 * BASEPRIMARY(UNITS) * FNI(BASEYR, YEAR, ESCINS) / FNI(TREF,
   YEAR, RINF)
4870 EXCESS = .1 * BASESECONDARY(UNITS) * FNI(BASEYR, YEAR, ESCINS) /
   FNI(TREF, YEAR, RINF)
4880 PROPIN = PRIMAR + EXCESS
4890 RPOWER = BASERPOWER(UNITS) * FNI(BASEYR, YEAR, ESCINS) / FNI(TREF, YEAR,
   RINF)
4900 REM
4910 IF OUTB$ = "L" THEN 4920 ELSE 4940
4920 GOSUB 8500    'adjusts to levelized basis
4930 GOTO 4950
4940 GOSUB 8850    'adjusts to annual costs for specified year
4950 REM
4960 'Calculate total maintenance materials expense
4970 TOTMNT = FIXMNT + VARMNT
4980 'Calculate total supplies expense
4990 VARSEL = LIMVAR * ANNGEN / 1000
5000 VARSEA = ASHVAR * ANNGEN / 1000
5010 VARSEP = VSEMILREF * ANNGEN / 1000
5020 VARSE = VARSEL + VARSEA + VARSEP
5030 SUPEXP = FIXSE + VARSE
5040 'Calculate fixed, variable, and total power generation costs
5050 FIXPOWER = COSTAF + FIXMNT + FIXSE + SUPORT
5060 VARPOWER = VARMNT + VARSE
5070 TOTPOWER = FIXPOWER + VARPOWER
5080 'Calculate other A&G costs
5090 OTHERAG = OTHERAGFAC * TOTPOWER
5100 'Calculate total A&G costs
5110 ADMGEN = PENSION + REGFEES + COMINS + PROPIN + RPOWER + OTHERAG
5120 'Sum fixed, variable, and total annual costs
5130 TOTFIX = FIXPOWER + ADMGEN
5140 TOTVAR = VARPOWER
5150 TOTAL = TOTFIX + TOTVAR
```

```
5160 'Calculate total annual and total unit costs less A&G
5170 TOTALNOAG = TOTAL - ADMGEN
5180 TOTMILNOAG = 1000 * TOTALNOAG / ANNGEN
5190 'Convert fixed, variable, and total annual costs to unit costs
5200 FIXMIL = 1000 * TOTFIX / ANNGEN
5210 VARMIL = 1000 * TOTVAR / ANNGEN
5220 TOTMIL = 1000 * TOTAL / ANNGEN
5230 '*************************************************************************
5240 '
5250 '
5260 '
5270 '*************************************************************************
5280 '***                        Print Results                                ***
5290 '*************************************************************************
5300 'Print input data
5310 CLS
5320 PRINT #1, "                ANNUAL NONFUEL O&M COST FOR ADVANCED "
5330 IF NTYP = 2 THEN 5360 ELSE 5340
5340 NAM$ = "            CIRCULATING FLUIDIZED-BED POWER PLANT"
5350 GOTO 5370
5360 NAM$ = "         NATURAL GAS-FIRED COMBINED CYCLE POWER PLANT"
5370 PRINT #1, "   "; NAM$
5380 IF OUTB$ = "A" THEN 5390 ELSE 5410
5390 PRINT #1, "                            FOR YEAR"; AYEAR
5400 GOTO 5420
5410 PRINT #1, "                            LEVELIZED BASIS"
5420 PRINT #1, V$
5430 PRINT #1, "                   VERSION DATE "; VER$
5440 PRINT #1, "                       RUN DATE "; DATE$
5450 PRINT #1, V$
5460 PRINT #1, V$; RUNID$
5470 PRINT #1, V$; "O&M COST MODEL NAME                                  "; TMOD$
5480 PRINT #1, V$; "LOCATION                                            "; CITY$
5490 PRINT #1, USING U$(1); MWN
5500 PRINT #1, USING U$(2); UNITS
5510 PRINT #1, USING U$(3); PLTFAC
5520 IF IESC = 1 GOTO 5530 ELSE 5610
5530 PRINT #1, "     ESCALATION RATES, fraction"
5540 PRINT #1, "         WAGES AND SALARIES                             "; ESWAGE
5550 PRINT #1, "         MATERIALS AND SUPPLIES                         "; ESMATL
5560 PRINT #1, "         LIMESTONE                                      "; ESLIME
5570 PRINT #1, "         ASH DISPOSAL                                   "; ESASH
5580 PRINT #1, "         REGULATORY FEES                                "; ESFEES
5590 'PRINT #1, "          INSURANCE                                      "; ESCINS
5600 GOTO 5620
5610 PRINT #1, USING U$(4); ESCGEN
5620 REM
5630 PRINT #1, USING U$(7); BASEYR; STAFCOS
5640 PRINT #1, USING U$(11); BASEYR; OFFSALARY
5650 IF DEVICEOUT = 2 THEN GOSUB 6500 'Pause for screen
5660 PRINT #1, USING U$(8); BTUVAL
5670 PRINT #1, USING U$(20); SULFUR
```

```
5680 PRINT #1, USING U$(23); ASH
5690 PRINT #1, USING U$(29); BASEYR; LIMECOST
5700 PRINT #1, USING U$(30); BASEYR; ASHCOST
5710 PRINT #1, USING U$(44); OTHERAGFAC
5720 PRINT #1, USING U$(9); YEAR
5730 PRINT #1, USING U$(35); BASEYR
5740 PRINT #1, USING U$(36); TREF
5750 PRINT #1, USING U$(37); RINF
5760 PRINT #1, USING U$(42); INTRATE
5770 PRINT #1, USING U$(43); LIFE
5780 PRINT #1, "----------------"
5790 IF DEVICEOUT = 2 THEN GOSUB 6500 'Pause for screen
5800 PRINT #1, CHR$(12)
5810 PRINT #1, NAM$
5820 IF OUTB$ = "A" THEN 5830 ELSE 5850
5830 PRINT #1, "                              YEAR"; AYEAR
5840 GOTO 5860
5850 PRINT #1, "                               LEVELIZED"
5860 PRINT #1, "          POWER GENERATION COSTS ("; TREF; "$million/year) "
5870 PRINT #1, "          ------------------------------------------"
5880 PRINT #1, V$
5890 PRINT #1, USING U$(10); PEOPLE, COSTAF
5900 PRINT #1, V$
5910 PRINT #1, USING U$(12); TOTMNT
5920 PRINT #1, USING U$(13); FIXMNT
5930 PRINT #1, USING U$(14); VARMNT
5940 PRINT #1, V$
5950 PRINT #1, USING U$(15); SUPEXP
5960 PRINT #1, USING U$(13); FIXSE
5970 PRINT #1, USING U$(48); VARSEP
5980 PRINT #1, USING U$(49); VARSEL
5990 PRINT #1, USING U$(50); VARSEA
6000 PRINT #1, V$
6010 PRINT #1, USING U$(17); OFFSTAFF, SUPORT
6020 IF DEVICEOUT = 2 THEN GOSUB 6500'Pause for screen
6030 PRINT #1, V$
6040 PRINT #1, U$(5)
6050 PRINT #1, USING U$(6); Z$; TOTPOWER
6060 PRINT #1, USING U$(13); FIXPOWER
6070 PRINT #1, USING U$(14); VARPOWER
6080 PRINT #1, V$
6090 PRINT #1, USING U$(40); ADMGEN
6100 PRINT #1, U$(46)
6110 PRINT #1, USING U$(47); PENSION
6120 'PRINT #1, USING U$(16); REGFEES
6130 'PRINT #1, USING U$(19); COMINS
6140 'PRINT #1, USING U$(22); PROPIN
6150 'PRINT #1, USING U$(24); RPOWER
6160 PRINT #1, USING U$(25); OTHERAG
6170 PRINT #1, V$
6180 PRINT #1, U$(5)
6190 PRINT #1, USING U$(41); Z$; TOTAL
```

```
6200 PRINT #1, USING U$(26); TOTFIX
6210 PRINT #1, USING U$(27); TOTVAR
6220 IF DEVICEOUT = 2 THEN GOSUB 6500'Pause for screen
6230 PRINT #1, V$: PRINT #1, V$
6235 IF OUTB$ = "L" THEN 6240 ELSE 6237
6237 PRINT #1, U$(56)
6238 GOTO 6260
6240 PRINT #1, U$(55)
6250 PRINT #1, V$
6260 PRINT #1, USING U$(52); Z$; TREF; TOTMILNOAG
6270 PRINT #1, USING U$(51); Z$; TREF; TOTMIL
6280 IF OUTB$ = "L" THEN 6290 ELSE 6320
6290 PRINT #1, V$
6300 PRINT #1, USING U$(53); Z$; TOTMILNOAG * FNC(1, INTRATE, LIFE) / FNC(1,
   RCOM, LIFE)
6310 PRINT #1, USING U$(54); Z$; TOTMIL * FNC(1, INTRATE, LIFE) / FNC(1, RCOM,
   LIFE)
6320 IF DEVICEOUT = 2 THEN GOSUB 6500'Pause for screen
6330 PRINT #1, CHR$(12)
6340 GOTO 1220
6350 '*************************************************************************
6360 '
6370 '
6380 '
6390 REM ****** Subroutine to reset escaltion rates to general value ******
6400 IESC = 2                                                              '*
6410 ESWAGE = ESCGEN                                                       '*
6420 ESMATL = ESCGEN                                                       '*
6430 ESLIME = ESCGEN                                                       '*
6440 ESASH = ESCGEN                                                        '*
6450 ESFEES = ESCGEN                                                       '*
6460 ESCINS = ESCGEN                                                       '*
6470 RETURN '*************************************************************
6480 '
6490 '
6500 REM ****** Subroutine to pause for screen output ******
6510 REM                                                  '*
6520 PRINT "Press any key to continue"                    '*
6530 A$ = INKEY$                                          '*
6540 IF A$ = "" THEN 6530                                 '*
6550 RETURN '*********************************************
6560 '
6570 '
6580 REM ****** Subroutine to select output destination **********************
6590 CLOSE #1                                                              '*
6600 PRINT "     select output destination as follows:"                    '*
6610 PRINT "          1 = printer"                                         '*
6620 PRINT "          2 = screen"                                          '*
6630 PRINT "          3 = A:FOSSILOM.DAT"                                  '*
6640 PRINT "          4 = C:FOSSILOM.DAT"                                  '*
6650 INPUT DEVICEOUT: IF DEVICEOUT < 1 OR DEVICEOUT > 4 THEN 6660 ELSE 6670 '*
6660 BEEP: PRINT "ERROR IN SELECTION -- TRY AGAIN": GOTO 6600              '*
```

```
6670 ON DEVICEOUT GOTO 6680, 6720, 6740, 6800                                  '*
6680 WIDTH "LPT1:", 80                                                         '*
6690 OPEN "LPT1:" FOR OUTPUT AS #1                                             '*
6700 PRINT #1, CHR$(27); "1"; CHR$(10)'set left margin to 10                   '*
6710 GOTO 6840                                                                 '*
6720 OPEN "SCRN:" FOR OUTPUT AS #1                                             '*
6730 GOTO 6840                                                                 '*
6740 OPEN "A:FOSSILOM.DAT" FOR APPEND AS #1                                    '*
6750 IF LOF(1) <> 0 THEN GOSUB 6870 ELSE 6840'Define append                    '*
6760 IF APPENDER = 1 THEN 6770 ELSE 6840                                       '*
6770 CLOSE #1                                                                  '*
6780 OPEN "A:FOSSILOM.DAT" FOR OUTPUT AS #1                                    '*
6790 GOTO 6840                                                                 '*
6800 OPEN "C:FOSSILOM.DAT" FOR APPEND AS #1                                    '*
6810 IF LOF(1) <> 0 THEN GOSUB 6870 ELSE 6840'Define append                    '*
6820 IF APPENDER = 1 THEN 6830 ELSE 6840                                       '*
6830 CLOSE #1: OPEN "C:FOSSILOM.DAT" FOR OUTPUT AS #1                          '*
6840 RETURN 1250 '*************************************************************
6850 '
6860 '
6870 REM ****** Append option subroutine ******************************
6880 PRINT "Please select the proper response:"                          '*
6890 PRINT "     1 = Write over existing FOSSILOM.DAT file"              '*
6900 PRINT "     2 = Append existing FOSSILOM.DAT file"                  '*
6910 INPUT APPENDER                                                      '*
6920 IF APPENDER < 1 OR APPENDER > 2 THEN BEEP: PRINT D$: GOTO 6880      '*
6930 RETURN '*************************************************************
6940 '
6950 '
6960 REM ****** Subroutine for price and fuel quality submenu ************
6970 CLS                                                                       '*
6980 PRINT : PRINT                                                             '*
6990 PRINT TAB(5); "PRICE AND FUEL QUALTIY SUBMENU"                            '*
7000 PRINT                                                                     '*
7010 PRINT TAB(10); " 0 = RETURN TO MAIN MENU"                                 '*
7020 PRINT TAB(10); " 1 = PLANT HEAT RATE (Btu/kWh)          "; HTRATE        '*
7022 IF NTYP = 1 THEN 7030 ELSE 7024                                           '*
7024 PRINT TAB(10); " 2 = FUEL HEATING VALUE (Btu/ cu. ft.)  "; BTUVALG       '*
7026 GOTO 7040                                                                 '*
7030 PRINT TAB(10); " 2 = FUEL HEATING VALUE (Btu/lb)        "; BTUVAL        '*
7040 PRINT TAB(10); " 3 = SULFUR CONTENT (wt. fraction)      "; SULFUR        '*
7050 PRINT TAB(10); " 4 = ASH CONTENT (wt. fraction)         "; ASH           '*
7060 PRINT TAB(10); " 5 = LIMESTONE COST ("; BASEYR; "$/ton)       "; LIMECOST
7070 PRINT TAB(10); " 6 = ASH DISPOSAL COST ("; BASEYR; "$/ton)    "; ASHCOST
7080 PRINT                                                                     '*
7090 PRINT TAB(5); "ENTER A NUMBER FROM THE MENU"                              '*
7100 INPUT SUBNUM                                                              '*
7110 IF SUBNUM < 0 OR SUBNUM > 6 THEN GOSUB 7370 ELSE 7130                     '*
7120 GOTO 6970                                                                 '*
7130 PRINT : PRINT                                                             '*
7140 SUBNUM = SUBNUM + 1                                                       '*
7150 ON SUBNUM GOTO 7340, 7160, 7190, 7220, 7250, 7280, 7310                   '*
```

```
7160 PRINT TAB(5); "ENTER NET PLANT HEAT RATE"  '***                    '*
7170 INPUT HTRATE                                '*                     '*
7180 GOTO 6970 '*************************************                  '*
7190 PRINT TAB(5); "ENTER HEATING VALUE"  '**                           '*
7200 INPUT BTUVAL                          '*                           '*
7210 GOTO 6970 '*******************************                        '*
7220 PRINT TAB(5); "ENTER SULFUR CONTENT (wt. fraction)"  '***          '*
7230 INPUT SULFUR                                  '*                   '*
7240 GOTO 6970 '*********************************************          '*
7250 PRINT TAB(5); "ENTER ASH CONTENT (wt. fraction)" '**               '*
7260 INPUT ASH                                      '*                  '*
7270 GOTO 6970 '****************************************               '*
7280 PRINT TAB(5); "ENTER LIMESTONE COST ("; BASEYR; "$/ton)" '**       '*
7290 INPUT LIMECOST                                          '*        '*
7300 GOTO 6970 '************************************************       '*
7310 PRINT TAB(5); "ENTER ASH DISPOSAL COST ("; BASEYR; "$/ton)" '***   '*
7320 INPUT ASHCOST                                              '*     '*
7330 GOTO 6970 '*************************************************      '*
7340 RETURN '*****************************************************************
7350 '
7360 '
7370 REM ****** Error message subroutine ******
7380 BEEP: BEEP                              '*
7390 PRINT : PRINT                           '*
7400 PRINT "ENTRY ERROR -- TRY AGAIN"        '*
7410 GOSUB 6500                              '*
7420 PRINT : PRINT : PRINT                   '*
7430 RETURN '********************************
7440 '
7450 '
7460 REM ****** Data assignment subroutine ******
7470 BASECF = .75                             '*
7480 FIXFAC = .6                              '*
7490 VARFAC = .4                              '*
7500 FULLYR = 8766                            '*
7510 MISCSUPP = 1200                          '*
7520 MAKEUP = 1200                            '*
7530 OTSTEAM = 0                              '*
7540 RENTS = 300                              '*
7550 TRAINING = 500                           '*
7560 DATAPROC = 500                           '*
7570 COMPSERV = 200                           '*
7580 WASTE = 600                              '*
7590 VSEMIL = .15                             '*
7600 Z$ = "&"                                 '*
7610 PAYTAXINSUR = .1                         '*
7620 OFFOVERHEAD = .6                         '*
7630 PENFACT = .2                             '*
7640 OTHERAGFAC = .2                          '*
7650 FOR I = 1 TO 4                           '*
7660 READ BASELIABIL(I)                       '*
7670 DATA 0, 0, 0, 0
```

```
7680 NEXT I                                          '*
7690 FOR I = 1 TO 4                                  '*
7700 READ BASEPRIMARY(I)                             '*
7710 DATA 0, 0, 0, 0
7720 NEXT I                                          '*
7730 FOR I = 1 TO 4                                  '*
7740 READ BASESECONDARY(I)                           '*
7750 DATA 0, 0, 0, 0
7760 NEXT I                                          '*
7770 FOR I = 1 TO 4                                  '*
7780 READ BASERPOWER(I)                              '*
7790 DATA 0, 0, 0, 0
7800 NEXT I                                          '*
7810 LIMEPUR = .9                                    '*
7820 CASURAT = 2.5                                   '*
7830 FOR I = 1 TO 11                                 '*
7840 FOR J = 1 TO 3                                  '*
7850 READ FUELREF(I, J)                              '*
7860 NEXT J                                          '*
7870 NEXT I                                          '*
7880 DATA 13100, .026, .091
7890 DATA 13700, .013, .096
7900 DATA 13100, .026, .091
7910 DATA 12300, .011, .138
7920 DATA 10100, .040, .160
7930 DATA  6825, .010, .093
7940 DATA  8020, .005, .064
7950 DATA  8220, .005, .060
7960 DATA 12350, .004, .096
7970 DATA 13170, .008, .073
7980 DATA 11026, .036, .116
7990 FOR I = 1 TO 11                                 '*
8000 READ LABFAC(I)                                  '*
8010 NEXT I                                          '*
8020 DATA 0.9366, 1.0826, 0.9802, 0.9632
8030 DATA 1.0775, 0.8930, 0.9762, 0.9762
8040 DATA 1.0736, 1.0187, 1.0000
8050 FOR I = 1 TO 11                                 '*
8060 READ LIMEFAC(I)                                 '*
8070 NEXT I                                          '*
8080 DATA 1.000, 1.000, 1.000, 1.000
8090 DATA 1.000, 1.000, 1.000, 1.000
8100 DATA 1.000, 1.000, 1.000
8110 'Menu data                                      '*
8120 OUTER$ = "ANNUAL"                               '*
8130 OUTB$ = "A"                                     '*
8140 LIFE = 30                                       '*
8150 CITY$ = "MIDDLETOWN"                            '*
8160 CITYNUM = 11                                    '*
8170 LABR = 1!                                       '*
8180 NTYP = 1                                        '*
8190 IESC = 2                                        '*
```

```
8200 BASEYR = 1989                                    '*
8210 OFFSALARY = 46000!                               '*
8220 ESCGEN = .05                                     '*
8230 GOSUB 6390  'Set individual rates                '*
8240 STAFCOS = 36000!                                 '*
8250 TMOD$ = "ACFB5"                                  '*
8260 BASEMWN = 500                                    '*
8270 HTRATE = 9690                                    '*
8280 BTUVAL = 11026                                   '*
8290 SULFUR = .0361                                   '*
8300 ASH = .116                                       '*
8310 ASHBASE = 84.3                                   '*
8320 ASHCOST = 9                                      '*
8330 LIMECOST = 16                                    '*
8340 LINERT = .07                                     '*
8350 RSTAF = 182                                      '*
8360 RMSTAF = 81                                      '*
8370 MATERFAC = 1!                                    '*
8380 MWN = 500                                        '*
8390 RINF = .05                                       '*
8400 INTRATE = .0957                                  '*
8410 RCOM = .0435                                     '*
8420 TREF = 1989                                      '*
8430 UNITS = 1                                        '*
8440 PLTFAC = .75                                     '*
8450 YEAR = 2000                                      '*
8460 AYEAR = 2000                                     '*
8470 RETURN '**************************************
8480 '
8490 '
8500 REM ****** Subroutine to convert annual costs to levelized costs ******
8510 FOR N = 1 TO 15                                                    '*
8520 COSTI(N) = 0                                                       '*
8530 NEXT N                                                             '*
8540 FOR N = 1 TO LIFE                                                  '*
8550  COSTI(1) = COSTI(1) + COSTAF * [(1 + ESWAGE) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8560  COSTI(2) = COSTI(2) + FIXMNT * [(1 + ESWAGE) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8570  COSTI(3) = COSTI(3) + VARMNT * [(1 + ESWAGE) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8580  COSTI(4) = COSTI(4) + FIXSE * [(1 + ESMATL) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8590  COSTI(5) = COSTI(5) + LIMVAR * [(1 + ESLIME) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8600  COSTI(6) = COSTI(6) + ASHVAR * [(1 + ESASH) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8610 COSTI(7) = COSTI(7) + VSEMILREF * [(1 + ESMATL) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8620  COSTI(8) = COSTI(8) + PENSION * [(1 + ESWAGE) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
```

```
8630 COSTI(9) = COSTI(9) + REGFEES * [(1 + ESFEES) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8640 COSTI(10) = COSTI(10) + COMINS * [(1 + ESCINS) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8650 COSTI(11) = COSTI(11) + PROPIN * [(1 + ESCINS) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8660 COSTI(12) = COSTI(12) + RPOWER * [(1 + ESCINS) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8670 COSTI(13) = COSTI(13) + SUPORT * [(1 + ESWAGE) / (1 + RINF)] ^ N /
   (1 + RCOM) ^ N
8680 NEXT N                                                          '*
8690 COSTAF = FNC(COSTI(1), RCOM, LIFE)                              '*
8700 FIXMNT = FNC(COSTI(2), RCOM, LIFE)                              '*
8710 VARMNT = FNC(COSTI(3), RCOM, LIFE)                              '*
8720 FIXSE = FNC(COSTI(4), RCOM, LIFE)                               '*
8730 LIMVAR = FNC(COSTI(5), RCOM, LIFE)                              '*
8740 ASHVAR = FNC(COSTI(6), RCOM, LIFE)                              '*
8750 VSEMILREF = FNC(COSTI(7), RCOM, LIFE)                           '*
8760 PENSION = FNC(COSTI(8), RCOM, LIFE)                             '*
8770 REGFEES = FNC(COSTI(9), RCOM, LIFE)                             '*
8780 COMINS = FNC(COSTI(10), RCOM, LIFE)                             '*
8790 PROPIN = FNC(COSTI(11), RCOM, LIFE)                             '*
8800 RPOWER = FNC(COSTI(12), RCOM, LIFE)                             '*
8810 SUPORT = FNC(COSTI(13), RCOM, LIFE)                             '*
8820 RETURN  '*******************************************************
8830 '
8840 '
8850 REM ****** Subroutine to 'move' annual costs **************
8860 N = AYEAR - TREF                                               '*
8870 COSTAF = COSTAF * [(1 + ESWAGE) / (1 + RINF)] ^ N              '*
8880 FIXMNT = FIXMNT * [(1 + ESWAGE) / (1 + RINF)] ^ N              '*
8890 VARMNT = VARMNT * [(1 + ESWAGE) / (1 + RINF)] ^ N              '*
8900 FIXSE = FIXSE * [(1 + ESMATL) / (1 + RINF)] ^ N                '*
8910 LIMVAR = LIMVAR * [(1 + ESLIME) / (1 + RINF)] ^ N              '*
8920 ASHVAR = ASHVAR * [(1 + ESASH) / (1 + RINF)] ^ N               '*
8930 VSEMILREF = VSEMILREF * [(1 + ESMATL) / (1 + RINF)] ^ N        '*
8940 PENSION = PENSION * [(1 + ESWAGE) / (1 + RINF)] ^ N            '*
8950 REGFEES = REGFEES * [(1 + ESFEES) / (1 + RINF)] ^ N            '*
8960 COMINS = COMINS * [(1 + ESCINS) / (1 + RINF)] ^ N              '*
8970 PROPIN = PROPIN * [(1 + ESCINS) / (1 + RINF)] ^ N              '*
8980 RPOWER = RPOWER * [(1 + ESCINS) / (1 + RINF)] ^ N              '*
8990 SUPORT = SUPORT * [(1 + ESWAGE) / (1 + RINF)] ^ N              '*
9000 RETURN  '*******************************************************
9010 '
9020 '
9030 '*************************************************************************
9040 '***                        List of Variables                          ***
9050 '*************************************************************************
9060 'ADMGEN     - Total annual cost of Administrative and General expenese,
9070 '             including other A&G (million TREF$ / year)
9080 'ANNGEN     - Annual net electrical generation (million kWh)
9090 'ASH        - Weight fraction of ash in fuel
```

```
9100 'ASHBASE   - Tons/hour of ash produced using reference coal and limestone
9110 'ASHCOST   - Ash disposal cost (BASEYR $ / ton)
9120 'ASHMULT   - Multiplier to adjust ASHBASE for different coals/limestones
9130 'ASHPD     - Pounds of ash produced per kWh of electricity
9140 'ASHVAR    - Annual cost of ash disposal (TREF mills/kWh)
9150 'AYEAR     - Year for annual O&M cost output
9160 'BASEMWN   - Net size of reference unit (MWe)
9170 'BASEYR    - Base year for cost input data
9180 'BASM      - Annual cost of maintenance materials for specifed plant
9190 '            size @ BASECF (million TREF $ / year)
9200 'BTUVAL    - Heating value of fuel (Btu/lb)
9205 'BTUVALG   - Heating value of gas (Btu/cu. ft.)
9210 'CASURAT   - Molar ratio of calcium/sulfur
9220 'CITY$     - String city name
9230 'CITYNUM   - Numeric counterpart of CITY$
9240 'COMINS    - Annual cost of commercial liability insurance (million TREF
9250 '            $ / year)
9260 'COMPSERV  - Annual cost of computer maintenance (thous. BASEYR $/year)
9270 'COSTAF    - Annual cost of total onsite staff (million TREF $ / year)
9280 'DATAPROC  - Annual cost of data processing (thousand BASEYR $ / year)
9290 'ESASH     - Average annaul rate of escalation of ash disposal cost
9300 'ESCINS    - Average annual rate of escalation of insurance premiums
9310 'ESFEES    - Average annual rate of escalation of regulatory fees
9320 'ESLIME    - Average annual rate of escalation of limestone price
9330 'ESMATL    - Average annual rate of escalation of materials and supplies
9340 'ESWAGE    - Average annual rate of escalation of wages and salaries
9350 'EXCESS    - Annual cost of excess property insurance (million TREF $ /
9360 '            year)
9370 'FIXFAC    - Fixed fraction of maintenance materials cost
9380 'FIXMIL    - Total annual fixed direct and indirect costs(TREF mills/kWh)
9390 'FIXPOWER  - Fixed annual power generation costs (million TREF $ / year)
9400 'FULLYR    - Number of hours in a calendar year
9410 'HTRATE    - Net plant heat rate (Btu/kWh)
9420 'IESC      - Escalation rates flag : (1 = individual rates used, 2 =
9430 '            general rate used)
9440 'INTRATE   - Annual nominal cost of money (fraction)
9450 'LABR      - Multiplication factor for adjusting labor rates for regional
9460 '            variation
9470 'LABFAC    - Array of values of LABR
9480 'LIFE      - Length of plant life (years from COP date)
9490 'LIMECOST  - Limestone cost (BASEYR $ / ton)
9500 'LIMEFAC   - Multiplication factor for adjusting LIMECOST for regional
9510 '            variation
9520 'LIMEPD    - Pounds of limestone used to produced 1 kWh of electricity
9530 'LIMEPUR   - Weight % of CACO3 in limestone
9540 'LIMVAR    - Annual cost of limestone (TREF mills/kWh)
9550 'LINERT    - Portion of limestone which is inert (fraction)
9560 'MAINTSTAF - Size of maintenance staff @ specified size
9570 'MAKEUP    - Annual cost of makeup materials and chemicals (thousand
9580 '            BASEYR $ / year)
9590 'MANCOS    - Average annual cost of an onsite staff member @ year of
9600 '            operation (YEAR $ / year)
```

```
9605 'MANCOSM    - MANCOS @ Middletown for use in calculating Maint. Materials
9610 'MATERFAC   - Annual cost of maintenance materials for specifed plant as
9620 '             a fraction of maintenance labor
9630 'MISCSUPP   - Annual cost of potable water, lubricants, communications,
9640 '             security, transportation, lab chemicals, clothing, gases,
9650 '             lamping, office supplies, etc (thous. BASEYR $ / year)
9660 'MWN        - Net unit size (MWe)
9670 'OFFANNUAL  - Total annual cost of offsite staff (BASEYR $ / year)
9680 'OFFOVERHEAD- Overhead factor for offsite staff
9690 'OFFSALARY  - Average cost of an offsite staff member before taxes and
9700 '             insurance (BASEYR $ / year)
9710 'OFFSTAFF   - Size of offsite staff for selected plant size
9720 'OTHERAG    - Annual cost of other Administrative and General expenses
9730 '             (million TREF $ / year)
9740 'OTHERAGFAC- Annual cost of other Administrative and General expenses as
9750 '             a fraction of total annual power generation costs
9760 'OTSTEAM    - Annual cost of steam from other sources (thous. BASEYR$/yr)
9770 'OUTER$     - Flag for type of output (annual or levelized)
9780 'PAYTAXINS  - Payroll taxes and insurance as a fraction of STAFCOS
9790 'PENFACT    - Annual pension expenses as a fraction of total annual
9800 '             wages and salaries
9810 'PENSION    - Annual pension expenses (million TREF $ / year)
9820 'PEOPLE     - Size of oniste staff @ specified plant size
9830 'PLTFAC     - Average annual plant capacity factor (decimal)
9840 'PRIMAR     - Annual cost of primary property insurance (million TREF $
9850 '             / year)
9860 'PROPIN     - Total annual cost of property insurance (mill TREF $ / year)
9870 'RCOM       - Anuual real cost of money (fraction)
9880 'REGFEES    - Annual regulatory fees (million TREF $ / year)
9890 'RENTS      - Annual cost of rents (thousand BASEYR $ / year)
9900 'RINF       - Average annual rate of inflation (decimal)
9910 'RMSTAF     - Size of maintenance staff @ reference size
9920 'RPOWER     - Annual cost of replacement power insurance (million TREF $
9930 '             / year)
9940 'RSTAF      - Size of onsite staff @ reference plant size
9950 'STAFCOS    - Average cost of an onsite staff member before taxes and
9960 '             insurance (BASEYR $ / year)
9970 'SULFUR     - Weight fraction of sulfur in fuel
9980 'SUPEXF     - Sum of MISCSUPP, MAKEUP, OTSTEAM, RENTS, TRAINING, DATAPROC,
9990 '           - COMPSERV, & WASTE adjusted to thousand TREF $/year
10000 'SUPORT     - Total annual cost of offiste staff (million TREF $ / year)
10010 'TREF       - Reference year for constant dollar output
10020 'TOTAL      - Total annual O&M costs (million TREF $ / year)
10030 'TOTALNOAG  - Total annual O&M costs less A&G costs(million TREF $ /
   year)
10040 'TOTFIX     - Total annual fixed direct and indirect costs (million TREF
10050 '             $ / year)
10060 'TOTMIL     - Total annual O&M costs (TREF mills/kWh)
10070 'TOTMILNOAG- Total annual O&M cost less A&G costs (mills/kWh)
10080 'TOTMNT     - Annual cost of maintenance materials for specified plant
10090 '             size @ specified capacity factor (million TREF $ / year)
10100 'TOTPOWER   - Total annual power generation costs (million TREF $ / year)
```

```
10110 'TOTVAR    - Total annual variable direct and indirect costs (million
10120 '            TREF $ / year)
10130 'TRAINING  - Annual training costs (thousand BASEYR $ / year)
10140 'VARFAC    - Variable fraction of maintenance materials cost @ BASECF
10150 'VARMIL      - Total annual var. direct and indirect costs (TREF
   mills/kWh)
10160 'VARPOWER  - Variable annual power generation costs (mill TREF $ / year)
10170 'VARSE     - Annual cost of total variable supplies and expenses
10180 '            (million TREF $/year)
10190 'VARSEA    - Annual cost of ash disposal (million TREF $/year)
10200 'VARSEL    - Annual cost of limestone (million TREF $/year)
10210 'VARSEP    - Annual cost of plant variable supplies and expenses
10220 '            (million TREF $/year)
10230 'VSEMIL    - Annual cost of variable supplies and expenses (BASEYR mills
10240 '            /kWh), excluding limestone and ash disposal
10250 'VSEMILREF - Annual cost of variable supplies and expenses (TREF mills/
10260 '            kWh)
10270 'WASTE     - Annual cost of waste management (thousand BASEYR $ / year)
10280 'YEAR      - Year of commercial operation
10290 '*************************************************************************
```

Appendix B. ACFB ASH FLOW RATE ALGORITHM

K. A. Williams

For a given coal-fired plant energy output, the amount of solids which must be handled as waste, i.e. the ash discharged from the burner and that captured from the stack gas in the baghouse, is dependent on the quality of the coal burned and the quality of the limestone used for SO_x removal. The Middletown reference plant design assumes a discharge rate of 84.3 tons per hour based on a reference high-sulfur coal described in reference 3.

If a lower sulfur coal with a larger heating value were to be used, one would expect to use less coal (because of the larger heating value and fewer non-carbon, non-hydrogen components) and less limestone (since limestone consumption is driven by sulfur removal requirements). The opposite would be expected for coals with inert content greater than the reference 11.62% or sulfur content greater that the reference 3.61%. In addition to coal consumption, the same can be said for total ash production, which also depends on the following factors:

- % inerts in the coal (ref value 11.62)
- % sulfur in the coal (ref value 3.61)
- % inerts in the limestone (ref value 7.00)
- mole ratio of Ca/S in the plant design (reference value 2.5)
- heat rate of the coal (ref value 11026 BTU/lb coal).

To calculate the ash rate for the non-Middletown cases (other regions and their reference coals) a multiplier on the Middletown case ash rate can be calculated by use of the following algorithm which has a value of 1.0 for the Middletown case:

$$\text{Multiplier} = \left(\frac{11026}{\text{Heating value}}\right)\left[0.31\left(\frac{\%\ \text{inerts}}{11.62}\right)\right.$$

$$\left. + 0.69\left(\frac{\text{Ca/S ratio}}{2.5}\right)^{0.7}\left(\frac{\%\ S}{3.61}\right)\left(\frac{1 + \%\ \text{inerts in lime}}{1.07}\right)\right]$$

This algorithm, which is based on a constant plant energy output of 500 MW(e), is used in FOSSILOM to calculate ash flow rate. The material

balance used to derive this relationship is based on the following assumptions:

1. 99% of the carbon in the coal is converted to CO_2.
2. All of the hydrogen in the coal not already in the form of water is converted to H_2O.
3. For medium and high sulfur coals 90% or more of the sulfur in the coal is retained in the ash. The amount of sulfur going out the stack can be no more than 0.58 lb SO_2/MBtu. For low sulfur coal the removal requirement is 70% or better and again assumes the 0.58 lb SO_2/MBtu regulatory requirement is met. These limits are consistent with the reference plant design and current Environmental Protection Agency requirements (see Elliot, T. C., "Standard Handbook of Power-plant Engineering," McGraw-Hill Publishing Company, New York, 1989, pp 4.8-4.9)
4. Sulfur in the ash is in the form of $CaSO_4$.
5. $MgCO_3$ in the limestone is calcined to MgO but does not react with SO_3.
6. All of the $CaCO_3$ (limestone) is calcined to CaO prior to some of it reacting with SO_3.
7. All non-combustible inerts in the coal and limestone remain in the bed ash discharged from the bottom of the burner.
8. No conversion of nitrogen in the coal or N_2 in the air to NO_x is assumed.

The algorithm generates a multiplier that agrees within 2% or less of the actual material balances within the following ranges for the driving variables:

Coal heating value	6825 to 12350 Btu/lb
% inerts in coal	6.0 to 16.0
% inerts in limestone	4.0 to 10.0
% sulfur in coal	0.4 to 4.0
Mole ratio of Ca to S	1.5 to 4.0

The material balance computer code is in the form of a LOTUS 1-2-3 file and can be obtained from K.A. Williams at ORNL.

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53. M. J. Hutzler, EI-54, 2G-053/FORS, Energy Information Administration, Washington DC 20585
54. J. Jones, EI-542, 2G-060/FORS, Energy Information Administration, Washington DC 20585
55. M. Kimbrough, EI-541, 2F-066/FORS, Energy Information Administration, Washington DC 20585
56. J. W. Maken, EI-541, 2F-072/FORS, Energy Information Administration, Washington DC 20585
57. F. Mayes, EI-522, 2F-021/FORS, Energy Information Administration, Washington DC 20585
58-59. M. L. Myers, 5404 Palmetto Road, Knoxville, TN 37921
60. B. O'Brien, EI-532, BG-041/FORS, Energy Information Administration, Washington DC 20585
61. R. Ramachandran, Electric Power Research Institute, Palo Alto, CA 94305
62. W. F. Savage, NE-44 E-477/GTN, Washington, DC 20545
63. R. M. Schnapp, EI-52, 2G-053/FORS, Energy Information Administration, Washington DC 20585
64. B. H. Shapiro, NE-12, D-420/GTN, Washington DC 20545
65. L. Spancake, EI-542, 2G-060/FORS, Energy Information Administration, Washington DC 20585
66. W. Trapmann, EI-442, BH-032/FORS, Energy Information Administration, Washington DC 20585
67. H. L. Walton, EI-53, BG-057/FORS, Energy Information Administration, Washington DC 20585
68. T. A. Werner, NE-44, E-477/GTN, Washington DC 20545
69. J. W. Witthuhn, Sargent & Lundy, Chicago, IL 60603
70-109. Given distribution as shown in DOE/OSTI-4500-R75 under category UC-103 (Fluidized Bed Combustion)
110-121. Given distribution as shown in DOE/OSTI-4500-R75 under category UC-224 (Electric Energy Generation Systems)