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MASTER

POWER PLANT PERFORMANCE ANALYSIS
AND
GUIDELINES STUDY

APPENDIX III

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BY

SYSTEM DEVELOPMENT CORPORATION
SANTA MONICA, CALIFORNIA

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**POWER PLANT
PERFORMANCE ANALYSIS
AND
GUIDELINES STUDY**

**APPENDIX III
RELIABILITY AND EFFICIENCY
INDEX DATA**

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- ABSTRACT -

Historical data from the EEI, FPC, NRC, FEA and participating utilities were evaluated for each of the four reliability and efficiency indices recommended to the California Energy Commission. Data were not available for all unit sizes for the full period 1971-1975. However, the available data were analyzed to arrive at historical averages and ranges of averages for each of the recommended indices. Feasible ranges and averages of each index for units of different sizes and fuel types are presented and trends for each index are discussed with respect to characteristics such as unit age, maturity, equipment problems, etc. The recommended application of these data to the power plant Reliability and Efficiency Guidelines are discussed in the main body of this report (Section B).

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SECTION 1.0
INTRODUCTION & SUMMARY

Section 1.0 INTRODUCTION & SUMMARY

Subsection 1.1 Introduction

This appendix summarizes the results of analyses performed on electrical power plant performance data obtained from the Edison Electric Institute (EEI), Federal Energy Administration (FEA), Nuclear Regulatory Commission (NRC), Federal Power Commission (FPC) and four participating California Utilities. These data included information available on all power plants in the United States for the period 1971-1975. The term "power plant" is used to denote a single generating unit.

The data were separated by fuel type, and size (within each fuel type) to determine averages and ranges-of-averages for the four reliability and efficiency indices recommended in this study: Plant Capacity Factor, Plant Operating Availability, Plant Equivalent Availability and Plant Heat Rate (Table 1.1). In addition, data on coal, nuclear and geothermal power plants were evaluated, to the extent possible, to determine the presence of trends relative to such factors as operational maturity (age), design alternatives, prior utility experience with each fuel type and design vintage.

The type of analyses performed on these data were kept relatively simple, consistent with the wide variability in the data base. That is, sophisticated statistical analyses were considered inappropriate since (1) there was a considerable degree of inseparable compounding of variables, (2) sample sizes were often very small, and multiple data sources were used. No attempt was made to reconcile discrepancies between data sources or validate the accuracy of the input data.

The results of the analyses provide useful indicators of power plant performance in terms of historical averages and trends. The use of these data in predicting future performance of a particular unit is not recommended; however, study of this data may be extremely useful in guiding a utility (or regulatory commission) in formulating meaningful questions on the ability of new designs to achieve desired levels of reliability and efficiency. To this extent, the data analysis has been extremely useful, but the original concept of using the data to establish feasible ranges for future California plants is not considered practical.

Table 1.1

FUEL TYPE AND SIZE OF PLANT	TYPE OF ANALYSIS BY INDEX	AVERAGES YEAR-BY-YEAR (1971-1975)					FIVE YEAR AVERAGES (1971-1975)				AVERAGES BY COMMERCIAL OPERATING AGE		
		Capacity Factor	Operating Availability	Equivalent Availability	Heat Rate	Capacity Factor	Operating Availability	Equivalent Availability	Heat Rate	Capacity Factor	Operating Availability	Equivalent Availability	
COAL													
o 60 - 89 MW	X	X	X	X	X	X	X						
o 90-129 MW	X	X	X	X	X	X	X						
o 130-199 MW	X	X	X	X	X	X	X						
o 200-389 MW	X	X	X	X	X	X	X						
o 390-599 MW	X	X	X	X	X	X	X						
o 600 & Above MW	X	X	X	X	X	X	X	X	X	X	X		
o 600-699 MW	X	X	X	X	X	X	X	X	X	X	X		
o 700-799 MW	X	X	X	X	X	X	X	X	X	X	X		
o 800-899 MW	X	X	X	X	X	X	X	X	X	X	X		
o 900 & Above MW	X	X	X	X	X	X	X	X	X	X	X		
NUCLEAR													
o 400 & Below MW	X	X	X	X	X	X	X	X	X	X	X	X	
o 400 & Above MW	X	X	X	X	X	X	X	X	X	X	X	X	
o 400-499 MW	X	X	X	X	X	X	X	X	X	X	X	X	
o 500-599 MW	X	X	X	X	X	X	X	X	X	X	X	X	
o 600 & Above	X	X	X	X	X	X	X	X	X	X	X	X	
o 600-699 MW	X	X	X	X	X	X	X	X	X	X	X	X	
o 700-799 MW	X	X	X	X	X	X	X	X	X	X	X	X	
o 800-899 MW	X	X	X	X	X	X	X	X	X	X	X	X	
o 900-999 MW	X	X	X	X	X	X	X	X	X	X	X	X	
o 1000 & Above MW	X	X	X	X	X	X	X	X	X	X	X	X	
GEOTHERMAL													
o 55 MW	X	X	X		X	X	X		X	X	X		
o 110 MW	X	X	X		X	X	X		X	X	X		
GAS TURBINE													
o Below 25 MW	X	X	X		X	X	X						
o 25 & Above MW	X	X	X		X	X	X						
GAS													
o 60 - 89 MW	X	X	X		X	X	X		X	X	X		
o 90-129 MW	X	X	X		X	X	X		X	X	X		
o 130-199 MW	X	X	X		X	X	X		X	X	X		
o 200-299 MW	X	X	X		X	X	X		X	X	X		
o 390-599 MW	X	X	X		X	X	X		X	X	X		
o 600 & Above MW	X	X	X		X	X	X		X	X	X		
OIL													
o 60 - 89 MW	X	X	X		X	X	X		X	X	X		
o 90-129 MW	X	X	X		X	X	X		X	X	X		
o 130-199 MW	X	X	X		X	X	X		X	X	X		
o 200-389 MW	X	X	X		X	X	X		X	X	X		
o 390-599 MW	X	X	X		X	X	X		X	X	X		
o 600 & Above MW	X	X	X		X	X	X		X	X	X		
COMBINED CYCLE		See Section 7.0											

Section 1.0 INTRODUCTION & SUMMARY

Subsection 1.2 Summary

Table 1.2 and 1.3 present a summary of the analysis of data for the four reliability and efficiency indices. The tables have been prepared based upon the low, mean, and high annual index averages achieved during the period 1971 - 1975. For the fuel types and size classifications shown, these annual averages represent (1) the lowest annual index average experienced during the five-year period (low), (2) the overall five-year average (mean), and (3) the highest annual index average achieved during the five year period (high).

For heat rate, the period of evaluation was 1971 - 1974 for nuclear plants, 1972 - 1973 for coal plants, and 1973 only for gas turbines. Data were not available for nuclear or gas turbines for any other years and additional data could not be compiled on coal-fired plants.

The data used to develop Table 1.2 and 1.3 did not contain the same number of plants/units for each unit/fuel type. Consequently, the results shown for the same size ranges of different unit/fuel types are based upon data on different number of units/plants. Comparison of historical performance of different unit/fuel types of the same size range, using Table 1.2 and 1.3 results, can lead to erroneous conclusions. Such comparisons are further compounded by the fact that the units included are of different design, age, vintage, utilization, etc.

Comparison of historical performance of different size ranges of the same unit/fuel types too, are to be made with caution; the units included in the data are of different design, age, vintage, utilization, etc. A primary limiter of comparisons between size ranges is the limited data (three or less plants in many cases) for certain fuel types. This is particularly true for the larger size geothermal and nuclear plants.

The results of the data analysis, shown in Tables 1.2 and 1.3, present an overview of the historical performance of the indices from a perspective quite different from that which may be achieved by reviewing individual

SUMMARY OF RELIABILITY AND EFFICIENCY INDEX ANALYSIS RESULTS

Table 1.2

Unit/Fuel Type and Size Range (MW)	Capacity Factor Annual Averages (%) (1971-1975)			Operating Availability Annual Averages (%) (1971-1975)			Equivalent Availability Annual Averages (%) (1971-1975)		
	Low	Mean	High	Low	Mean	High	Low	Mean	High
Coal	60.1	65.5	68.9	79.4	82.4	85.4	75.5	79.4	83.3
60-89	61.0	70.0	73.3	82.7	85.2	88.5	79.8	83.5	87.7
90-129	57.2	63.6	67.5	82.8	85.2	87.4	80.4	83.6	86.2
130-199	63.9	69.6	73.1	82.7	85.6	88.6	80.4	83.9	87.4
200-389	60.8	66.0	69.0	78.4	82.5	85.3	74.1	78.8	83.0
390-599	55.4	60.5	65.2	73.3	75.8	79.8	68.3	70.9	75.9
600 & Above	56.8	59.8	63.4	72.2	73.9	76.0	66.3	67.5	70.1
600-699	57.8	60.6	65.1	66.3	75.8	77.3	63.8	68.0	71.8
700-799	52.0	60.8	65.9	71.2	72.8	73.9	65.3	65.3	66.8
800-899	48.5	56.4	60.7	53.6	70.8	75.7	52.5	62.5	65.9
900 & Above	55.4	60.6	66.0	67.2	72.8	80.5	56.4	64.5	74.9
Nuclear	58.1	59.1	61.6	66.2	70.0	74.6	62.6	64.8	69.8
400 & Below	53.8	57.7	61.5	63.9	70.7	74.2	59.4	61.0	62.7
400-499	63.3	71.8	83.6	77.1	80.2	84.6	76.0	79.3	83.4
500-599	35.5	59.7	73.1	67.2	75.6	87.9	65.1	73.4	87.9
600 & Above	54.9	58.3	72.1	64.9	67.5	74.3	57.6	61.3	67.9
600-699	63.3	67.0	80.8	67.8	75.3	79.9	69.4	69.9	84.1
700-799	41.6	67.5	82.1	46.7	73.3	85.2	46.7	69.6	84.5
800-899	39.6	54.9	59.4	58.4	66.0	70.6	43.4	59.2	65.0
900-999	45.7	53.1	68.0	54.2	68.9	98.4	50.3	66.3	98.4
1000 & Above	47.3	47.7	48.0	55.3	58.4	62.1	46.6	51.1	56.4
Geothermal	36.8	74.5	83.4	49.0	83.3	89.9	42.5	76.8	83.0
55	36.8	74.8	85.9	49.0	83.6	91.6	42.5	77.1	85.3
110	68.5	68.5	68.5	75.6	75.6	75.6	69.1	69.1	69.1
Gas Turbine	5.5	9.7	16.4	77.9	81.3	91.3	77.7	81.2	91.3
Below 25	4.6	9.4	17.7	80.6	84.4	92.6	80.5	84.5	92.6
25 & Above	7.8	10.4	16.1	70.1	73.3	81.4	69.5	73.0	81.4
Gas	50.6	56.6	59.7	83.3	85.3	88.6	82.8	84.5	88.1
60-89	26.7	35.3	48.8	68.4	88.8	95.4	68.3	88.6	95.3
90-129	27.3	45.7	56.3	82.8	86.1	88.8	82.7	85.9	88.8
130-199	48.2	69.6	81.8	81.2	88.9	96.6	81.2	88.3	94.7
200-389	49.9	54.9	58.6	82.1	84.8	91.1	79.5	83.6	90.4
390-599	61.0	66.3	70.4	78.2	85.5	89.7	77.6	85.0	89.1
600 & Above	39.9	60.9	70.0	55.7	74.5	81.4	53.5	73.2	81.1
Oil	49.3	59.2	65.5	74.2	83.4	85.4	70.5	78.5	82.9
60-89	66.5	73.0	81.2	87.3	91.4	95.7	87.3	90.9	94.5
90-129	60.6	66.4	69.1	85.3	88.9	90.9	85.1	88.6	90.9
130-199	25.2	40.5	49.2	57.7	72.8	86.4	54.4	70.4	85.2
200-389	53.1	58.2	66.2	60.7	70.2	81.6	53.9	64.2	75.5
390-599	51.5	59.7	74.0	74.8	81.1	86.4	68.9	76.0	80.2
600 & Above	40.2	52.2	68.2	70.8	77.1	91.6	66.8	72.5	89.5
Combined Cycle	See Section 7.0								

Note: The data used to develop chart includes different number of units for coal unit/fuel type, of different design, age, vintage, utilization, etc.

Source: EEI Special Analysis for SDC

Table 1.3

Plant Size Type Range (MW)	Heat Rate Annual Averages (Net)		
	Low	Mean	High
Coal (1)	10168	10303	10403
60-89	11490	11899	12048
90-129	10723	10762	10789
130-199	10206	10268	10320
200-389	9951	10000	10035
390-599	9739	9943	9948
600 & Above	9584	9792	9797
600-699	9788	9914	10022
700-799	9520	9555	9590
800-899	10190	10190	10190
900 & Above	9276	9337	9460
Nuclear	10897	11220	11336
400 & Below	11239	11628	12359
400-499	10517	10764	10944
500-599	10452	11013	11168
600 & Above	-	-	-
600-699	10498	10600	10661
700-799	10988	11487	12851
800-899	10699	11318	11843
900-999	10376	10376	10376
1000 & Above	11593	12322	14146
Geothermal	21989	22826	25056
55	22128	22896	25056
110	21156	21156	21156
Gas Turbine	12328	16918	23680
Below 25	12328	16364	23680
25 & Above	12356	17753	22782
Gas			
60-89	See Section 8.0		
90-129			
130-199			
200-389			
390-599			
600 & Above			
Oil			
60-89	See Section 9.0		
90-129			
130-199			
200-389			
390-599			
600 & Above			
Combined Cycle	See Section 7.0		

Note: The data used to develop chart includes different number of units for each unit/fuel type, of different design, age, vintage, utilization, etc.

Source: SDC Analysis of FPC data

1) Plants using coal fuel only.

Section 1.0 INTRODUCTION & SUMMARY

Subsection 1.2 Summary (Continued)

Fuel types and size classifications separately. In addition to illustrating the average performance levels, the table identifies the worst level and the best level achieved by distinct fuel types/size classes. Since these are all annual averages, they illustrate more than just one time lows or highs and for this reason are believed to better represent the feasibility of achieving specific performance levels. With respect to the trends observed in the data the following highlights are presented:

1) Plant Age: All sizes and fuel types show a similar pattern of reliability and efficiency as a function of the plant age. Plant Capacity factor, equivalent availability, operating availability, and heat rate all improve with age. It appears that plants require about two years of commercial operation before they achieve annual index values comparable to the average first five-year index value.

Figure 1.1 shows the typical behavior which may be expected for the indices during the life of a power plant. The figure is divided into four regions:

- Region 1: The period of learning experience with the "new" facility and potential infant mortality problems.
- Region 2: The period of most "stable" operating conditions; usually the period of most useful life.
- Region 3: The period of life where economics and other factors dictate less emphasis on the utilization and/or maintenance of the plant.
- Region 4: The end-of-life (retirement) phase of the plant.

Figure 1.1 is most indicative of a baseloaded power plant. A knowledge of the original loading scheme intended for a power plant provides a firm basis for evaluation of its historical data, using the example of the figure. Region 1 can readily be anticipated regardless of the intended duty or design of a power plant; for peaking units, however, where the state-of-the-art has remained relatively unchanged, OA and EA should not exhibit the traditional "learning phase", as the newer and more advanced power plant designs have experienced. Region 2 for a baseloaded plant should find OF, OA, and EA,

Figure 1.1: Typical Expected Behavior of R&E Indices

Section 1.0 INTRODUCTION & SUMMARY

Subsection 1.2 Summary (Continued)

practically the same: If the plant is used intermittently as a baseloaded and load following plant then CF will deviate from OA and EA. For Region 2, if OA is much higher than EA (and similarly CF) for a baseloaded plant, it can be due only to partial outages. This is indicative of low reliability. For all regions, OA may be expected to be greater than EA which can be expected to be greater than CF; under no circumstances can CF exceed EA or OA and neither may EA exceed OA. The figure also illustrates the influence of service time on heat rate.

- 2) Plant Design: Comparison between plants of different design vintage, but same size and fuel type, show that plants with older designs exhibit lower values of the reliability and efficiency indices. The historical changes in plant design have thus been beneficial to obtaining higher plant reliability and efficiency.
- 3) Utility Experience: The historical data verifies that the level of reliability and efficiency achieved by a plant of particular size and fuel type is dependent upon the experience the operating utility has with plants of the same size and fuel type. As the experience increase so does the reliability and efficiency of a new plant.

The three elements discussed above, namely, plant age, plant design and utility experience influence the achievable levels of each of the four recommended reliability and efficiency indices. Immaturity in any of these elements can cause significant decreases in capacity factor, equivalent availability and operating availability (or increases in heat rate). A review of the data did not provide strong evidence that all of these elements had acquired sufficient degree of maturity for the historical data to provide significant insight into future utility design, or operational processes. That is, the size of plants has increased steadily and increased numbers of utilities are currently operating plants in Region (1) of Figure 1.1. Also, expected future design changes (addition of pollution equipment, etc.) and compliance with new regulations will influence the achievable levels of reliability and efficiency.

SECTION 2.0

FEASIBLE RANGES OF RELIABILITY & EFFICIENCY INDICES

Section 2.0 FEASIBLE RANGES OF RELIABILITY AND EFFICIENCY INDICES

In establishing the levels of reliability and efficiency that new power plants in California can achieve, as measured by the four recommended reliability and efficiency indices, it was necessary to review the historical data on the indices for each of the different unit/fuel types and sizes proposed. The historical data is indicative of the levels that can possibly be achieved by new power plants in California. The five electric generating plant types proposed by California utilities to meet increasing demand are: 1) Coal, 2) Nuclear, 3) Geothermal, 4) Combined Cycle, and 5) Gas Turbine.

The data analysis concentrated upon these five plant/fuel types along with gas fired and oil fired plants. No oil fired or gas fired plants are planned to be sited in the state of California during the period 1980-1995. Thus, projections of feasible ranges of the reliability and efficiency indices are not made for oil or gas fired plants. The results of analysis of available historical data on the indices is, however, included in this report for both gas fired and oil fired plants.

Geothermal plants proposed for startup during the 1980-1985 period include plants based on both the liquid-dominated-system and the vapor-dominated-system. Geothermal plants currently in commercial operation are based upon the vapor dominated system. A few liquid dominated power plants do exist in California and other states. These are pilot plants and are not in commercial operation. Available data on liquid dominated geothermal plants is data on short periods of operation, under experimental conditions. Estimates of the reliability and efficiency levels that can be achieved by liquid-dominated-system plants have no historical data base, and are, thus, not included in this document.

The data available on combined cycle units to establish feasible ranges and averages of units proposed for California is severely limited. As most of the units currently in operation have been designed to meet the specific requirements of each utility, the historical data cannot be combined to arrive at averages or ranges for each of the recommended indices. The index averages and ranges that have historically been obtained are dependant upon the unit/plant design and its specific application/use by the utility. This historical data may not be representative of the, as yet unknown, combined cycle plants that are proposed to be built in California. Thus, no estimation of the range

Section 2.0 FEASIBLE RANGES OF RELIABILITY AND EFFICIENCY INDICES (Continued)

of levels that each index can achieve are made. However, the very broad spread of values achieved by each index are included for combined cycle plants, in section 7.0.

In the case of gas turbines, the feasible levels of CF, EA and OA are somewhat academic. These plants are designed for high levels of OA and EA, but low levels of CF. The state-of-the-art of design, construction, operation and maintenance are such that the most feasible levels are what the utility perceives as the most practical, in an economic sense.

The historical annual average and the five year average of each recommended reliability and efficiency index for coal fired plants are listed in table 1.2 and 1.3. The highest annual average capacity factor achieved by any MW size range was 73.3%. The average annual capacity factor for coal fired power plants of the size planned for California (600 MW+) are predominantly between 63% and 66%. However, the annual equivalent availabilities have, at the same time for these larger plants, ranged from 66% to 75%, illustrating that capacity factors many percentage points higher than have historically achieved by the 600MW+ plants are possible; if partial outages can be better controlled, CF's and EA's may feasibly approach the higher percentages.

For nuclear power plants, the results of the data analysis may be used to illustrate feasible R&E levels from many different perspectives. When many sizes and different design maturities are reviewed collectively, the results or historical performance levels, may not appear encouraging for what may be considered attainable by future nuclear plants. However, when data are viewed more realistically by more closely grouping units of equivalent size, design vintage and maturity there are clearer signs that higher levels of OA, EA and CF are more than feasible. Table 1.2 shows that for units 600 MW+, significantly high annual average OA and EA have been achieved. Since it is both feasible and practical for CF to approach EA, it may be projected that this will occur for nuclear power plants. Table 1.2 illustrates some considerably lower annual average values for these indices; however, when it is realized that over half of the plants in the 600 MW+ range have been in commercial operation for two

Section 2.0 FEASIBLE RANGES OF RELIABILITY AND EFFICIENCY INDICES (Continued)

years of less, these lower values are not entirely surprising. As the results of utility and industry efforts to eliminate generic problems to better plan, staff and manage large nuclear plants are realized, it is projected that higher annual averages will become the standard rather than the exception.

To summarize, the historical levels of the four recommended reliability and efficiency indices can be exceeded for all plant types. The historical data does show that almost any level, from the mid thirties to the high eighties, of the indices have been achieved by all plant/fuel types and sizes. In other words, on an individual unit basis, some power plants have achieved what may be considered as the highest possible levels of capacity factor, equivalent availability, operating availability and the lowest possible heat rate. When viewed collectively, however, a much different picture is formed of the levels that have, on an average, been historically achieved by plants of the same fuel type and size. These average values are, generally, about twenty percentage points (20%) lower than the high levels achieved by individual plants.

Virtually all levels are feasible for all plant/fuel types and sizes. The attainability of any level is a function of the deliberate action, that a utility takes. These actions encompass the life cycle of the plant and can be summarized under six (6) distinct categories, namely, design, procurement, construction, operation, maintenance and management/organization. The actions, a utility can take under each of these categories are constrained by the requirements of the utility generation system and the cost incurred in implementing each action. For an individual plant the utility strikes a balance between 1) the energy demand on the units (its loading order, etc.), 2) the target level of each index and 3) the cost of achieving the targets. The historical level actually achieved, is the result of tradeoffs a utility is required to make between the above factors.

SECTION 3.0

COAL FIRED STEAM ELECTRIC POWER PLANTS

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.1 Introduction

Four indices of power plant reliability and efficiency are being recommended for use by the State of California, Energy Conservation and Development Commission, for evaluating utility AFC submittals for new coal fired power plants. These indices are 1) Capacity Factor, 2) Operating Availability, 3) Heat Rate and 4) Equivalent Availability.

To establish feasible ranges and averages for each of the above four indices, a review of historical data was necessary.

The period 1971-1975 includes the latest advances in coal fired plant design, effects of increased regulation, effects of restrictive environmental controls, and the oil embargo of 1973 which increased the nation's reliance on coal fired plants. Data from this period reflects these historical factors. Projections of future power plant performance based upon this data can be made only after the effects of each of the factors is evaluated. As a result, the historical data available for coal fired power plants in operation during the period 1971-1975 were evaluated in depth.

The principal source of annual average capacity factors, annual average operating availability and annual average equivalent availability was the Edison Electric Institute's (EEI) Equipment Availability Data bank. These annual summaries were purchased by SDC from EEI. Table 3.1 lists the number of plants EEI used to arrive at their annual summaries. It is EEI's policy not to reveal individual plant names in it's annual operation data summaries; a list of the plants included in each year's analysis is, thus, not available.

The primary source of the annual average heat rates of existing coal fired steam electric power plants was the Federal Power Commission's (FPC) "Steam Electric Plant Construction Cost and Annual Production Expenses Supplements" for 1971, 1972, 1973, and 1974. (As of this analysis, the 1975 supplement was not available.) Table 3.2 lists the number of plants comprising the heat rate data base for 1973 and 1974.

Table 3.1

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.	
Year	Number of Units [†]
1971	292
1972	319
1973	330
1974	347
1975	355
[†] Source: EEI Special Analysis for SDC	

Table 3.2

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.	
Year	Number of Units [†]
1973	272
1974	200
[†] Source: SDC Analysis of FPC "Cost and Annual Production Expenses Supplements"	
Note: The number of units that were operated using <u>coal only</u> as fuel during 1974 were less than the number of units operated only as <u>coal</u> in 1973.	

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.1 Introduction (Continued)

Table 3.3 show the six power plant size ranges considered in the evaluation of the averages and ranges of the reliability and efficiency indices. These sizes were selected to better match plants of equivalent size. Data were obtained, on an annual basis, for each of the size ranges from EEI.

The historical levels achieved for each index reflect the size of the plant, its design maturity, the operating utility experience, and the plant's operational maturity. To better define and assess the effects of each of these factors on the levels achieved, individual coal fired power plant data collected by EEI were obtained from the FEA for earlier years (in some cases, as far back as 1966) and assimilated in these evaluations.

Data on individual coal fired power plants used to compile and evaluate the averages and ranges of three indices, (Capacity Factor Operating Availability, and Equivalent Availability), were obtained from the Federal Energy Administration (FEA). This data was compiled for the FEA by EEI from its Equipment Availability Data bank.

The attempts to study the affects of utility maturity, plant design maturity and operational maturity on heat rate were unsuccessful. A major limiter was the limited Heat Rate data available.

Table 3.3

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.					
Size Range	Number of Units †				
	1971	1972	1973	1974	1975
60- 89 MW	8	10	5	6	5
90-129 MW	52	56	61	65	66
130-199 MW	108	114	111	108	101
200-389 MW	71	74	78	84	95
390-599 MW	33	37	41	43	47
600 MW & Above	20	28	34	41	41
†Source: EEI special analysis for SDC					

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.1 Introduction (Continued)

Only 600 MW and greater size plants are proposed for siting during the period 1980-1995 in the State of California.

To arrive at ranges and averages of the recommended indices, which would be most helpful for California, the 600 MW-and-above size range has been further subdivided into four new ranges, namely, 600-699 MW, 700-799 MW, 800-899 MW and 900 MW-and-above.

The units that fall into each of these ranges were extracted from the EEI data supplied by the FEA, to SDC. These include coal fired steam electric power plants whose capacity (megawatt rating) falls into the established ranges.

Table 3.4 lists the number of units that comprise the data base, used for this analysis, of each size range. The number of units in the EEI size category "600 MW and greater" exceed the total number in all the four new ranges combined.

Data on the units included in the four new size ranges were compared with that in the council of Economic Priorities (CEP) data base, also supplied by the FEA. Data for establishing ranges and analysis did not include all the specific units that were included in the CEP data base.

Table 3.4

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Units	Source
600 MW & above	41	EEI Composite Unit Summary
600 - 699 MW	11	EEI data from FEA
700 - 799 MW	9	"
800 - 899 MW	8	"
900 MW & above	3	"

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.1 Introduction (Continued)

Coal fired power units greater than 60 MW have operated at an average capacity factor of 65.5%, average equivalent availability of 79.4%, average operating availability of 82.4% during the five-year period 1971-1975. The average net heat rate of coal units, greater in size than 60 MW and using coal as fuel only, in operation during 1973 and 1974 has been 10303 Btu/Kwh. The data used to develop these figures includes units of different size, design, age, vintage, and utilization.

As a group, the annual average capacity factor, equivalent availability and operating availability declined over the five-year study period (1971-1975) while the annual average heat rate has improved from 10403 Btu/Kwh to 10168 Btu/Kwh.

In general, the value of each reliability and efficiency index has reduced with increasing coal fired unit size. This apparent conclusion may be erroneous as the data used to develop the charts includes units of different design, age, vintage and utilization. Further detailed analysis beyond the scope of this effort is required to support or nulify this apparent conclusion.

The index values achieved by each size range reflect the unit design maturity, vintage, unit operational maturity (age) and utility experience. The large coal units, 600 MW and above, are generally exhibiting increasing values but have yet to achieve the high averages obtained by the smaller units. This is primarily due to the limited operational experience with the large units when compared with industry experience in designing, operating and maintaining the smaller units. The effects of the ever increasing regulations and environmental restrictions (scrubbers, etc.) on the indices could not be assessed with certainty as the data available did not reflect these effects.

The coal units projected for siting and startup in California are all greater than 600 MW in capacity. The analysis of 600 MW and above unit data shows that, in general, two years of operation are required before the first five-year average index value can be achieved or exceeded. It is also shown that increase in utility experience with similar units results in the achievement of higher values of capacity factor, equivalent availability and operating availability.

Table 3.5

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Year	Number of Unit-Years	Average Capacity Factor (%) [†]	Average Equivalent Availability (%) [†]	Average Operating Availability (%) [†]
1971	292	68.45	83.3	85.36
1972	319	67.96	79.7	82.48
1973	330	68.92	80.5	83.15
1974	347	63.09	78.6	82.21
1975	355	60.14	75.5	79.36
NOTE: The data used to develop chart includes units of different design, age, vintage, utilization, etc.				
*Source: EEI special analysis for SDC				

Table 3.6

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Size Range	Number of Unit-Years	Average Capacity Factor (%)	Average Equivalent Availability (%) [*]	Average Operating Availability (%)
60-89 MW	34 ⁺	70.00 ⁺	83.5 ⁺	85.19 ⁺
90-129 MW	300 ⁺	63.58 ⁺	83.6 ⁺	85.22 ⁺
130-199 MW	542 ⁺	69.59 ⁺	83.9 ⁺	85.62 ⁺
200-389 MW	402 ⁺	65.96 ⁺	78.8 ⁺	82.48 ⁺
390-599 MW	201 ⁺	60.46 ⁺	70.9 ⁺	75.75 ⁺
600 MW & Above	164 ⁺	59.82 ⁺	67.5 ⁺	73.94 ⁺
600 MW & Above	122 ⁺⁺	59.94 ⁺⁺	65.8 ⁺⁺	73.68 ⁺⁺
600-699 MW	50 ⁺⁺	60.6 ⁺⁺	68.0 ⁺⁺	75.81 ⁺⁺
700-799 MW	36 ⁺⁺	60.8 ⁺⁺	65.3 ⁺⁺	72.84 ⁺⁺
800-899 MW	21 ⁺⁺	56.4 ⁺⁺	62.5 ⁺⁺	70.75 ⁺⁺
900 MW & Above	15 ⁺⁺	60.6 ⁺⁺	64.5 ⁺⁺	72.81 ⁺⁺
NOTE: The data used to develop chart includes units of different design, age, vintage, utilization, etc.				
*Source: EEI Special Analysis for SDC				
**Source: SDC analysis of EEI data supplied by FEA				
*Average over the five-year period 1971-1975				

Table 3.7

COAL FIRED STEAM ELECTRIC UNITS IN THE U.S.				
Range of Average Size of Unit (MW)	Number of Unit-Years		Average Heat Rate (Net) [†]	
	1973	1974	1973	1974
60-89	33	12	12048	11490
90-129	22	15	10789	10723
130-199	89	74	10320	10206
200-389	98	71	10035	9951
390-599	18	13	9739	9948
600 & Above	12	15	9797	9584
600-699	7	6	10022	9788
700-799	2	2	9520	9590
800-899	-	1	-	10190
900 & Above	3	6	9400	9276
All Units	272	200	10403	10168
*Source: SDC analysis of FPC data on units using coal fuel only				
NOTE: The data used to develop chart includes units of different design, age, utilization, vintage, etc.				

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.2 Plant Capacity Factors

Coal fired power plants have operated at an average capacity factor of 65.52%. This figure includes only greater-than-60 MW coal fired plants in operation during the period of 1971-1975, on whom data were available from EEI. A 1643 unit-year sample is used to compute this average capacity factor.

Capacity factors have declined during the period 1971-1975. As shown in Table 3.8, the high capacity factor of 68.92% in 1973 reduced to 60.14% by 1975.

From Table 3.9 it can be concluded that capacity factors of coal fired power plants are, for the five-year average, generally inversely proportional to plant size. This conclusion is premature without allowing for many factors, e.g. the different designs, ages, different utilization of the smaller but older plants, etc. As shown, the capacity factor varies from a high of 70.00% (for 60-89 MW plants) to 59.82% (for plants larger than 600 MW). The plants included in the sample are those in operation during 1971-1975, and on whom data were available through the EEI.

Table 3.9 also lists average capacity factors for four additional size classifications, of the 600 MW-and-above size range. The 800-899 MW range show a markedly lower capacity factor. The capacity factors of the other three classes (600-699 MW, 700-799 MW and 900 MW and above) are in close agreement with those provided by EEI.

Table 3.8

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Year	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	292	68.45
1972	319	67.96
1973	330	68.92
1974	347	63.09
1975	355	60.14
[†] Source: EEI Special Analysis for SDC		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 3.9

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years	Average Capacity Factor (%)
60- 89 MW	34 [†]	70.00 [†]
90-129 MW	300 [†]	63.58 [†]
130-199 MW	542 [†]	69.59 [†]
200-389 MW	402 [†]	65.96 [†]
390-599 MW	201 [†]	60.46 [†]
600 MW & Above	164 [†]	59.82 [†]
600 MW & Above	122 ^{††}	59.94 ^{††}
600-699 MW	50 ^{††}	60.6 ^{††}
700-799 MW	36 ^{††}	60.8 ^{††}
800-899 MW	21 ^{††}	56.4 ^{††}
900 MW & Above	15 ^{††}	60.6 ^{††}
[†] Source: EEI Special Analysis for SDC		
^{††} Source: SDC Analysis of EEI data supplied by FEA		
* Average over the Five Year Period 1971-1975		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.2 Plant Capacity Factors (Continued)

Average capacity factors of coal fired plants of all size ranges, have not been constant during the period 1971-1975, as shown in Tables 3.10-3.19. They list the annual average capacity factor and the five-year average capacity factor for each of the sizes.

The capacity factors for all plants smaller than 800 MW have generally reduced over the period 1971-1975. On the other hand, annual average capacity factors of 800 MW-and-above units have fluctuated dramatically on a year to year basis. The 800 to 899 MW group is the only size range to show a higher CF at the end of the five year period.

In general, for plants less than 800 MW the capacity factors for the first few years are higher than the five-year average. In other words, for their size range, the five-year average is reduced by the lower capacity factors of the latter years, namely, 1974, and 1975.

The range 600 MW and above also exhibits, as a whole, the reduction in capacity factors and a reliance of higher five-year averages on the first few years. On closer examination, this is found to be true for the two size ranges 600-699 MW and 700-799 MW.

The 800-899 MW and the 900 MW and above show an increasing capacity factor trend. The five-year average of these sizes is strongly weighted by the higher capacity factors in the latter years.

To summarize, coal plants 800 MW and greater are exhibiting increasing capacity factors but have yet to achieve the high averages obtained by the older but smaller plants. As discussed before, the capacity factors achieved reflect the levels of utility experience, plant design maturity, plant operational maturity, etc. It can be projected that, with time, the capacity factors of 600 MW-and-above plants may increase to the high seventies (70%+) as have been achieved by the smaller plants.

Table 3.10

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 60-89 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	8	72.8
1972	10	84.1
1973	5	67.1
1974	6	70.8
1975	5	61.0
1971-1975	34	70.0
Source: EEI special Analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.11

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 90-129 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	52	64.0
1972	56	67.5
1973	61	67.5
1974	65	62.7
1975	66	57.2
1971-1975	300	63.6
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.12

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 130-199 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	108	72.2
1972	114	72.4
1973	111	73.9
1974	108	65.0
1975	101	63.9
1971-1975	542	69.6
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.13

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 200-389 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	71	68.5
1972	74	66.3
1973	78	69.0
1974	84	66.6
1975	95	60.8
1971-1975	402	66.0
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.2 Plant Capacity Factors (Continued)

An analysis of large (600 MW and above) plants for evaluating the effect on capacity factors of utility experience, plant design maturity, and plant operational maturity is described in the next section.

Table 3.14

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 390-599 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	33	65.2
1972	37	63.5
1973	41	63.4
1974	43	57.0
1975	47	55.4
1971-1975	201	60.5
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.15

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 600 MW & Above		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	20	63.4
1972	28	59.4
1973	34	62.1
1974	41	56.8
1975	41	59.6
1971-1975	164	59.8
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.16

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 600-699 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	8	62.5
1972	10	58.0
1973	11	65.1
1974	10	57.8
1975	11	59.0
1971-1975	50	60.6
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.17

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 700-799 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	4	65.9
1972	6	52.0
1973	8	65.1
1974	9	62.0
1975	9	59.3
1971-1975	36	60.8
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.18

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 800-899 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	1	51.1
1972	4	48.5
1973	4	60.7
1974	6	58.2
1975	6	57.5
1971-1975	21	56.4
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.19

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 900 MW & above		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	3	56.5
1972	3	63.7
1973	3	61.4
1974	3	66.0
1975	3	55.4
1971-1975	15	60.6
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.2 Plant Capacity Factors (Continued)

DESIGN VINTAGE

As described earlier, the coal plants projected for siting in the State of California during 1980-1995 are greater than 600MW in capacity. The development of the design of coal fired plants and the current design alternatives available will be evaluated for their effects on the historical capacity factors of existing coal plants, of capacity greater than 600MW. The following discussion does not apply to coal plants smaller in capacity than 600MW.

The effect of design vintage on coal fired plant capacity factors is shown in Table 3.20 for the four size ranges. The objective is to compare the plants with start-up dates in the period 1965-1968 with those that have a start-up date during the period 1970-1975.

The table shows the average capacity factors for the first five years of commercial operation. This time span has been chosen to ensure that the average capacity factors will not greatly reflect the low capacity factors obtained during a plant's first year or two of commercial operation.

For the two size ranges for which data are available for both periods, and improvement in the five year average capacity factor is evident for the newer vintage plants. It appears, then, that the new coal plants that may be built in California can exceed the average capacity factor values of Table 3.15. The affect on annual capacity factors of the addition of pollution control equipment cannot be ascertained from the data.

ALTERNATIVE DESIGN STRATEGIES

An objective of this study was to assess the effect, if any, of different design strategies on the historical capacity factors of coal fired power plants. The study attempted to collect data on the average historical capacity factors of

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.2 Plant Capacity Factors (Continued)

plants that differ in design. Some of the design differences considered were:

Subcritical and supercritical boilers

Single and multiple boilers

Header and non-header plants

Plants with reheat and plants with out reheat

The data collection effect to distinguish between historical capacity factors, of each of the above design option was unsuccessful.

Table 3.20

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Size Range (MW)	Plants With Start-Up Dates in the Period 1965-1969		Plants With Start-Up Dates in the Period 1970-1975	
	No. of Unit-Years	Average [†] Capacity Factor (%) ^{††}	No. of Unit-Years	Average [†] Capacity Factor (%) ^{††}
600-699	19	61.9	29	63.2
700-799	5	46.7	22	56.1
800-899	0	-	21	56.3
900 & Above	19	68.0	0	-
† Source: SDC Analysis of EEI data supplied by FEA				
† Average Capacity Factor of First Five Years of Commercial Operation.				
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.				

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.2 Plant Capacity Factors (Continued).

COAL PLANT OPERATIONAL MATURITY

Coal plant capacity factors vary greatly with the design vintage of the plant. Generally, the older the vintage the lower the capacity factor. To study the effect of plant age on its capacity factor the latest vintage plants are chosen in each size range.

As the coal plants projected for startup in the State of California are all greater than 600 MW in capacity, only plants of capacity greater than 600 MW were studied to assess the effects of plant age on plant capacity factor.

Annual plant data, obtained from the FEA, were used for this analysis. The results are presented for four size ranges, namely, 600-699 MW, 700-799 MW, 800-899 MW and 900 MW and above.

Plants included in the data base, used to correlate performance with age, were in the case of the three smaller size ranges, plants with start-up dates during the period 1970-1975. As no 900MW-and-above plants went commercial during the 1970-1975 period, 900MW-and-above plants with start-up dates during the period 1965-1969 were included. Use of this data resulted then in plants of the same commercial operating age for the three smaller size ranges, while the largest size was made up of plants from an earlier time period.

Table 3.21 lists the average capacity factor for each of four size ranges. Shown are the average capacity factors which plants have achieved during the first five years of commercial operation. Table 3.22 lists a year-by-year average capacity factor for each size range.

From table 3.22 it can be seen that plants of each size range generally require more than one or two years of operation before they achieve their five year average capacity factor.

Although the 900 MW and above size range has the largest five year average

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS
Subsection 3.2 Plant Capacity Factors (Continued)

COAL PLANT OPERATIONAL MATURITY (CONTINUED)

capacity factor, their annual capacity factors have, generally, reduced over the years. Each of the other size ranges, on the other hand, shows some improvement with time. The reduction in capacity factors of the largest size are in part due to the fact that the plants included in that size are of an earlier vintage and, thus, their design may not be as mature as that of the smaller plants.

Table 3.21

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years	Average [†] Capacity Factor (%) [†]
600 - 699	29	63.2
700 - 799	22	56.1
800 - 899	21	56.3
900 & above	12	68.0
[†] Average of First Five Years of Commercial Operations Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.		

Table 3.22

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S. [†]								
Year of Commercial Operation	600 - 699 MW		700 - 799 MW		800 - 899 MW		900 MW & above	
	Number of Unit-Years	Average Capacity Factor (%)	Number Of Unit-Years	Average Capacity Factor (%)	Number of Unit-Years	Average Capacity Factor (%)	Number of Unit-Years	Average Capacity Factor (%)
FIRST	6	61.3	5	44.8	2	40.3	- ^{††}	- ^{††}
SECOND	7	65.4	6	59.0	4	56.9	3	75.4
THIRD	7	56.2	5	63.0	5	63.0	3	74.3
FOURTH	6	71.3	4	58.2	6	54.5	3	62.0
FIFTH	3	61.6	2	53.9	4	58.1	3	60.1
[†] SDC Analysis of EEI data supplied by FEA ^{††} No Data Available								
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.								

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.2 Plant Capacity Factors (Continued)

UTILITY OPERATING EXPERIENCE

Historical capacity factors achieved by coal fired plants are also dependent upon the experience the operating utility has had on the operation and maintenance of coal plants.

No coal fired power plants are currently in operation in the State of California. Only one California utility has direct hands-on experience with coal plants; this is a share in three coal fired plants operating outside the state. While this one California utility now has some experience with coal plants, the problems and idiosyncrasies experienced in the operation and maintenance of these plants is somewhat unique. Two of the plants are experimental first-of-a-kind installations and the experience gained here would mostly fall under the general heading of "Research and Development." To summarize, California utilities have very little hands-on experience in the operation/maintenance/management of coal fired power plants.

For discussion purposes, utilities can be divided into two broad types. Type 1 is defined as that which has no "hands-on" experience at all, with any coal fired power plant. Type 2 is defined to be that which has some experience (although limited) with coal fired plants of a different size than are projected for siting in California and no experience at all with those proposed.

The FEA data base was searched to determine if any Type 1 and Type 2 utilities could be identified that have brought coal fired plants greater than 600 MW on line during the period 1970-1975. Of all the utilities that brought 600 MW and above plants on line during 1970-1975 only one satisfied the requirements of Type 1. All the rest were Type 2 utilities. Type 2 utilities brought between one (1) and four (4) coal plants on-line during 1970-1975. The two utilities with the highest number of such plants were chosen for comparison with the single Type 1 utility found.

Table 3.23 lists the annual average capacity factors achieved by the three utilities chosen. Each utility brought different sized plants on-line during the period 1970-1975. Table 3.24 shows the first five-year average capacity factor achieved by these utilities.

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.2 Plant Capacity Factor (Continued)

UTILITY OPERATING EXPERIENCE (Continued)

The Type 1 utility (no previous experience with coal power plants) achieved a much lower five-year average capacity factor than did the Type 2 utilities (previous experience). Also, the Type 1 utility achieved a five-year average capacity factor less than that of the Type 2 utilities. While the Type 1 utility did achieve annual average capacity factors comparable with those of Type 2 utilities in later years, it was unsuccessful in maintaining these capacity factors. The utilities with prior experience not only maintained but generally improved their annual average capacity factors.

Table 3.23

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.						
Year of Commercial Operation	Utility Type 1*		Utility Type 2**		Utility Type 2***	
	No. of Unit-Years	Average Capacity Factor (%) [†]	No. of Unit-Years	Average Capacity Factor (%) [†]	No. of Unit-Years	Average Capacity Factor (%) [†]
1971	-	-	2	44.4	1	51.1
1972	2	40.7	3	47.2	1	47.9
1973	2	57.7	4	58.8	3	56.4
1974	2	49.4	4	52.8	4	57.5
1975	2	46.7	4	63.7	4	62.9
[†] Source: SDC Analysis of EEI data supplied by FEA * 800-899 MW Size Plant Data ** 600-699 MW Size Plant Data *** 700-799 MW Size Plant Data						
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Table 3.24

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.			
Utility Type	1	2	2
Number of Unit-Years	8	17	13
Five-Year Average Capacity Factor (%)	48.6	54.8	57.7
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.			

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.3 Plant Operating Availability

Coal fired power plants have been "available" to generate some electric power 82.4% of the time during the period 1971-1975. This figure includes only greater-than-60 MW coal fired plants in operation during the period 1971-1975, and on whom data is available in the EEI Equipment availability data bank. A 1643 unit-year sample was used for computing this five year average operating availability.

Operating availability of coal fired power plants has steadily declined during the period 1971-1975. As shown in Table 3.25, the highest annual average operating availability was 85.36% in 1971 which reduced to 79.36% by 1975.

From the data in Table 3.26 it can be concluded that operating availability of coal fired power plants is, in general, inversely proportional to the size of the plant. This conclusion is not final, however, as the data used to compile Table 3.26 includes units of different age, design, vintage, utilization, etc. The operating availability varies from a high of 85.62% (for 130-199 MW plants) to 73.94% (for plants larger than 600 MW). Plants included in this sample are those that were in operation in 1971-1975 and on which data were available through the EEI data bank (see Table 3.26).

The five year average operating availability of 73.68% computed for 600 MW-and-above coal fired power plants by SDC using the EEI data supplied by the FEA agrees closely with the EEI computed five year average operating availability of 73.94%. The former computation is based upon 121 unit-year data while the latter is based upon a 164 unit-year sample.

Table 3.26 also lists the five-year average operating availability of four new size ranges defined to include plants 600MW-and-greater in capacity. The 800-899 MW size range exhibits the lowest five-year average operating availability. For the other three size ranges, as the size increases the average operating availability reduces.

Table 3.25

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Year	Number of Unit-Years	Average Operating Availability (%) [†]
1971	292	85.36
1972	319	82.48
1973	330	83.15
1974	347	82.21
1975	355	79.36
[†] Source: EEI Special Analysis for SDC		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 3.26

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit Years	Average* Operating Availability (%)
60-89 MW	34 [†]	85.19 [†]
90-129 MW	300 [†]	85.22 [†]
130-199 MW	542 [†]	85.62 [†]
200-389 MW	402 [†]	82.48 [†]
390-559 MW	201 [†]	75.75 [†]
600 MW & Above	164 [†]	73.94 [†]
600 MW & Above	121 ^{††}	73.68 ^{††}
600-699 MW	49 ^{††}	75.81 ^{††}
700-799 MW	36 ^{††}	72.84 ^{††}
800-899 MW	21 ^{††}	70.75 ^{††}
900 MW & Above	15 ^{††}	72.81 ^{††}
[†] Source: EEI Special Analysis for SDC		
^{††} Source: SDC Analysis of EEI data supplied by FEA		
* Average Over the Five-Year Period 1971-1975		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.3 Plant Operating Availability (Continued)

The annual average operating availability of coal fired power plants in all the size ranges has fluctuated during the period 1971-1975 as shown in Tables 3.27-3.36. They list the annual average operating availability and the five-year average operating availability for each size range.

The annual average operating availability for all plants smaller than 600 MW has, in general, reduced over the period 1971-1975. On the other hand, the annual average operating availability of 600 MW and above units has increased during the years studied.

In general, for plants less than 600 MW the average operating availability for the first few years is higher than the five-year average. In other words, for these size ranges, the five-year average is reduced by the lower capacity factors of later years.

The size range 600 MW and above, as a whole, exhibits a reduction in average operating availability during the first few years, followed by what seems to be a gradual increase. This phenomenon is found to be generally true for each of the new four subdivisions of the 600 MW and above size range; but the trend of increasing average operating availability is stronger. The five-year average operating availability of these new size ranges is higher primarily due to high average annual operating availability during the latter years.

The change in annual average operating availability during the period 1971-1975 is the lowest for the 700-799 MW size range. The largest increase occurred in the 800-899 MW size range.

Coal plants are, in general, exhibiting lower annual average operating availabilities as their size increases. The large sizes have yet to achieve the high average operating availabilities that have been achieved by the smaller plants. The smaller plants have been in operation for a much longer time period, some exceeding twenty years, than have the larger plants. As the operating availability of a power plant is strongly dependent upon the utility experience, plant design maturity and plant operational maturity, etc., it

Table 3.27

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 60-89 MW		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	8	87.0
1972	10	83.6
1973	5	84.0
1974	6	88.5
1975	5	82.7
1971-1975	34	85.2
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.28

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 90-129 MW		
Period	Number of Unit-Years	Average Operating Availability
1971	52	86.4
1972	56	87.4
1973	61	85.9
1974	65	84.2
1975	66	82.8
1971-1975	300	85.3
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.29

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 130-199 MW		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	108	88.6
1972	114	85.5
1973	111	86.6
1974	108	84.5
1975	101	82.7
1971-1975	542	85.6
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.30

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 200-389 MW		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	71	85.2
1972	74	81.9
1973	78	82.5
1974	84	85.3
1975	95	78.4
1971-1975	401	82.5
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.3 Plant Operating Availability (Continued)

can be projected that, given time, the average operating availability of the larger plants can be increased to the high eighties (85%+) as has been achieved by the smaller plants. This conclusion is reinforced by the fact that the large size ranges are already exhibiting an increasing average operating availability trend.

An analysis of the average operating availability of the large plant size range (600 MW and above) to assess the effect on average operating availability of plant design maturity, plant operational maturity (age) and utility experience, follows.

Table 3.31

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 390-599 MW		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	33	79.8
1972	37	74.4
1973	41	76.8
1974	43	75.5
1975	47	73.3
1971-1975	201	75.8
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.32

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 600 MW & Above		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	20	74.3
1972	28	72.2
1973	34	76.0
1974	41	72.8
1975	41	74.4
1971-1975	164	73.9
Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.33

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 600-699 MW		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	8	74.9
1972	9	66.3
1973	11	77.0
1974	10	82.2
1975	11	77.3
1971-1975	49	75.8
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.34

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 700-799 MW		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	4	71.8
1972	6	71.2
1973	8	73.6
1974	9	73.9
1975	9	72.6
1971-1975	36	72.8
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.35

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 800-899 MW		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	1	53.6
1972	4	60.7
1973	4	72.5
1974	6	75.7
1975	6	75.2
1971-1975	21	70.8
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.36

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 900 MW & above		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	3	67.2
1972	3	72.9
1973	3	71.1
1974	3	80.5
1975	3	72.3
1971-1975	15	72.8
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart included units of different design, vintage, utilization, etc.		

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.3 Plant Operating Availability (Continued)

DESIGN VINTAGE

The coal plants projected for start-up in **California** during the period 1980-1995 are all greater than 600 MW in capacity. To assess the effects of design vintage and design maturity on historical coal plant average operating availability, the historical data was sorted to identify plants that went into commercial operation in the period 1965-1969 and those that went commercial in 1970-1975.

The effects of design vintage on coal fired plant average operating availability is shown in Table 3.37. In the table, average operating availabilities of plants with start-up dates in the period 1965-1969 are compared with those of plants with start-up dates in the period 1970-1975.

The table shows the average operating availability for the first five years of commercial operation. This five-year time span has been chosen to insure that the average operating availability value obtained will not be overly influenced by the low operating availabilities which may be experienced during a plant's initial years of operation.

For the two size ranges, for which data are available on both plant vintages, the five-year average operating availability does not exhibit any marked change. Also, the five-year average operating availability for both size range is in the low seventy percent.

Design of coal plants has matured to the extent that an average operating availability of 70% + is feasible for the plants due to be started up in California. From Table 3.37 the minimum five-year average operating availability expected of large (600 MW and above) coal plants is estimated/projected to be 70%.

ALTERNATIVE DESIGN STRATEGIES

An objective of this study was to assess the effect, if any, of different design strategies on the historical operating availability achieved by coal fired power plants. The study attempted to collect data on the average historical operating availability of plants that differ in design. Some of the

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.3 Plant Operating Availability (Continued)

design differences considered were:

Subcritical and supercritical boiler types

Single and multiple boilers

Header and non-header plants

Plants with reheat and plants without reheat

The data collection effort to distinguish between historical average operating availability of each of the above design options was unsuccessful.

Table 3.37

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Size Range (MW)	Plants With Start-Up Dates in the Period 1965-1969		Plants With Start-Up Dates in the Period 1970-1975	
	No. of Unit-Years	Average [†] Operating Availability(%) [‡]	No. of Unit-Years	Average [†] Operating Availability(%) [‡]
600-699	19	73.4	28	74.8
700-799	5	73.5	21	72.2
800-799	-	-	21	70.8
900 & Above	12	78.8	-	-
[†] Average Operating Availability of First Five Years of Commercial Operation				
[‡] Source: SDC Analysis of EEI data supplied by FEA				
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.				

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.3 Plant Operating Availability (Continued)

PLANT OPERATIONAL MATURITY

Coal plant operating availability does not appear to vary greatly with the design vintages of plants. To study the effect of plant age on its operating availability, the latest vintage plants in each of the four size ranges exceeding 600MW were chosen for comparison.

The plants included in the three smaller size ranges (600-699 MW, 700-799 MW, and 800-899 MW) were plants with commercial operation start-up dates during the period 1970-1975. As no 900 MW or larger plants could be identified as being placed into commercial operation during the 1970-1975 period, the 900 MW and larger size range included plants of an earlier vintage: those with commercial operation start-up dates in the period 1965-1969.

Table 3.38 lists the five-year average operating availability for each of the four size ranges. This is the average operating availability of the plants over the first five years of commercial operation. Table 3.39, on the other hand, lists the annual average operating availability of plants in each size range, for each of the first five years of commercial operation.

Although the largest size range, 900 MW and above, has the largest five-year average operating availability, its annual operating availability has, generally, reduced during the five-year period. Each of the other size ranges shows some improvement in the form of increased annual average operating availability with time. The improvement (increase) is greatest for the 800-899 MW size range. The reduction in annual average operating availability of the 900 MW and above size could be due, in part, to the older vintage of the plants included in this size classification.

From the tables, it can be concluded that plants require one or two years of operation before they achieve their five-year average operating availability for their respective size range. In all cases, except the 900 MW-and-above size range, the five-year average operating availability represents the lifetime average operating availability, through 1975, of each size range. Thus, to achieve their lifetime average operating availability, coal fired plants generally require one or two years of commercial operation.

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.3 Plant Operating Availability (Continued)

Based on these observations, it may be projected that coal fired power plants due for start-up in California will achieve low operating availability (50%) during their first year of operation. This is expected to improve to over 70% in the second or third year of commercial operation. The feasible operating availability after the first few years of operation of coal power plants should be in the high seventies and could range from the low seventies to the mid-eighties.

Table 3.55

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range (MW)	Number of Unit-Years	Average [†] Operating Availability (%)
600-699	28	74.8
700-799	21	72.2
800-899	21	70.8
900 & Above	12	78.8
[†] Average of First Five Years of Commercial Operation Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.		

Table 3.56

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S. [†]								
Year of Commercial Operation	600-699 MW		700-799 MW		800-899 MW		900 MW & Above	
	No. of Unit-Years	Average Operating Availability (%) [†]	No. of Unit-Years	Average Operating Availability (%) [†]	No. of Unit-Years	Average Operating Availability (%) [†]	No. of Unit-Years	Average Operating Availability (%) [†]
First	4	61.9	5	68.5	2	45.1	- ^{††}	- ^{††}
Second	7	76.7	6	71.4	4	70.5	3	80.8
Third	7	67.8	5	72.6	5	76.6	3	78.2
Fourth	6	86.8	3	78.6	6	72.5	3	75.8
Fifth	4	78.2	2	73.2	4	74.0	3	80.3
[†] SDC Analysis of EEI data supplied by FEA ^{††} No Data Available								
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.								

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.3 Plant Operating Availability (Continued)

UTILITY OPERATING EXPERIENCE

No coal fired power plants are currently in operation in the State of California. Only one California utility has a share in three coal fired plants in operation outside the State of California. These plants are, however, operated by an out-of-state utility. While this one California utility has some experience with coal plant problems and idiosyncracies, it has no "hands-on" experience in the operation and maintenance of coal fired plants. Furthermore, two of the plants are experimental, first-of a-kind installations and the experience gained here would mostly fall under the general heading of "Research and Development." To summarize, California utilities have very little, if any, hands-on experience in the operation/maintenance/management of coal power plants.

In general, utilities can be divided into two broad types. Type 1 are defined to be those that have no "hands-on" experience at all with any coal fired power plant. Type 2 are defined to be those that have some experience (which is very limited) with coal fired plants: the experience be based upon different size coal plants than are projected for start-up in California and no experience at all with sizes similar to those proposed.

The EEI data supplied by the FEA were scanned to identify Type 1 and/or Type 2 utilities that brought coal fired plants greater than 600 MW into commercial operation during the period 1970-1975. Only one Type 1 utility could be identified. The Type 2 utilities brought from one (1) to four (4) coal plants on-line during 1970-1975. The two utilities with the highest number of such coal plants were chosen for comparison with the Type 1 utility identified. Table 3.40 lists the average annual operating availability achieved by the coal plants (commercial date between 1970 and 1975) of both type 1 and type 2 utilities. Table 3.41 lists the first five-year average of the large coal fired plants operated by each utility.

The Type 1 utility (no previous experience) achieved a first five-year average operating availability lower than the Type 2 utilities (some previous experience).

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS
Subsection 3.3 Plant Operating Availability (Continued)

UTILITY OPERATING EXPERIENCE (CONTINUED)

Each utility experienced low average annual operating availabilities during the first few years of operation. In the third year, 1973, the Type 1 utility achieved an average operating availability comparable with that achieved by the Type 2 utilities. But the Type 1 utility was unable in later years to successfully maintain the level of operating availability. The utilities with some previous experience (Type 2's) improved upon their average operating availability.

Based upon these observations, it may be projected that, in general, it will be difficult for California utilities to attain the average national operating availability, which is in the high seventies. Of course, with time and hands-on experience it is feasible for California utilities to achieve annual average operating availability of their coal plants, very close to or even exceed the national average.

Table 3.40

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.						
Year of Commercial Operation	Type 1 Utility*		Type 2 Utility**		Type 2 Utility ***	
	Number of Unit-Years	Avg. Operating Availability [†] (%)	Number of Unit-Years	Avg. Operating Availability [†] (%)	Number of Unit-Years	Avg. Operating Availability [†] (%)
1971	-	-	2	58.6	1	53.5
1972	2	49.7	2	41.4	1	60.0
1973	2	69.6	4	73.3	3	68.1
1974	2	67.5	4	72.3	4	73.8
1975	2	61.6	4	81.8	4	75.3
[†] Source: SDC Analysis of EEI data supplied by FEA * 800-899 MW Size Plant Data ** 600-699 MW Size Plant Data *** 700-799 MW Size Plant Data Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Table 3.41

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.			
Utility/Type	1	2	2
Number of Unit-Years	8	16	13
Five-Year Average Operating Availability (%)	62.1	69.3	70.3
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.			

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.4 Plant Equivalent Availability

Coal fired power plants have operated with an average equivalent availability of 79.4% during the period 1971-1975. This figure includes only greater-than-60 MW coal fired plants in operation during the period 1971-1975 on which data are collected by the EEI Equipment Availability Task Group. A 1643 unit-year sample was used to arrive at an average equivalent availability of 79.4%.

The equivalent availability of coal fired power plants has declined during the period 1971-1975. As shown in Table 3.42, the highest annual average equivalent availability is 83.3% in 1971 which reduced to 75.5% by 1975.

Equivalent availability of coal fired plants is, in general, inversely proportional to the size of the plant. The equivalent availability varies from a high of 83.9% (for 130-199 MW size plants) to 67.5% (for 600 MW and above size plants). These figures are based upon the plants in operation during the period 1971-1975 and on whom data were available through the EEI data bank (see Figure 3.43).

The average equivalent availability of 65.8% computed for 600 MW and larger coal plants by SDC from EEI data supplied by the FEA, is less than two percentage points different from that computed by EEI (67.5%).

Table 3.43 also lists the average equivalent availability of each of four new size ranges made by SDC of the EEI 600 MW-and-above power plants. The 800-899 MW size range has the lowest historical average equivalent availability while the 600-699 MW range has the highest. For the three size ranges other than the 800-899 MW range, as the size increases the average equivalent availability reduces.

The average equivalent availability of all sizes of coal fired plants has fluctuated during the period 1971-1975 as shown in Tables 3.44-3.53. They list the annual average equivalent availability and the five-year average equivalent availability for each size range.

The average equivalent availability for all plants smaller than 600 MW have, in general, reduced over the period 1971-1975. On the other hand, average equivalent availability of 600 MW and larger plants have increased during the same time period.

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Year	Number of Unit-Years	Average Equivalent Availability (%) †
1971	292	83.3
1972	319	79.7
1973	330	80.5
1974	347	78.6
1975	355	75.5
† Source: EEI Special analysis for SDC		
Note: The data used to develop chart includes units of different size, age, utilization, vintage, etc.		

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years	Average Equivalent Availability (%) *
60- 89 MW	34†	83.5†
90-129 MW	300†	83.6†
130-199 MW	542†	83.9†
200-389 MW	402†	78.8†
390-599 MW	201†	70.9†
600 MW & Above	164†	67.5†
600 MW & Above	122††	65.8††
600-699 MW	50††	68.0††
700-799 MW	36††	65.3††
800-899 MW	21††	62.5††
900 MW & Above	15††	64.5††
† Source: EEI Special Analysis for SDC		
†† Source: SDC Analysis of EEI Data Supplied by FEA		
* Average over the Five Year Period 1971-1975		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.4 Plant Equivalent Availability (Continued)

In general, for plants less-than-600 MW, the average equivalent availability for the first few years is higher than the five-year average. For these size ranges, the five-year average has been reduced by the lower capacity factors of later years.

The average equivalent availability (600 MW and above plants) first reduces, then increases and later reduces again. In each case, however, the change is small compared to the annual average value. Each of the four subdivisions usually show a generally increasing trend during the same period, but as the increase is small compared to the annual average equivalent availability, the five year average is not greatly affected by any one year's average equivalent availability.

The variation in annual average equivalent availability is the lowest for the 700-799 MW size range while it is the greatest for the 900 MW and larger size plants.

Tables 3.44 through 3.53 indicate that coal plants are exhibiting lower annual average equivalent availabilities as their size increases. The larger size plants have yet to achieve the high average equivalent availabilities that have been attained by the smaller plants. However, the smaller plants have been in commercial operation for a greater period of time than have the large plants. As the equivalent availability of a power plant is dependent upon the utility experience, plant design maturity and plant operational maturity (age), etc., it may be projected that, with time, the average equivalent availability of the large plants will increase to the high eighties (85% +). This conclusion is reinforced by the fact that the large plants are already exhibiting an increasing average equivalent availability trend.

An analysis of the average equivalent availability of the larger (600 MW and above) plants to assess the effects of plant design maturity, plant operational maturity, (age) and utility experience follow.

Table 3.44

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 90 - 129 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	52	85.2
1972	56	86.2
1973	61	84.8
1974	65	82.3
1975	66	80.4
1971-1975	300	83.6
Note: The data used to develop chart includes units of different design, vintage, utilization, etc. Source: EEI special analysis for SDC		

Table 3.45

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 60 - 89 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	8	86.8
1972	10	80.4
1973	5	83.8
1974	6	87.7
1975	5	79.8
1971-1975	34	83.5
Note: The data used to develop chart includes units of different design, vintage, utilization, etc. Source: EEI special analysis for SDC		

Table 3.46

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 130 - 199 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	108	87.4
1972	114	84.1
1973	111	85.1
1974	108	82.3
1975	101	80.4
1971-1975	542	83.9
Note: The data used to develop chart includes units of different design, vintage, utilization, etc. Source: EEI special analysis for SDC		

Table 3.47

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 200 - 389 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	71	83.0
1972	74	77.8
1973	78	79.5
1974	84	80.6
1975	95	74.1
1971-1975	402	78.8
Note: The data used to develop chart includes units of different design, vintage, utilization, etc. Source: EEI special analysis for SDC		

Table 3.48

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 390 - 599 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	33	75.6
1972	37	69.6
1973	41	71.9
1974	43	70.1
1975	47	68.3
1971-1975	201	70.9
Note: The data used to develop chart includes units of different design, vintage, utilization, etc. Source: EEI special analysis for SDC		

Table 3.49

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 600 MW & Above		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	20	68.0
1972	28	66.8
1973	34	70.1
1974	41	66.3
1975	41	66.6
1971-1975	164	67.5
Note: The data used to develop chart includes units of different design, vintage, utilization, etc. Source: EEI special analysis for SDC		

Table 3.50

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 600-699 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	8	67.8
1972	10	63.8
1973	11	71.8
1974	10	66.6
1975	11	69.3
1971-1975	50	68.0
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.51

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 700-799 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	4	65.5
1972	6	66.5
1973	8	66.7
1974	9	66.8
1975	9	65.3
1971-1975	36	65.3
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.52

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 800-899 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	1	52.5
1972	4	55.6
1973	4	63.7
1974	6	65.9
1975	6	61.9
1971-1975	21	62.5
Source: SDC analyses of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Table 3.53

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
SIZE: 900 MW & above		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	3	61.2
1972	3	56.4
1973	3	64.6
1974	3	74.9
1975	3	65.5
1971-1975	15	64.5
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, vintage, utilization, etc.		

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS
Subsection 3.4 Plant Equivalent Availability (Continued)

DESIGN VINTAGE

The coal plants projected for startup in California during the period 1980-1995 are all greater than 600 MW in capacity. To assess the effect of design vintage on the historical equivalent availability of coal, plants 600MW-and-greater, the historical data base was sorted to identify power plants that went into commercial operation during the period 1965-1969 and these with commercial start up dates in the period 1970-1975.

The effects of design vintage on average equivalent availability is shown in Table 3.54. In this table, plants with startup dates in the period 1965-1969 are compared with those with startup dates during the period 1970-1975. The table lists the average equivalent availability of the first five years of commercial operation for each size range. This time span has been chosen to ensure that average equivalent availability values obtained will not be overly influenced by the low equivalent availabilities experienced during the initial year of operation.

No major change in average equivalent availability is shown by 600-699 MW plants of the two vintages. However, the 700-799 MW size does show a lower average equivalent availability for the newer vintage plants. It appears that the design of coal plants has matured to the extent that an average equivalent availability greater than 60% is feasible for plants, in this range, which may be sited in California.

ALTERNATIVE DESIGN STRATEGIES

An objective of this study was to assess the effects, if any, of different designs on the historical equivalent availability achieved by coal fired power plants. An attempt was made to collect data on the average equivalent availability of plants that differ in design. Some of the design differences considered were:

- subcritical boilers and supercritical boilers
- single and multiple boilers
- header and non-header plants
- plants with reheat and plants without reheat

The data collection efforts to distinguish between historical equivalent availability of each of the above design options was unsuccessful.

Table 3.54

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Size Range (MW)	Plants With Startup Dates in the Period 1965-1969		Plants With Startup Dates in the Period 1970-1975	
	Number of Unit-Years	Average ^{††} Equivalent Availability(%) [†]	Number of Unit-Years	Average ^{††} Equivalent Availability(%) [†]
600-699	19	67.1	27	67.6
700-799	5	69.7	21	62.8
800-899	-	-	21	62.5
900 & Above	12	74.2	-	-
[†] Source: SDC Analysis of EEI Data Supplied by FEA ^{††} Average Equivalent Availability of first five years of Commercial Operation				
Note: The data used to develop chart includes units of dif- ferent design, utilization, vintage, etc.				

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.4 Plant Equivalent Availability (Continued)

OPERATIONAL MATURITY (AGE)

The historical data does not show that average equivalent availability of coal plants has varied greatly with vintage. To study the affect of plant age, if any, on its average equivalent availability, the latest vintage plants in each of the four size ranges over 600 MW were reviewed.

The plants included in the three smaller size ranges (600-699 MW, 700-799 MW, 800-899 MW) are plants with commercial operation startup dates in the period 1970-1975. No plants 900 MW or greater were brought into commercial operation status after 1969. The 900 MW and greater size range includes plants of an earlier vintage: those with commercial operation startup dates in the period 1965-1969.

Table 3.55 lists the average equivalent availability for each of the four size ranges. This is the average equivalent availability, of the plants in each size range, for the first five years of commercial operation. Table 3.56 lists the annual (year-by-year) average equivalent availability of plants in each size range, for each of the first five years of commercial operation.

Although the largest size plants (900 MW and above) have the largest first five year average equivalent availability, their annual average equivalent availability has, generally, reduced during this five year period. Each of the other size ranges shows an improving (increasing) trend in annual average equivalent availability, with time. This improvement is most marked for the 800-899 MW size range. The decrease in the first few years of the annual average equivalent availability of 900 MW+ plants could be due, in part, to the older vintage (e.g., design maturity) included in this size classification.

For each plant size, except 900 MW-and-above, the five year average equivalent availability is the lifetime average equivalent availability, through 1975. The tables show these plants to require one or two years of commercial operation before achieving their five year average.

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.4 Plant Equivalent Availability (Continued)

OPERATIONAL MATURITY (AGE) CONTINUED

Coal fired plants projected to be sited in California may be expected to achieve low equivalent availabilities (50%-60%) during their first few years of commercial operation. This may be anticipated to improve to over 75% in latter years. In other words, the feasible levels of equivalent availability after the first few years of commercial operation is in the high seventies and could range from the low seventies (70%+) to the low eighties (80%+).

Table 3.38

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range (MW)	Number of Unit-Years	Average† Equivalent Availability (%)
600-699	27	67.6
700-799	21	62.8
800-899	21	62.5
900 & Above	12	74.2
† Average of first five years of commercial operation Source: SDC Analysis of ERI data supplied by FEA		
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.		

Table 3.39

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S. †								
Year of Commercial Operation	600-699 MW		700-799 MW		800-899 MW		900 MW & Above	
	Number of Unit-Years	Average Equivalent Availability (%)	Number of Unit-Years	Average Equivalent Availability (%)	Number of Unit-Years	Average Equivalent Availability (%)	Number of Unit-Years	Average Equivalent Availability (%)
First	4	57.1	5	60.5	2	43.8	-††	-††
Second	7	70.0	6	62.8	4	63.8	3	77.9
Third	7	60.7	5	63.8	5	68.6	3	72.8
Fourth	6	78.8	3	67.2	6	61.7	3	72.2
Fifth	3	69.5	2	59.3	4	64.0	3	79.3
† SDC Analysis of EEI Data supplied by FEA								
†† No Data Available								
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.								

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.4 Plant Equivalent Availability (Continued)

UTILITY OPERATING EXPERIENCE

The historical average equivalent availability of coal fired plants is dependent upon the experience the operating utility has with the operation and maintenance of coal plants. No coal fired power plants are currently in operation in the State of California. One California utility has a share in three coal fired plants, in operation outside the State of California. These plants are, however, operated by an out-of-state utility. While this California utility has some experience with coal plant problems and idiosyncracies, it has no "hands-on" experience in the operation and maintenance of coal fired plants. Furthermore, two of the plants may be classified as experimental first-of-a-kind installations and the experience gained here would mostly fall under the general heading of "Research and Development." To summarize, California utilities have very little, if any, hands-on experience in the operation/maintenance/management of coal power plants.

Utilities, in general, may be classified in two broad categories. Type 1 may be defined as those with no "hands-on" experience at all with any size of coal fired power plants. Type 2 may be defined as those with some experience (which is very limited) with coal fired plants: The experience be based upon different sized coal plants than are projected for siting in California, and no experience at all with sizes similar to those proposed.

EEI data supplied by the FEA were reviewed to identify possible Type 1 and Type 2 utilities that brought large (600 MW+) coal plants into commercial operation during the period 1970-1975. Only one Type 1 utility was found. The Type 2 utilities brought a total of four (4) new plants on-line during the 1970-1975 period.

Table 3.57 lists the annual average equivalent availability achieved by coal plants (commercial startup data: 1970-1975) of both Type 1 and Type 2 utilities. Table 3.58 lists the first five-year average equivalent availability of the large coal plants operated by each utility.

Table 3.57

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.						
Year of Commercial Operation	Type 1 Utility*		Type 2 Utility**		Type 2 Utility***	
	Number of Unit-Years	Average Equivalent Availability [†] (%)	Number of Unit-Years	Average Equivalent Availability [†] (%)	Number of Unit-Years	Average Equivalent Availability [†] (%)
1971	-††	-††	2	51.3	1	52.5
1972	2	48.3	2	34.0	1	47.6
1973	2	62.3	4	64.5	3	54.7
1974	2	59.5	4	62.0	4	61.9
1975	2	50.7	4	68.8	4	63.1
[†] Source: SDC analysis of EEI data supplied by FEA ^{††} No data available [*] 800-899 MW size plant data ^{**} 600-699 MW size plant data ^{***} 700-799 MW size plant data						
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.4 Plant Equivalent Availability (Continued)

The Type 1 utility (no previous experience with coal fired plants) achieved a first five-year average equivalent availability lower than the Type 2 utilities (previous coal fired plant experience).

Each utility type showed low annual average equivalent availabilities during the first few years of commercial operation of large coal plants. In the third year, 1973, Type 1 achieved an average equivalent availability comparable with that achieved by the Type 2 utility operating the 600 to 699 MW plant, and exceeded that achieved by the Type 2 utility operating the 700 to 799 MW plant. However, the Type 1 utility was unable, in later years, to successfully maintain this high level of equivalent availability. The utilities with previous coal plant experience, however, improved upon their annual average equivalent availability each succeeding year.

Based upon the limited discussion above, it can be concluded that, in general, utilities without prior experience will find it difficult to attain the national average equivalent availability of the mid-sixties. Of course, with the increase of "hands-on" experience with time, it is feasible for utilities to achieve annual average equivalent availabilities of large coal fired plants of nearly 70%.

Table 3.58

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.			
Utility Type	1	2	2
Number of Unit-Years	8	16	13
5 Year Average Equivalent Availability (%)	55.2	59.5	58.8
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.			

Section 3.0 COAL FIRED STEAM ELECTRIC PLANTS IN THE U.S.

Subsection 3.5 Plant Heat Rate

Table 3.59 lists the average heat rate for 1973 and 1974 for coal fired plants in the U.S. The data were obtained from the Federal Power Commission (FPO) "Steam-Electric Plant Construction Cost and Annual Production Expenses" supplements for 1973 and 1974. These reports list average heat rates by each coal fired station. It was assumed, for the purpose of this analysis, that the average heat rate values provided in the report were valid for each individual coal plant at any given station. The average size of the coal plant was obtained by dividing the station installed capacity (MW) by the number of coal plants at the station. This average value was used to arrive at the average heat rate of the different size ranges of Table 3.59.

The annual average heat rate of all coal plants has dropped from 10403 Btu/Kwh in 1973 to 10168 Btu/Kwh in 1974. This drop in annual average heat rate is mirrored by all the size ranges except the 390-599 MW and the 700-799 MW ranges, for which the annual average heat rate increased.

In both 1973 and 1974 the lowest and the highest sizes exhibit relatively high heat rates (over 10000 Btu/Kwh). The medium size plants, 200-899 MW have operated at an annual average heat rate equal to or less than 1000 Btu/Kwh.

Table 3.59

COAL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Range of Average Size of Plant (MW)	Number of Unit-Years		Average Heat Rate (Net) [†]	
	1973	1974	1973	1974
60-89	33	12	12048	11490
90-129	22	15	10789	10723
130-199	89	74	10320	10206
200-389	98	71	10035	9951
390-599	18	13	9739	9948
600 & Above	12	15	9797	9584
600-699	7	6	10022	9788
700-799	2	2	9520	9590
800-899	-	1	-	10190
900 & Above	3	6	9400	9276
All Plants	272	200	10403	10168

[†] Source: SDC Analysis of FPC Data on Plants Using Coal Fuel Only

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.6 Key Components/systems

To identify the key components, subsystems and systems that have resulted in a reduction in the historical level of each reliability and efficiency index, it was necessary to review the data on historical failures, malfunctions and off-specification performance of coal fired plant components, subsystems and systems. Failure of a pulverizer that results in a reduction of the power generating capability of a coal plant (a reduced capacity factor), is an example of a component affecting the performance of the plant and inhibiting the attainability of a higher level of an index.

Data on coal fired plant components and systems that have historically been responsible for reduced capacity factors, equivalent availability, and operating availability, were reviewed to arrive at a listing of the key components and systems of coal fired plants. Components/systems responsible for over 100 equivalent full power outage hours, per calendar year, are defined as key components/systems.

The primary source of coal plant failure data was the Edison Electric Institute (EEI) Equipment Availability Task Force data bank. This data bank contains information on the historical failures by cause code headings. An EEI cause code heading is a title under which all the outages due to either (1) a group of equipment, (2) similar multiple equipment, or (3) individual equipment, are assigned.

No data was available on historical malfunction or off-specification performance of components, subsystems and systems if no failure occurred and if the coal plant did not undergo a partial or full outage condition.

Table 3.60 lists the EEI cause codes that have been responsible for over 100 equivalent full power outage hours, per unit year, for coal plants in operation during the period 1971-1975. Thirty-three (33) cause codes have resulted in more than a hundred (100) outage hours. These thirty-three (33) cause codes of Table 3.60 cover all the major equipment/systems in a coal fired power plant. The "general" codes (100, 600, 700, 800, and 900) have consist-

Table 3.60

COAL FIRED STEAM ELECTRIC POWER PLANTS IN THE U.S.							
Size: 600 MW and Above							
EEI Cause Code	EEI Cause Code Title	Average Equivalent Full Power Outage Hours Per Unit-Year†					
		1971	1972	1973	1974	1975	Five Year Total 1971-1975
100	Boiler, General	803	799	562	502	644	3330
101	Water Walls	176	158	150	282	318	1084
102	Generating Tubes	26	23	38	56	199	199
103	Superheater	49	48	56	77	46	276
104	Reheat	18	83	37	37	58	233
107	Air Preheater	87	1	13	3	6	110
108	Air Preheater	27	42	13	35	20	137
109	Induced Draft Fans	15	9	14	57	94	189
110	Forced Draft Fans	38	31	42	36	45	192
116	Steam Valves & Piping	4	13	15	18	60	110
119	Slag & Fly Ash Disposal	35	27	51	37	21	171
121	Pulverizers	94	39	61	75	118	387
122	Cyclones	3	36	27	8	32	106
126	Boiler Casing	9	12	22	64	14	121
134	Boiler Controls	11	19	25	26	48	129
136	Furnace Slagging	41	23	44	82	100	290
139	Air Heater Fouling	17	62	23	10	17	129
142	Wet Coal	23	28	22	35	23	131
151	Boiler, Inspection	—	119	128	217	144	608
600	Turbine, General	599	747	460	376	347	2529
622	Turbine, Control	16	18	28	35	81	178
629	Buckets or Blades	126	29	—	82	7	244
630	Vibration	58	65	21	19	16	179
631	Lube Oil System	243	29	23	10	11	316
648	Inspection	68	77	—	47	80	272
700	Generator, General	692	745	419	180	212	2248
706	Stator Windings	—	—	70	52	4	126
714	Control	5	—	97	2	4	108
800	Condenser, General	449	169	175	143	100	1036
900	Other, General	362	250	172	165	109	1058
901	Feedwater Heaters	14	25	31	18	31	119
905	Boiler Feed Pumps	88	124	63	37	40	352
919	Boiler Feed Pump Drive	—	—	23	26	55	104
(All Others)		305	365	424	445	448	

†Source: EEI Special Analysis for SDC

Table 3.61

COAL FIRED STEAM ELECTRIC POWER PLANTS IN THE U.S.								
Size: 600 MW and Above								
Key Components/Systems			Average Equivalent Full Power Outage Hours Per Unit-Year*					
Rank	EEI Cause Code	EEU Cause Code Title	1971	1972	1973	1974	1975	Five Year Total 1971-1975
1	100	Boiler, General	803	799	562	502	644	3330
2	600	Turbine, General	599	747	460	376	347	2529
3	700	Generator, General	692	745	419	180	212	2248
4	101	Water Walls	176	158	150	282	318	1084
5	900	Other, General	362	250	172	165	109	1058
6	800	Condenser, General	449	169	175	143	100	1036
7	121	Pulverizers	94	39	61	75	118	387
8	136	Furnace, Slagging	41	23	44	82	100	290

Section 3.0 COAL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 3.6 Key Components/Systems

antly been responsible for very high outage hour values.

In many instances, simultaneous preventative maintenance and repairs are necessary, on more than one component/system, to remove the outage condition and bring the plant back on-line. In such cases the outage may be reported under more than one cause code heading. Table 3.60 is based upon EEI data and unit outage projections based upon combining individual cause code hours should be made with caution.

The EEI cause codes with either high outage hours in 1974 and 1975, the latter years in the sample, or with an increasing five-year outage-hours trend, are deemed to be significant for the purpose of this study. Table 3.61 lists these key EEI cause codes.

SECTION 4.0

NUCLEAR STEAM ELECTRIC POWER PLANTS

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.1 Introduction

The four indices of power plant reliability and efficiency recommended for use by the State of California, Energy Conversation and Development Commission, for evaluating AFC submittals for new nuclear power plants are: 1) Capacity Factor, 2) Operating Availability, 3) Equivalent Availability and 4) Heat Rate. To establish the historical ranges and averages achieved by each of the four indices, a review and analysis of historical data available on each of the four indices was necessary.

Table 4.1 is a list of all the nuclear power plants in the U.S. which were identified as being in commercial operation during the period 1971-1975. The data collection effort attempted to collect historical data on each of these fifty-three nuclear power plants. Historical data were available from three major sources, namely, the Federal Energy Administration (FEA) data base comprised of EEI data, the NRC "Operating Unit Status Reports" and the Federal Power Commission (FPC) "Steam Electric Plant Construction Cost and Annual Production Expenses" supplements.

Operating and facility description data in the FEA (FEI) data base were not entirely consistent with those in the NRC data base. In several instances no data were available while in others there were significant differences. Table 4.1 illustrates the disparity between the FEA and NRC ratings of electrical capacity.

In the analysis of historical data to arrive at the historical ranges and averages of each index, no data from any data system were rejected. EEI data supplied by FEA frequently identify a power plant as being in commercial operation many months before it is reported by the NRC as being in a commercial operating status. In addition to anomalies that many arise in using first partial year data, the data evaluation is further compounded if pre-commercialization data are used. However, no attempt has been made to "alter" these data or determine which data (i.e., NRC vs. FEA) are more accurate. Thus, if a utility reported operating data for a power plant in a year preceding the NRC published commercial operations date, these were used in the evaluation and were not discarded.

Table 4.1

UTILITY SYSTEM	PLANT NAME/LOCATION	EET NAME- PLATE RATING (GROSS)	NRC NAME- PLATE RATING (GROSS)	EET MDC (GROSS)	NRC MDC (GROSS)	NRC MDC (NET)	NRC DER (NET)	DATE OF COMMERCIAL OPERATIONS
Pacific Gas & Electric Co.	Humboldt Bay 3 (Humboldt Bay, Cal.)	70	75	{52} {65}	64	65	72	03/29/63
Dairyland Power Cooperative	La Crosse BWR (Genoa, Wis.)	60	65	{48} {52}	50	48	50	09/13/69
Consumers Power Co.	Big Rock Point (Big Rock Point, Mich.)	75	75	{60} {75}	64	65	72	03/29/63
Yankee Atomic Electric Co.	Yankee (Rowe, Mass.)	185	185	{167} {188}	180	175	175	09/61
Commonwealth Edison Company	Dresden 1 (Morris, Ill.)	210	209	{200} {210}	205	197	200	07/04/60
Consolidated Edison Company of N.Y.	Indian Point 1 (Indian Point, N.Y.)	—	275	{235} {285}	0	0	265	
Southern California Edison and San Diego Gas & Electric Co.	San Onofre 1 (San Clemente, Cal.)	450	450	450	450	436	430	01/01/68
Omaha Public Power District	Fort Calhoun 1 (Fort Calhoun, Neb.)	482	502	482	468	445	457	09/26/73
Rochester Gas & Electric Co.	Robert E. Ginna (Ontario, N.Y.)	496	517	{418} {477}	498	470	490	07/70
Wisconsin Electric Power Co. and Wisconsin Michigan Power Co.	Point Beach 1 (Two Creeks, Wis.)	503	524	{495} {508}	518	495	497	12/21/70
	Point Beach 2 (Two Creeks, Wis.)	5032	524	{408} {508}	518	495	497	10/01/72
Northern States Power Co.	Prairie Island 1 (Red Wing, Minn.)	560	593	520	550	507	530	12/16/73
	Prairie Island 2 (Red Wing, Minn.)	560	593	520	550	507	530	12/21/74
Wisconsin Public Service Corporation	Kewaunee (Carlton, Wis.)	563	560	535	549	523	535	06/74
Connecticut Yankee Atomic Power Co.	Haddam Neck (Haddam Neck, Conn.)	616	600	{500} {610}	577	550	575	01/01/68
Florida Power & Light Co.	Turkey Point 3 (Florida City, Fla.)	728	760	{730} {748}	700	666	693	12/14/72
	Turkey Point 4 (Florida City, Fla.)	728	760	{730} {748}	700	666	693	09/07/73
Carolina Power & Light Co.	Robinson 2 (Hartsville, S.C.)	702	769	{700} {705}	700	665	700	03/07/71
Consumers Power Co.	Palisades (South Haven, Mich.)	812	812	{585} {726}	675	635	805	12/31/71
Virginia Electric & Power Co.	Surry 1 (Gravel Neck, Va.)	822	848	{788} {824}	811	775	822	12/22/72
	Surry 2 (Gravel Neck, Va.)	822	848	788	811	775	822	05/01/73
Maine Yankee Atomic Power Co.	Maine Yankee (Wiscasset, Me.)	830	810	{690} {760}	800	760	790	12/28/72
Metropolitan Edison Co.	Three Mile Island 1 (Goldsboro, Pa.)	837	871	{824} {826}	840	792	819	09/02/74
Northeast Utilities	Millstone 2 (Waterford, Conn.)	NA	909	NA	828	798	830	12/26/75
Baltimore Gas & Electric Co.	Calvert Cliffs 1 (Lusby, Md.)	883	918	810	835	810	845	05/08/75
Duke Power Co.	Oconee 1 (Seneca, S.C.)	886	934	{881} {887}	899	860	887	07/15/73
	Oconee 2 (Seneca, S.C.)	886	934	871	899	860	887	09/09/74
	Oconee 3 (Seneca, S.C.)	886	934	871	899	860	887	12/16/74
Arkansas Power & Light Co.	Arkansas 1 (Russellville, Ark.)	902	902	{845} {886}	886	836	850	12/19/74
Sacramento Municipal Utility District	Rancho Seco (Clay Station, Cal.)	NA	963	NA	917	873	918	04/17/75
Consolidated Edison Co.	Indian Point 2 (Indian Point, N.Y.)	1022	1022	900	900	864	873	08/73
Commonwealth Edison Co.	Zion 1 (Zion, Ill.)	1085	1085	{914} {1100}	1050	1010	1040	12/31/73
	Zion 2 (Zion, Ill.)	1085	1085	{914} {1100}	1050	1010	1040	09/17/74
Indiana & Michigan Electric Co.	Donald C. Cook 1 (Bridgman, Mich.)		1152		1083	1044	1054	08/27/75
Vermont Yankee Nuclear Power Corp.	Vermont Yankee (Vernon, Vt.)	537	563	{504} {508}	535	504	514	11/29/72
Northern States Power Co.	Monticello (Monticello, Minn.)	543	569	580	564	536	545	06/30/71
Iowa Electric Light & Power Co.	Duane Arnold (Palo, Iowa)	565	565	540	543	515	538	02/01/75
Niagara Mohawk Power Corp.	Nine Mile Point 1 (Scriba, N.Y.)	610	640	610	630	610	610	12/69
Boston Edison Co.	Pilgrim 1 (Plymouth, Mass.)	670	678	{664} {670}	690	670	655	12/72
Northeast Utilities	Millstone 1 (Waterford, Conn.)	650	662	678	677	654	660	03/71
Central Jersey P&L Co.	Oyster Creek 1 (Toms River, N.J.)	688	650	{560} {650}	670	620	650	12/69
Nebraska Public Power District	Cooper (Brownville, Neb.)	836	836	{730} {764}	787	764	778	07/01/74
Georgia Power Company	Edwin I. Hatch 1 (Baxley, Ga.)		850		730	700	786	12/31/75
Commonwealth Edison Company	Dresden 2 (Morris, Ill.)	810	828	{809} {840}	812	772	794	06/09/72
	Dresden 3 (Morris, Ill.)	810	824	{838} {840}	811	773	794	11/16/71
Commonwealth Edison Co. and Iowa-Illinois Gas & Electric Co.	Quad-Cities 1 (Cordova, Ill.)	810	828	832	813	769	789	02/18/73
	Quad-Cities 2 (Cordova, Ill.)	810	828	832	813	769	789	03/10/73
Carolina Power & Light Co.	Brunswick 2 (Southport, N.C.)	849	867	90	815	790	821	11/03/75
Niagara Mohawk Power Corp., and Power Authority of the State of New York	James A. FitzPatrick (Scriba, N.Y.)		883		792	800	821	07/28/75
Philadelphia Electric Co.	Peach Bottom 2 (Peach Bottom, Pa.)	1098	1152	{1051} {1056}	1098	1051	1065	01/05/74
	Peach Bottom 3 (Peach Bottom, Pa.)	1098	1152	1035	1098	1035	1065	12/23/74
Tennessee Valley Authority	Browns Ferry 1 (Decatur, Ala.)	1152	1152	{1098} {1116}	1098	1065	1065	08/01/74
	Browns Ferry 2 (Decatur, Ala.)	1152	1152	1098	1098	1065	1065	03/01/75

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.1 Introduction (Continued)

Data used to compile average values and ranges of capacity factor (CF) and operating availability (OA), and equivalent availability (EA) were those provided by the Federal Energy Administration from the EEI data system. Table 4.2 lists the number of units for which data were available for each of the study years 1971, 1972, 1973, 1974 and 1975 for annual capacity factor, annual operating availability and annual equivalent availability computations.

The Federal Power Commission's (FPC) "Steam Electric Plant Construction Cost and Annual Production Expenses" Supplements for 1971, 1972, 1973 and 1974 provided the study with historical heat rate data. Table 4.3 lists the number of units comprising the heat rate data base for each of the years 1971, 1972, 1973 and 1974. 1975 data were not available.

Table 4.4 shows the eight size ranges considered in the evaluation of the four indices. These ranges were selected in an attempt to better match units of equivalent size and age. The FEA nameplate rating (EEI data) was used as the basis for grouping power plants into these eight size classifications.

The historical data were analyzed to determine averages and ranges of all four indices as follows:

1. Average values for all nuclear power plants
2. Average values by discrete size classification
3. Average values by plant age
4. Average values for distinct design types (PWR vs. BWR)

The averages were computed for each of the years 1971, 1972, 1973, 1974 and 1975; an average for the period 1971-1975 was also computed. Ranges were established based on the ranges of the averages for the year or period considered. No statistical schemes were used and no attempts of weighing estimates have been performed.

Nuclear units have been operated at an average capacity factor of 59.1%, an average equivalent availability of 64.8% and an average operating availability of 70.0% during the five-year period 1971-1975. The average net heat rate of nuclear units in operation during 1971 through 1974 and on which data was available, was 11209 Btu/Kwh. The data used to develop these figures includes units of different size, design, age, vintage and utilization.

Table 4.2

NUCLEAR STEAM ELECTRIC POWER UNITS		
Year	Number of Units [†]	
	U.S.	California
1971	11	2
1972	11	1
1973	21	2
1974	43	2
1975	48	3

[†] SDC analysis of EEI data supplied by FEA

Table 4.3

NUCLEAR STEAM ELECTRIC POWER UNITS		
Year	Number of Units [†]	
	U.S.	California
1971	13	1
1972	22	1
1973	29	1
1974	38	1

[†]Source: SDC Analysis of FPC "Cost and Annual Production Expenses Supplements"

Table 4.4

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size Range	Number of Units in Operation					
	Prior to 1971	1971	1972	1973	1974	1975
Less than 400 MW	6	0	0	0	0	0
400 to 499 MW	3	0	0	0	0	0
500 to 599 MW	1	1	2	1	2	1
600 to 699 MW	3	1	1	0	0	0
700 to 799 MW	0	1	1	1	0	0
800 to 899 MW	0	2	3	4	4	5
900 to 999 MW	0	0	0	0	1	1
1000 MW & Greater	0	0	0	2	4	2
All Plants	13	5	7	8	11	9

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.1 Introduction (Continued)

As a group, the annual average capacity factor, equivalent availability and operating availability have generally declined over the five-year study period (1971-1975). The annual average net heat rate has increased from 10897 Btu/Kwh to 11306 Btu/Kwh.

In general, the value of each reliability and efficiency index has reduced with increasing nuclear unit size. This apparent conclusion may be erroneous as the data used to develop the charts includes units of different design, age, vintage and utilization. Further detailed analysis, beyond the scope of this effort, is required to support or nullify this apparent conclusion.

The index values achieved by each size range reflect the unit design maturity, vintage, unit operational maturity (age) and utility experience. The large units, 900 MW and above, are generally exhibiting increasing values but have yet to achieve the high averages obtained by the smaller units. This is primarily due to the limited operational experience of these large units when compared with industry experience in designing, operating and maintaining the smaller units. The effects of the ever increasing regulations and environmental restrictions on the indices could not be assessed with certainty as the available historical data did not distinguish between possible effects.

The nuclear units projected for siting and startup in California are all greater than 600 MW in capacity. The analysis of 600 MW-and-above unit data shows that, in general, two years of operation are required before the first five-year average index value can be achieved or exceeded. Both Pressurized Water Reactor (PWR) units and Boiling Water Reactor (BWR) units are proposed for siting in California. Analysis of the historical data shows that the five-year average capacity factor, equivalent availability and operating availability of Pressurized Water Reactor units is significantly higher than that of Boiling Water Reactor units. The all time high values of each index, however, are very close for both PWR's and BWR's. The PWR unit average net heat rate, on the other hand, is significantly higher than that of BWR units (11,394 Btu/Kwh vs. 10973 Btu/Kwh).

Table 4.5

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.				
Period	Number of Unit-Years	Average Capacity Factor (%) [†]	Average Equivalent Availability (%) [†]	Average Operating Availability (%) [†]
1971	11	58.1	66.2	73.9
1972	11	61.6	66.1	72.7
1973	21	59.7	69.8	74.6
1974	43	55.9	62.6	66.2
1975	48	61.4	63.9	70.7
1971-1975	134	59.1	64.8	70.0
NOTE: The data used to develop chart includes units of different design, size, vintage, utilization, etc. [†] Source: SDC analysis of EEI data supplied by FEA				

Table 4.6

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.				
Size Range	Number of Unit-Years	Average [†] Capacity Factor (%) ^{††}	Average [†] Equivalent Availability (%) ^{††}	Average [†] Operating Availability (%) ^{††}
Less than 400 MW	23	57.7	60.9	70.7
400 to 499 MW	12	71.8	79.3	80.2
500 to 599 MW	21	59.7	73.4	75.6
600 to 699 MW	15	67.0	69.9	75.3
700 to 799 MW	9	67.5	69.6	73.3
800 to 899 MW	38	54.9	59.2	66.0
900 to 999 MW	3	53.1	66.3	68.9
1000 MW & Greater	13	47.7	50.9	58.4
NOTE: The data used to develop chart includes units of different design, age, vintage, utilization, etc. [†] Average over the five-year period 1971-1975 ^{††} Source: SDC analysis of EEI data supplied by FEA				

Table 4.7

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.								
Size Range	Number of Units				Average Heat Rate (Net)			
	1971	1972	1973	1974	1971	1972	1973	1974
Less than 400 MW	4	4	4	4	11239	11390	12359	11523
400 - 499 MW	2	2	3	3	10517	10641	10944	10832
500 - 599 MW	1	3	3	4	10452	11168	11101	10972
600 - 699 MW	4	5	5	5	10661	10498	10647	10607
700 - 799 MW	1	2	3	3	11099	12851	11205	10988
800 - 899 MW	1	6	9	13	11474	11082	10699	11843
900 - 999 MW	-	-	-	1	-	-	-	10376
1000 MW & Greater	-	-	2	5	-	-	14146	11593
All Units	13	22	29	38	10897	11138	11276	11306
[†] SDC analysis of FPC data NOTE: The data used to develop chart includes units of difference design, age, vintage, utilization, etc.								

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.2 Plant Capacity Factor

Nuclear power plants have operated at a national average capacity factor of 59.1% during the period 1971-1975 (see Table 4.8). This includes all nuclear plants in operation in the U.S. and for which data exists in the FEA data base for the 1971-1975 period. A 134 unit-year sample is the basis of this national average of 59.1%.

Nuclear plants in California have operated at an average capacity factor of 70.4% during the same 1971-1975 period. This figure includes the three nuclear plants in operation in the state. Data were not, however, complete for plants for all five years in the FEA data base. This five year average capacity factor is based on a 10 unit-years sample (see Table 4.9). The five year average capacity factor of nuclear plants in the state of California is much higher than the average of all the nuclear plants in the U.S.

Average annual capacity factors for all nuclear plants in the U.S. and the State of California have varied from year to year. The maximum range of variation of average annual capacity factors for all U.S. nuclear plants is 5.7% while that for California plants is 18.1%.

Annual average capacity factors of nuclear plants in California have, in general, steadily declined over the years. As shown in Table 4.10 the five year average of 70.4% is influenced (reduced) by the low average capacity factor of later years. This apparent trend is based upon three power plants only, two of which have had operational problems in their first few years of commercial operation. Nuclear plants, on a national basis, do not exhibit this trend.

The average annual capacity factor for U.S. nuclear plants is, generally, inversely proportional to the plant size. Table 4.3 presents the average capacity factors for each MW size range for the period 1971 through 1975. The highest average of 71.8% was achieved by the 400-499 MW group. The lowest averages are those of the 800 MW and higher size ranges. However, as shown in Table 4.4 the larger size plants have been in commercial operation for a larger period of time. This trend of capacity factors varying with size could be influenced by the fact that plants are being compared that are of significantly different operational maturity (age), have operated under less stringent regulations, etc. Thus, projections made from the computed averages must be considered of, amongst other factors, design and age differences.

Table 4.8

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	11	58.1
1972	11	61.6
1973	21	59.7
1974	43	55.9
1975	48	61.4
71-75	134	59.1

[†]Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 4.9

NUCLEAR STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	2	76.5
1972	1	78.5
1973	2	70.15
1974	2	75.4
1975	3	60.42
71-75	10	70.4

[†]Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 4.10

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years	Average [†] Capacity Factor (%) ^{††}
Less than 40	23	57.7
400 to 499 MW	12	71.8
500 to 599 MW	21	59.7
600 to 699 MW	15	67.0
700 to 799 MW	9	67.5
800 to 899 MW	38	54.9
900 to 999 MW	3	53.1
1000 MW & Greater	13	47.7

[†] Average over the five year period 1971-1975

^{††}Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.11

NUCLEAR STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size Range	Number of Unit-Years	Average [†] Capacity Factor (%) ^{††}
Less than 400 MW	4	68.6
400 to 499 MW	5	80.78
500 to 599 MW	~	~
600 to 699 MW	~	~
700 to 799 MW	~	~
800 to 899 MW	~	~
900 to 999 MW	1	25.06
1000 MW & Greater	~	~

[†] Average over the five year period 1971-1975

^{††}Source: SDC analysis of FEA and California Utility data

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.12

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 600 MW and Greater		
Period	Number of Unit Years	Average Capacity Factor (%) [†]
1971	4	72.1
1972	5	65.6
1973	10	61.1
1974	27	54.9
1975	32	57.5
71-75	78	58.3

[†]Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.2 Plant Capacity Factor (Continued)

Nuclear plants in the State of California also show average capacity factors inversely proportional to size. But, the number of plants in the data base is severely limited. Table 4.11 lists the average capacity factors for California's nuclear plants by each size range. Although only a single power plant is included in the 400-499 MW size range, it has achieved one of the highest annual average capacity factors of any nuclear plant in the U.S.

Annual average capacity factors in all the size ranges have changed during the 1971-1975 period as shown in Tables 4.13 through 4.20. The tables present data for all plants in the U.S. Similar tables for plants in California would be based, for most years, on a single plant's yearly operation. As this California data may not be at all representative of the nuclear industry, or the specific requirements of the State of California, the California data has not been presented separately.

The highest annual average capacity factor (83.6% in 1971) is recorded for the 400-499 MW size range (Table 4.14). The lowest annual average capacity factor (35.5% in 1972) is recorded for the 500-599 MW size range (Table 4.15). Except for isolated instances, the annual average capacity factors, as shown by these tables are predominantly less than 70%.

The nuclear power plants proposed for California are all large units. Table 4.12 lists the historical performance of the large units. As an average, over the five year period, this table shows power plants of 600 MW-and-above to be approximately 2% lower in capacity factor than all nuclear units as a group.

Table 4.13

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: Less than 400 MW		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	4	53.8
1972	4	58.8
1973	4	57.2
1974	6	56.5
1975	5	61.5
71-75	23	57.7

[†]SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.14

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 400 to 499 MW		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	2	83.6
1972	1	78.5
1973	3	67.0
1974	3	63.3
1975	3	71.9
71-75	12	71.8

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.15

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 500 to 599 MW		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	1	39.7
1972	1	35.5
1973	4	53.5
1974	7	54.3
1975	8	73.1
71-75	21	59.7

[†]Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.16

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 600 to 699 MW		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	2	67.5
1972	2	80.8
1973	2	70.1
1974	4	63.3
1975	5	63.0
71-75	15	67.0

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.17

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 700 to 799 MW		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	1	41.6
1972	1	82.1
1973	1	65.0
1974	3	69.8
1975	3	69.9
71-75	9	67.5

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.18

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 800 to 899 MW		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	1	39.6
1972	2	42.2
1973	7	57.9
1974	13	51.1
1975	15	59.4
71-75	38	54.9

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.19

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 900 to 999 MW		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	---	---
1972	---	---
1973	---	---
1974	1	68.0
1975	2	43.7
1971-1975	3	53.1

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.20

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 1000 MW and greater		
Period	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	---	---
1972	---	---
1973	---	---
1974	6	48.2
1975	7	47.3
1971-1975	13	47.7

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.2 Plant Capacity Factor (Continued)

Capacity Factors For Alternate Nuclear Plant Designs

Capacity factors of nuclear plants can be compared by distinguishing between Pressurized Water Reactors (PWR's) and Boiling Water Reactors (BWR's). As shown in Table 4.21 the five year average capacity factor of Pressurized Water Reactor plants is significantly higher than that of Boiling Water Reactor plants. (61.0% vs. 56.7%).

The annual average capacity factors of both PWR's and BWR's have changed over the years but the trend of the change is significantly different. During the five year period 1971-1975, PWR's exhibited a reduction in annual average capacity factor followed by an increase. BWR's, however, exhibit an increase followed by a reduction in annual average capacity factor. Based upon the limited data of Table 4.21 it may not be valid to conclude that Pressurized Water Reactor plants will exhibit, after 1975, increasing capacity factors while Boiling Water Reactor plants will exhibit reducing capacity factors.

The all time high annual average capacity factor for both PWR's and BWR's is the same (≈70%). The PWR average, based upon a higher number of unit-year data (27 vs. 5), may be considered more representative of the capacity factors PWR plants can achieve.

Tables 4.21 through 4.31 list the annual average capacity factors and the five year average capacity factor of Pressurized Water Reactor plants and Boiling Water Reactor plants in the U.S. The highest annual average capacity factor (80.8% in 1972) is recorded for the 600-699 MW size classification.

Pressurized Water Reactors, 1000 MW-and-larger, registered the lowest annual average capacity factor of 32.7% in 1974. The lowest annual average capacity factor of Boiling Water Reactor plants was 34.2% recorded in 1975, for plants greater than 1000 MW.

The highest five-year-average capacity factor of 86.1% was achieved by 600-699 MW Pressurized Water Reactor plants. For Boiling Water Reactor plants the

Table 4.21

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: All sizes						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
1971	5	60.5	6	56.0	11	58.0
1972	6	55.0	5	69.5	11	61.6
1973	10	55.1	11	64.0	21	59.7
1974	26	55.6	17	56.3	43	55.9
1975	27	70.0	21	50.4	48	61.4
71-75	74	61.0	60	56.7	134	59.1
† Source: SDC analysis of EEI data supplied by FEA						
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.						

Table 4.22

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Less Than 400 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
1971	1	54.0	3	53.8	4	53.8
1972	2	48.4	2	69.2	4	58.8
1973	—	—	4	57.2	4	57.2
1974	2	58.8	4	55.3	6	56.5
1975	1	82.0	4	56.4	5	61.5
71-75	6	58.4	17	57.4	23	57.7
† Source: SDC analysis of EEI data supplied by FEA						
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.2 Plant Capacity Factor (Continued)

Capacity Factors For Alternate Nuclear Plant Designs (Continued)

highest five year average capacity factor was 64.4% for 500-599 MW size plants. The 600-699 MW Boiling Water Reactor plants achieved a five-year-average capacity factor of 64.1%

To summarize, PWR's have historically attained higher average capacity factors than BWR's. The most highly utilized plants are those in the 600-699 MW capacity classification. Historically, the least utilized plants are those greater than 999 MW.

The nuclear plants proposed for California are all greater than 600 MW. Table 4.30 was prepared to present the historical annual average capacity factors and the five year annual average capacity factor of plants greater than 600 MW. Also, in this size class, Pressurized Water Reactor plants have achieved higher five year average capacity factors than have Boiling Water Reactor plants.

Table 4.23

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 400 to 499 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
1971	2	83.6	—	—	2	83.6
1972	1	78.5	—	—	1	78.5
1973	3	67.0	—	—	3	67.0
1974	3	66.3	—	—	3	66.3
1975	3	71.9	—	—	3	71.9
71-75	12	71.8	—	—	12	71.8
† Source: SDC analysis of EEI data supplied by FEA						
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Table 4.24

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 500 to 599 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
1971	1	39.7	—	—	1	39.7
1972	1	35.5	—	—	1	35.5
1973	3	49.0	1	67.2	4	53.5
1974	5	52.0	2	60.0	7	54.3
1975	5	77.1	3	66.5	8	73.1
71-75	15	57.8	6	64.4	21	59.7

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.25

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 600 to 699 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
1971	—	—	2	67.5	2	67.5
1972	—	—	2	80.8	2	80.8
1973	—	—	2	70.0	2	70.0
1974	1	88.4	3	55.0	4	63.3
1975	1	83.8	4	57.8	5	63.0
71-75	2	86.1	13	64.1	15	67.0

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.26

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 700 to 799 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
1971	1	41.6	—	—	1	41.6
1972	1	82.1	—	—	1	82.1
1973	1	65.0	—	—	1	65.0
1974	3	69.8	—	—	3	69.8
1975	3	69.9	—	—	3	69.9
71-75	9	67.5	—	—	9	67.5

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.27

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 800 to 899 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor † (%)	Number of Unit Years	Average Capacity Factor † (%)	Number of Unit Years	Average Capacity Factor † (%)
1971	—	—	1	39.6	1	39.6
1972	1	37.0	1	47.4	2	42.2
1973	3	45.9	4	67.0	7	57.9
1974	8	50.6	5	51.9	13	51.1
1975	9	49.6	6	44.1	15	50.4
71-75	21	57.4	17	51.8	38	54.9

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.28

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 900 to 999 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor † (%)	Number of Unit Years	Average Capacity Factor † (%)	Number of Unit Years	Average Capacity Factor † (%)
1971	—	—	—	—	—	—
1972	—	—	—	—	—	—
1973	—	—	—	—	—	—
1974	1	68.0	—	—	1	68.0
1975	2	45.7	—	—	2	45.7
71-75	3	53.1	—	—	3	53.1

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.29

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 1000 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
1971	—	—	—	—	—	—
1972	—	—	—	—	—	—
1973	—	—	—	—	—	—
1974	3	32.7	3	63.7	6	48.2
1975	3	64.7	4	34.2	7	47.3
71-75	6	48.7	7	46.9	13	47.7

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.30

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 600 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
1971	1	41.6	3	58.3	4	54.1
1972	2	59.5	3	69.7	5	65.6
1973	4	50.6	6	68.0	10	61.1
1974	16	54.3	11	55.9	27	55.0
1975	18	67.0	14	45.2	32	57.5
71-75	41	59.5	37	55.2	78	57.4

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.2 Plant Capacity Factor (Continued)

OPERATIONAL MATURITY (AGE)

Tables 4.31 - 4.38 list annual average capacity factors of each of the first five years of operation of different sizes of nuclear plants. Plants greater than 400 MW exhibit an increase in average annual capacity factor with age. Table 4.32 lists the annual average for PWR plants only, BWR plants only, and all nuclear plants (PWR's + BWR's). The annual average capacity factor of all nuclear plants has steadily improved from 51.6% in the first year of operation to 66.5% in the fifth year. This increasing trend for all nuclear plants, is mirrored by both BWR's, and PWR's. While the first year average capacity factor of PWR's is about ten percentage points lower than that of BWR's, the PWR plants exhibit greater capacity factors for later years of commercial operation.

The first year average capacity factors of all plants (BWR's + PWR's) vary from a low of 41.9% (plants greater than 1000 MW) to a high of 65.1% (600-699 MW plants). Pressurized water reactor plants exhibit a first-year-average capacity factor range from 48.7% to 73.5%. Boiling Water Reactor plants exhibit first year average capacity factor range from 48.7% to 73.5%.

The fifth-year-average capacity factor of all nuclear plants greater than 400 MW vary from a low of 42.5% to a high of 71.7%. Pressurized Water reactor plants exhibit a fifth-year-average capacity factor range from 66.2% to 71.7%. The range for boiling Water Reactor, is 42.5% to 71.7%.

Table 4.31

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 400 to 499 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
First	3	47.2	—	—	3	47.2
Second	3	68.3	—	—	3	68.3
Third	2	66.9	—	—	2	66.9
Fourth	2	93.1	—	—	2	93.1
Fifth	2	66.2	—	—	2	66.2
† Source: SDC analysis of EEI data supplied by FEA						
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.						

Table 4.32

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 400 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
First	26	47.5	17	57.9	43	51.6
Second	24	65.2	12	58.3	36	62.9
Third	10	64.9	7	53.7	17	60.3
Fourth	6	76.3	4	61.6	10	70.5
Fifth	4	68.3	3	61.6	7	66.5
† Source: SDC analysis of EEI data supplied by FEA						
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.						

Table 4.33

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 500 to 599 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
First	5	38.1	3	59.7	8	46.2
Second	5	57.9	2	72.6	7	62.1
Third	3	81.3	1	59.4	4	75.8
Fourth	1	75.6	—	—	1	75.6
Fifth	1	69.2	—	—	1	69.2

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.34

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 600 to 699 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
First	1	31.8	4	73.5	5	65.1
Second	1	72.1	2	75.2	3	74.2
Third	1	71.9	2	56.5	3	61.7
Fourth	1	69.6	3	65.9	4	66.8
Fifth	—	—	2	71.1	2	71.1

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.35

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 700 to 799 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
First	3	56.2	—	—	3	56.2
Second	3	73.4	—	—	3	73.4
Third	1	65.0	—	—	1	65.0
Fourth	1	82.6	—	—	1	82.6
Fifth	1	71.7	—	—	1	71.7

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.36

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 800 to 899 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
First	9	56.9	6	52.6	15	55.2
Second	8	64.4	5	54.1	13	60.5
Third	3	47.8	4	50.9	7	48.3
Fourth	1	44.0	1	48.8	2	46.4
Fifth	—	—	1	42.5	1	42.5

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.37

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 900 to 999 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
First	2	46.5	—	—	2	46.5
Second	1	66.4	—	—	1	66.4
Third	—	—	—	—	—	—
Fourth	—	—	—	—	—	—
Fifth	—	—	—	—	—	—

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.38

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 1000 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)	Number of Unit Years	Average Capacity Factor† (%)
First	3	32.7	4	48.7	7	41.9
Second	3	64.7	3	44.4	6	54.5
Third	—	—	—	—	—	—
Fourth	—	—	—	—	—	—
Fifth	—	—	—	—	—	—

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.3 Plant Operating Availability

Nuclear power plants have operated at a national average operating availability of 70.0% during the period 1971-1975 (see Table 4.39). This includes all nuclear plants in operation in the U.S. and for which data exists in the FEA data base for the 1971-1975 period. A 134 unit-year sample was the basis of the national average of 70.0%.

Nuclear plants in California have operated at an average operating availability of 77.3% during the same 1971-1975 period. This figure includes the three nuclear plants in operation in the State. Data were not completely available, however, on all these plants, for all five years, in the FEA data base. This five-year-average operating availability was based on a 10 unit-year sample (see Table 4.40). The five-year-average operating availability for nuclear plants in the State of California is much higher than the average of all the nuclear plants in the U.S.

Average annual operating availability for all the nuclear plants in the U.S. and the State of California have varied from year to year. The maximum range of variation of average annual operating availability for all the U.S. nuclear plants is 8.5% while that for California plants is 17%.

Annual average operating availability for the nuclear plants in California have, in general, steadily declined over the years. As shown in Table 4.40, the five-year-average of 77.3% is influenced (reduced) by the low average operating availability of later years. This apparent trend is based upon three power plants only, two of which have had major operational problems during their first few years of commercial operation. National nuclear plant averages do not exhibit this trend.

The average annual operating availability is, generally, inversely proportional to the plant size. Table 4.41 presents the average operating availability for each size range for the period 1971 through 1975. The highest average of 80.2% was achieved by the 400-499 MW group. The lowest averages are those of the 1000 MW and greater size ranges. However, as shown in Table 4.4 the larger size

Table 4.39

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	11	73.9
1972	11	72.7
1973	21	74.6
1974	43	66.2
1975	48	70.7
1971-1975	134	70.0

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 4.40

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	2	84.5
1972	1	78.9
1973	2	76.0
1974	2	84.9
1975	3	67.9
1971-1975	10	77.3

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 4.41

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years	Average Operating Availability (%) ^{††}
Less than 400 MW	23	70.7
400 to 499 MW	12	80.2
500 to 599 MW	21	75.6
600 to 699 MW	15	75.3
700 to 799 MW	9	73.3
800 to 899 MW	38	66.0
900 to 999 MW	3	68.9
1000 MW & Greater	13	58.4

[†] Average over the five year period 1971-1975
^{††} Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.42

NUCLEAR STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size Range	Number of Unit Years	Average Operating Availability (%) ^{††}
Less than 400 MW	4	83.1
400 to 499 MW	5	81.72
500 to 599 MW	-	-
600 to 699 MW	-	-
700 to 799 MW	-	-
800 to 899 MW	-	-
900 to 999 MW	1	32.2
1000 MW & Greater	-	-

[†] Average over the five year period 1971-1975
^{††} Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.43

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 600 MW & Above		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	4	65.1
1972	5	74.3
1973	10	72.03
1974	27	64.9
1975	32	67.4
1971 - 1975	78	78.0

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.3 Plant Operating Availability (Continued)

plants have been in commercial operation for the shortest period of time while the smaller plants have been in commercial operation for a longer period of time. This trend of average operating availability varying with size may be influenced by the fact that plants are being compared that are of different operational maturity (age), have operated under less stringent regulations, etc. Thus, projections made using these computed averages must be sensitive to such differences.

Nuclear plants in the State of California also show average operating availability values inversely proportional to size. But the number of plants in the data base is severely limited. Table 4.42 lists the average operating availability for California's nuclear plants by the eight size ranges. Although only a single power plant is included in the 400-499 MW size range it has achieved one of the highest annual average operating availability values of any nuclear plant in the U.S.

Annual average operating availability in all the size ranges have changed during the 1971-1975 period as shown in Tables 4.44 - 5.51. The Tables present data for all plants in the U.S. Similar Tables for plants in California would be based, for most years, on a single plant's yearly operation. As the California data may not be at all representative of the nuclear industry or the specific requirements of the State of California, these data have not been presented separately.

The highest annual average operating availability (98.4% in 1971) is recorded for the 900-999 MW size range (Table 4.50). The lowest annual average operating availability (46.7% in 1971) is recorded for the 700-799 MW size range (Table 4.48). Except in isolated instances, the annual average capacity factor, as shown by the Tables are predominately greater than 70%.

The nuclear power plants proposed for California are all large units. Table 4.43 lists the performance of 600 MW-and-above units. The table shows power plants of 600 MW and above to have higher five-year-average operating availability (78.0%) than all nuclear plants which, as a group, have a five-year-average operating availability of 70.0%.

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: Less than 400 MW		
Period	Number of Unit Years	Average Operating Availability (%) [†]
1971	4	74.0
1972	4	69.2
1973	4	74.2
1974	6	63.9
1975	5	70.5
71-75	23	70.7

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.46

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 500 - 599 MW		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	1	87.9
1972	1	72.3
1973	4	76.3
1974	7	67.2
1975	8	81.6
71-75	21	75.6

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.48

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 700 - 799 MW		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	1	46.7
1972	1	85.2
1973	1	75.2
1974	3	76.7
1975	3	74.2
71-75	9	73.3

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The Data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.50

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 900 - 999 MW		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	-	-
1972	-	-
1973	-	-
1974	1	98.4
1975	2	54.2
1971-1975	3	68.9

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 400-499 MW		
Period	Number of Unit Years	Average Operating Availability (%) [†]
1971	2	84.6
1972	1	78.9
1973	3	81.6
1974	3	79.2
1975	3	77.1
71-75	12	80.2

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.47

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 600 - 699 MW		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	2	74.2
1972	2	84.7
1973	2	79.9
1974	4	67.8
1975	5	76.1
71-75	15	75.3

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.49

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 800 - 899 MW		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	1	65.0
1972	2	58.4
1973	7	69.3
1974	13	60.2
1975	15	70.6
71-75	38	66.0

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.51

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 1000 MW & Above		
Period	Number of Unit-Years	Average Operating Availability (%) [†]
1971	-	-
1972	-	-
1973	-	-
1974	6	62.1
1975	7	55.3
1971-1975	13	58.4

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.3 Plant Operating Availability (Continued)

Operating Availability of Alternate Nuclear Plant Designs

Operating availability of nuclear plants can be compared by distinguishing between Pressured Water Reactors (PWR's) and Boiling Water Reactors (BWR's). As shown in Table 4.52, the five-year-average operating availability of Pressurized Water Reactor plants is about the same as that of Boiling Water Reactor plants. (69.7% vs. 70.3%).

The annual average operating availability of both PWR's and BWR's have changed over the years, but the trend of the change is significantly different. During the five-year period 1971-1975, PWR's showed first a reduction in annual average operating availability followed by an increase. The BWR's, on the other hand show an increase followed by a reduction in annual average operating availability. Based upon the limited data of Table 4.52 it may not be valid to conclude that Pressurized Water Reactor plants will exhibit, after 1975, increasing operating availabilities while Boiling Water Reactor plants will exhibit reducing operating availabilities.

The all time high annual average operating availability of Boiling Water Reactor plants is 78.7% while that of Pressurized Water Reactor plants is 75.5%.

Tables 4.53 through 4.61 list the annual average operating availabilities and the five-year-average operating availabilities of Pressurized Water Reactor plants and Boiling Water Reactor plants in the U.S. The highest annual average operating availability (90.4% in 1974) is recorded for Pressurized Water Reactor plants of 900-999 MW size. The highest annual average operating availability for Boiling Water Reactors (84.7% in 1972) is recorded for the 600-699 MW size classification.

Pressurized Water reactors, 1000 MW-and-larger, registered the lowest annual average operating availability of 48.7% in 1972. The lowest annual average operating availability of Boiling Water Reactor plants was 42.5% recorded in 1974 also for plants greater-than-1000 MW.

The highest five-year-average operating availability of 88.7% was achieved by 600-699 MW Pressurized Water Reactor plants. For Boiling Water Reactor plants the highest five year average operating availability was 78.7% for 500-599 MW

Table 4.52

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: All sizes						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
1971	5	74.4	6	73.5	11	73.9
1972	6	68.7	5	77.4	11	72.7
1973	10	70.2	11	78.7	21	74.6
1974	26	64.4	17	68.9	43	66.2
1975	27	75.5	21	64.6	48	70.7
71-75	74	69.7	60	70.3	134	70.0

† Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 4.53

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Less Than 400 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
1971	1	68.3	3	75.9	4	74.0
1972	2	59.4	2	78.9	4	69.2
1973	—	—	4	74.2	4	74.2
1974	2	66.6	4	67.6	6	64.0
1975	1	82.4	4	67.5	5	70.5
71-75	6	67.1	17	72.0	23	70.7

† Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.54

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 400 to 499 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
1971	2	84.6	—	—	2	84.6
1972	1	78.9	—	—	1	78.9
1973	3	81.6	—	—	3	81.6
1974	3	79.2	—	—	3	79.2
1975	3	77.1	—	—	3	77.1
71-75	12	80.2	—	—	12	80.2

† Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.3 Plant Operating Availability (Continued)

size plants. The 600-699 MW Boiling Water Reactor plants recorded a five-year-average operating availability of 73.3%.

To summarize, PWR's have historically attained higher average operating availability values than BWR's. The most highly available plants are those in the 600-699 MW capacity classification. Historically, the least utilized plants are those greater than 999 MW.

As the nuclear plants proposed for California are all greater than 600 MW, Table 4.61 was prepared to present the historical annual average operating availability and the five-year annual average of plants greater than 600 MW. Pressurized Water Reactor plants have achieved slightly lower five-year-average operating availability values than have Boiling Water Reactor plants.

Table 4.55

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 500 to 599 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
1971	1	87.9	—	—	1	87.9
1972	1	72.3	—	—	1	72.3
1973	3	73.9	1	83.8	4	76.3
1974	5	64.3	2	74.5	7	67.2
1975	5	82.6	3	79.8	8	81.6
71-75	15	74.4	6	78.7	21	75.6
† Source: SDC analysis of EEI data supplied by FEA						
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Table 4.56

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 600 to 699 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
1971	—	—	2	74.2	2	74.2
1972	—	—	2	84.7	2	84.7
1973	—	—	2	79.9	2	79.9
1974	1	91.2	3	60.0	4	67.8
1975	1	86.1	4	73.6	5	76.1
71-75	2	88.65	13	73.3	15	75.3

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.57

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 700 to 799 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
1971	1	46.7	—	—	1	46.7
1972	1	85.2	—	—	1	85.2
1973	1	75.2	—	—	1	75.2
1974	3	76.7	—	—	3	76.7
1975	3	74.2	—	—	3	74.2
71-75	9	73.3	—	—	9	73.3

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.58

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 800 to 899 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%)†	Number of Unit Years	Average Operating Availability (%)†	Number of Unit Years	Average Operating Availability (%)†
1971	—	—	1	65.0	1	65.0
1972	1	57.0	1	59.8	2	58.4
1973	3	53.4	4	81.3	7	69.3
1974	8	54.7	5	69.0	13	60.2
1975	9	75.2	6	63.7	15	70.6
71-75	21	63.4	17	69.2	38	66.0

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.59

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 900 to 999 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%)†	Number of Unit Years	Average Operating Availability (%)†	Number of Unit Years	Average Operating Availability (%)†
1971	—	—	—	—	—	—
1972	—	—	—	—	—	—
1973	—	—	—	—	—	—
1974	1	98.4	—	—	1	98.4
1975	2	54.2	—	—	2	54.2
71-75	3	68.9	—	—	3	68.9

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.60

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 1000 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) [†]	Number of Unit Years	Average Operating Availability (%) [†]	Number of Unit Years	Average Operating Availability (%) [†]
1971	—	—	—	—	—	—
1972	—	—	—	—	—	—
1973	—	—	—	—	—	—
1974	3	48.7	3	75.4	6	62.1
1975	3	72.3	4	42.5	7	55.3
71-75	6	60.5	7	56.6	13	58.4

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.61

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 600 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) [†]	Number of Unit Years	Average Operating Availability (%) [†]	Number of Unit Years	Average Operating Availability (%) [†]
1971	1	46.7	3	71.2	4	65.0
1972	2	71.1	3	76.4	5	74.3
1973	4	58.8	6	80.8	10	72.0
1974	16	62.7	11	68.3	27	65.0
1975	18	72.8	14	60.5	32	67.4
71-75	41	66.8	37	68.3	78	67.5

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.3. Plant Operating Availability (Continued)

Operational Maturity (Age)

Tables 4.62 - 4.69 list annual average operating availability values for each of the first five years of operation of different sizes of nuclear plants. Plants great than 400 MW exhibit an increase in average annual operating availability with age. Table 4.62 lists the annual average operating availability of PWR plants only, BWR plants only, and all nuclear plants (BWR's + PWR's). The annual average operating availability of all nuclear plants greater than 400 MW has steadily improved from 67.3% in the first year to 79.4 % in the fourth year. The trend of increasing average annual operating availability with age is mirrored by Pressurized Water Reactor plants. The first-year-average operating availability of 64.2% for PWR's increase to 84.5% from the fourth year. Boiling Water Reactor plants greater than 400 MW, on the other hand show a small decreasing trend of average annual operating availability with age.

The first-year-average operating availability of all plants (BWR's + PWR's) greater than 400 MW vary from a low of 54.0% (1000 MW and greater plants) to a high of 78.9% (400-499 MW size plants). Pressurized Water Reactor plants exhibit a first year average operating availability varying from 41.6% (600-699 MW plants) to 78.9% (400-499 MW plants). First-year-annual average operating availability values for Boiling Water Plants range from 29.1% (500-599 MW plants) to 81.8% (600-699 MW size plants.)

The fifth-year-average operating availability of all nuclear plants greater than 400 MW, varies from a low of 55.1% for 800-899 MW plants to 77.2% for 400-499 MW plants. The corresponding ranges in annual average operating availability of Pressurized Water Reactor plants and Boiling Water Reactor plants are 72.7% to 77.2% and 55.1% to 73.8%, respectively.

Table 4.62

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 400 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%)†	Number of Unit Years	Average Operating Availability (%)†	Number of Unit Years	Average Operating Availability (%)†
First	26	64.2	17	72.1	43	67.3
Second	24	73.1	12	70.3	36	72.1
Third	10	71.5	7	66.8	17	69.6
Fourth	6	84.5	4	71.8	10	79.4
Fifth	4	74.8	3	67.6	7	71.7
† Source: SDC analysis of EEI data supplied by FEA						
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.						

Table 4.63

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 400 to 499 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%)†	Number of Unit Years	Average Operating Availability (%)†	Number of Unit Years	Average Operating Availability (%)†
First	3	78.9	—	—	3	78.9
Second	3	80.3	—	—	3	80.3
Third	2	75.2	—	—	2	75.2
Fourth	2	94.2	—	—	2	94.2
Fifth	2	77.2	—	—	2	77.2
† Source: SDC analysis of EEI data supplied by FEA						
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.						

Table 4.64

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 500 to 599 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
First	5	69.3	3	29.1	8	73.0
Second	5	71.6	2	81.3	7	74.4
Third	3	86.2	1	72.2	4	82.7
Fourth	1	81.4	—	—	1	81.4
Fifth	1	72.2	—	—	1	72.2

† Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.65

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 600 to 699 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
First	1	41.6	4	81.8	5	73.8
Second	1	76.8	2	81.8	3	80.1
Third	1	87.3	2	59.8	3	69.0
Fourth	1	89.5	3	74.4	4	78.1
Fifth	—	—	2	73.8	2	73.8

† Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.66

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 700 to 799 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
First	3	64.5	—	—	3	64.5
Second	3	78.4	—	—	3	78.4
Third	1	75.2	—	—	1	75.2
Fourth	1	83.3	—	—	1	83.3
Fifth	1	72.7	—	—	1	72.7

† Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.67

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 800 to 899 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
First	9	63.6	6	71.4	15	66.7
Second	8	68.8	5	70.6	13	69.5
Third	3	47.9	4	69.0	7	59.9
Fourth	1	64.5	1	64.1	2	64.3
Fifth	—	—	1	55.1	1	55.1

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.68

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S..						
Size: 900 to 999 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%)	Number of Unit Years	Average Operating Availability (%)	Number of Unit Years	Average Operating Availability (%)
First	2	65.8	—	—	2	65.8
Second	1	76.1	—	—	1	76.1
Third	—	—	—	—	—	—
Fourth	—	—	—	—	—	—
Fifth	—	—	—	—	—	—

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.69

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S..						
Size: Greater Than 1000 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †	Number of Unit Years	Average Operating Availability (%) †
First	3	48.7	4	58.0	7	54.0
Second	3	72.3	3	54.7	6	63.5
Third	—	—	—	—	—	—
Fourth	—	—	—	—	—	—
Fifth	—	—	—	—	—	—

† Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.4 Plant Equivalent Availability

Nuclear power plants have operated at a national average equivalent availability of 64.8% during the period 1971-1975 (see Table 4.70). This includes all nuclear plants in operation in the U.S. and for which data were available in the FEA data base for the 1971-1975 period. A 134 unit-year sample was the basis of this national average of 64.8%.

Nuclear plants in California have operated at an average equivalent availability of 73.0% during the same 1971-1975 period. This figure includes the three nuclear plants in operation in the State. Data were not completely available on all these plants for all five years in the FEA data base. This five-year-average equivalent availability was based on a 10 unit-year sample (see Table 4.71). The five-year-average equivalent availability for nuclear plants in the State of California is much higher than the average equivalent availability of the nuclear plants in the U.S.

Average annual equivalent availability for all the nuclear plants in the U.S. and the State of California has varied from year to year. The maximum range of variation of average annual equivalent availability for all U.S. nuclear plants is 7.2% while that for California plants is 20.1%.

Annual average equivalent availability of nuclear plants in California has, in general, steadily declined over the years. As shown in Table 4.71, the five year average of 73.0% is influenced (reduced) by the low average equivalent availability of later years. For national nuclear plants this is not so.

For the nuclear plants in the U.S., the average annual equivalent availability is, generally, inversely proportional to the plant size. Table 4.72 presents the average capacity factors for each MW size range for the period 1971 through 1975. The highest average of 79.3% was achieved by the 400-499 MW group. The lowest national average was achieved by the 1000 MW-and-greater-size ranges. However, as shown in Table 4.4 the larger size plants have been in commercial operation for the shortest period of time, while the smaller plants have been in commercial operation for a longer time period. This trend of average equivalent availability varying with size may be influenced by the fact that comparisons are being performed of plants of different operational maturity (age), etc. Thus, projections made using the historical averages need to be considerate of these differences.

Table 4.70

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	11	66.2
1972	11	66.1
1973	21	69.8
1974	43	62.6
1975	48	63.9
71-75	134	64.8

[†] Source: SDC analysis of EEI data supplied by FEA
 Notes: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 4.71

NUCLEAR STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	2	81.2
1972	1	76.0*
1973	2	74.3
1974	2	79.8
1975	3	61.1
1971-1975	10	73.0

[†] Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different size age, design, utilization, vintage, etc.

Table 4.72

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years	Average [†] Equivalent Availability ^{††} (%)
Less than 400 MW	23	60.9
400 to 499 MW	12	79.3
500 to 599 MW	21	73.4
600 to 699 MW	15	69.9
700 to 799 MW	9	69.6
800 to 899 MW	38	59.2
900 to 999 MW	3	66.3
1000 MW & Greater	13	50.9

[†] Average over the five year period 1971-1975
^{††} Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.73

NUCLEAR STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size Range	Number of Unit-Years	Average [†] Equivalent Availability (%)
Less than 400 MW	4	76.7
400 to 499 MW	5	79.8*
500 to 599 MW	—	—
600 to 699 MW	—	—
700 to 799 MW	—	—
800 to 899 MW	—	—
900 to 999 MW	1	24.6*
1000 MW & Greater	—	—

[†] Average over the five year period 1971-1975
^{††} Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.74

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 600 MW and Greater		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	4	57.6
1972	5	67.9
1973	10	66.9
1974	27	60.9
1975	32	59.5
71-75	78	61.3

[†]Source: SDC analysis of EEI data supplied by FEA
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.4 Plant Equivalent Availability (Continued)

Nuclear plants in the State of California also show average equivalent availability inversely proportional to size. But the number of plants in the data base is severely limited. Table 4.73 lists the average equivalent availability for California's nuclear plants by size range. Although only a single power plant is included in the 400-499 MW size range it has achieved one of the highest annual average equivalent availability values of any nuclear plant in the U.S.

Annual average equivalent availability of plants in all the size ranges has changed during the 1971-1975 period as shown in Tables 4.75-4.82. The tables present data for all plants in the U.S. Similar tables for plants in California would be based, for most years, on a single plant's yearly operation. At the California data may not be at all representative of the nuclear industry or the specific requirements of the State of California, the California data have not been presented separately.

The highest annual average equivalent availability (98.4% in 1974) is recorded for the 900-999 MW size range (Table 4.81). The lowest annual average equivalent availability (43.4% in 1982) is recorded for the 800-899 MW size range (Table 4.80). Except for isolated instances, the annual average equivalent availability values, as shown by these tables, are predominantly greater than 55%.

The nuclear power plants proposed for California are all greater than 600 MW. Table 4.74 was prepared to examine the performance of the units. The table shows power plants of 600 MW and above to be on an average lower in equivalent availability than the smaller size plants.

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: Less than 400 MW		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	4	60.7
1972	4	59.9
1973	4	62.5
1974	6	59.4
1975	5	62.7
71-75	23	61.0

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.76

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 400 to 499 MW		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	2	83.4
1972	1	76.0*
1973	3	81.1
1974	3	78.6
1975	3	76.7
71-75	12	79.3

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.77

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 500 to 599 MW		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	1	87.9
1972	1	72.3
1973	4	76.3
1974	7	65.1
1975	8	77.6
71-75	21	73.4

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.78

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 600 to 699 MW		
Period	Number of Unit Years	Equivalent Availability [†] (%)
1971	2	73.5
1972	2	84.1
1973	2	69.4*
1974	4	65.8
1975	5	66.2
71-75	15	69.9*

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.79

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 700 to 799 MW		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	1	46.7
1972	1	84.5
1973	1	74.1
1974	3	73.5
1975	3	66.9*
71-75	9	69.6

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.30

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: 800 to 899 MW		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	1	36.8*
1972	2	43.4
1973	7	65.0
1974	13	55.8
1975	15	63.0
71-75	38	59.2

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.81

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size 900 to 999 MW		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	—	—
1972	—	—
1973	—	—
1974	1	98.4
1975	2	50.3
1971-1975	3	66.3
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 4.82

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size: > 1000 MW		
Period	Number of Unit-Years	Equivalent Availability [†] (%)
1971	—	—
1972	—	—
1973	—	—
1974	6	56.4
1975	7	46.6*
1971-1975	13	51.1
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.4 Plant Equivalent Availability (Continued)

Equivalent Availability of Alternate Nuclear Plant Designs

Equivalent availability of nuclear plants can be compared by distinguishing between Pressurized Water Reactors (PWR's) and Boiling Water Reactors (BWR's). As shown in Table 4.83, the five year average equivalent availability of Pressurized Water Reactor plants is significantly higher than that of Boiling Water Reactor plants. (67.4% vs. 61.7%)

The annual average equivalent availability of both PWR's and BWR's has changed over the years but the trend of the change is significantly different. During the five year period 1971-1975, PWR's showed first a reduction in annual average equivalent availability followed by an increase. BWR's, on the other hand, show an increase followed by a reduction in annual average equivalent availability. Based upon the limited data of Table 4.83 it may not be valid to conclude that Pressurized Water Reactor plants will exhibit, after 1975, increasing equivalent availability values while Boiling Water Reactor plants will exhibit reducing values.

The all time high annual average equivalent availability for PWR's is 73.4% while for BWR's is 71.5%. PWR averages are based upon a lower number of unit-year data (5 vs. 11), which is less representative of the future average equivalent availability that PWR plants may achieve.

Tables 4.84-4.92 list the annual average equivalent availability, and the five year average equivalent availability of Pressurized Water Reactor plants and Boiling Water Reactor plants in the U.S. The highest annual average equivalent availability (98.4% in 1974) is recorded for Pressurized Water Reactor plants of 900-999 MW size. The highest annual average equivalent availability for Boiling Water Reactors (84.0% in 1972) is that recorded for the 600-699 MW size classification.

Table 4.83

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
All Sizes						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	5	73.4	6	60.2	11	66.2
1972	6	63.1	5	69.7	11	66.1
1973	10	67.9	11	71.5	21	69.8
1974	26	62.8	17	62.3	43	62.6
1975	27	71.5	21	54.2	48	63.9
71-75	74	67.4	60	61.7	134	64.8

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different size, age, utilization, vintage, etc.

Table 4.84

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Less than 400 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit-Years	Average Equivalent Availability [†] (%)	Number of Unit-Years	Average Equivalent Availability [†] (%)	Number of Unit-Years	Average Equivalent Availability [†] (%)
1971	1	65.1	3	59.1	4	60.7
1972	2	53.9	7	65.9	4	59.9
1973	-	-	4	62.5	4	62.5
1974	2	61.8	4	58.2	6	59.4
1975	1	81.4	4	58.0	5	62.7
71-75	6	63.1	17	60.2	23	61.0

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.85

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 400 to 499 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	2	83.4	-	-	2	83.4
1972	1	76.0	-	-	1	76.0
1973	3	81.1	-	-	3	81.1
1974	3	78.6	-	-	3	78.6
1975	3	76.7	-	-	3	76.7
71-75	12	79.3	-	-	12	79.3

[†] Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.4 Plant Equivalent Availability (Continued)

Pressurized Water Reactors, 1000 MW and larger, registered the lowest annual average equivalent availability of 44.9% in 1974. The lowest annual average equivalent availability of Boiling Water Reactor plants was 29.9% recorded in 1975, also for plants greater than 1000 MW.

The highest five-year-average equivalent availability of 85.9% was achieved by 600-699 MW Pressurized Water Reactor plants. For Boiling Water Reactor plants the highest five-year-average equivalent availability was 72.8% for 500-599 MW size plants. The 600-699 MW Boiling Water Reactor plants recorded a five-year-average equivalent availability of 67.0%.

To summarize, PWR's have historically attained higher average equivalent availabilities than BWR's. The most highly available plants are those in the 600-699 MW capacity classification. Historically, the least utilized plants are those greater than 999 MW.

As the nuclear plants proposed for California are all greater than 600 MW. Table 4.92 was prepared to present the historical annual average equivalent availability value and the five-year-annual-average equivalent availability of plants greater than 600 MW. Again, as shown by this table, Pressurized Water Reactor plants have achieved higher five-year-average equivalent availabilities than have Boiling Water Reactor plants.

Table 4.86

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 500 to 599 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	1	87.9	—	—	1	87.9
1972	1	72.3	—	—	1	72.3
1973	3	73.8	—	83.8	4	76.3
1974	5	63.8	2	68.5	7	65.1
1975	5	81.0	3	72.0	8	77.6
71-75	15	73.7	6	72.8	21	73.4
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Table 4.87

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 800 to 899 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	—	—	1	36.8	1	36.8
1972	1	38.2	1	48.6	2	43.4
1973	3	46.8	4	78.6	7	6
1974	8	51.3	5	63.0	13	55.8
1975	9	69.3	6	53.6	15	63.0
71-75	21	57.8	17	61.0	38	59.2

[†] Source: SDC analysis of EEI data supplied by FEA.
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.88

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 900 to 999 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	—	—	—	—	—	—
1972	—	—	—	—	—	—
1973	—	—	—	—	—	—
1974	1	98.4	—	—	1	98.4
1975	2	50.3	—	—	2	50.3
71-75	3	66.3	—	—	3	66.3

[†] Source: SDC analysis of EEI data supplied by FEA.
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.89

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size 600 to 699 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	—	—	2	73.5	2	73.5
1972	—	—	2	84.0	2	84.0
1973	—	—	2	69.4	2	69.4
1974	1	89.3	3	58.0	4	65.8
1975	1	82.5	4	62.1	5	66.2
71-75	2	85.9	13	67.0	15	69.9

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.90

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 700 to 799 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	1	46.7	—	—	1	46.7
1972	1	84.5	—	—	1	84.5
1973	1	74.1	—	—	1	74.1
1974	3	73.5	—	—	3	73.5
1975	3	66.9	—	—	3	66.9
71-75	9	69.6	—	—	9	69.6

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.91

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 1000 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	—	—	—	—	—	—
1972	—	—	—	—	—	—
1973	—	—	—	—	—	—
1974	3	44.9	3	66.9	6	56.4
1975	3	68.8	4	29.9	7	46.6
71-75	6	56.8	7	45.8	13	50.9
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Table 4.92

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 600 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
1971	1	46.7	3	61.3	4	57.6
1972	2	61.3	3	72.2	5	67.9
1973	4	53.6	6	75.5	10	66.8
1974	16	59.6	11	67.7	27	60.9
1975	18	67.4	14	49.3	32	59.5
71-75	41	62.2	37	60.4	78	61.3
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.						

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.4 Plant Equivalent Availability (Continued)

Operational Maturity (Age)

Tables 4.93-4.100 list annual average equivalent availability values for each of the first five years of operation of different sizes of nuclear plants. Plants greater than 400 MW exhibit an increase in average equivalent availability with age. Table 4.93 lists the annual average operating availability of PWR plants only, BWR plants only and all nuclear plants (PWR + BWR). The annual average equivalent availability of all nuclear plants greater than 400 MW has improved from 63.1% in the first year to 72.9% in the fourth year. A slight decline occurred in the fifth year to 66.9%. The trend of increasing average annual equivalent availability is mirrored by Pressurized Water Reactor plants. The first-year-average equivalent availability of 61.0% for PWR's increase to 78.2% in 1974 and then decline to 80.3% in the fifth year. Boiling Water Reactors plants greater than 400 MW, on the other hand, show first a decreasing trend for three years of commercial operation followed by increasing annual average equivalent availability values.

The first-year-average equivalent availability of all nuclear power plants (BWR's + PWR's), greater than 400 MW, vary from a low of 48.8% (greater than 1000 MW plants) to a high of 78.1% (400-499 MW plants). Pressurized Water Reactor plants exhibit a first-year-average equivalent availability ranging from 40.7% (600-699 MW) to 78.1% (400-499 MW plants). First-year-annual-average equivalent availability of BWR plants ranges from 51.6% (greater than 1000 MW plants) to 79.6% (600-699 MW plants).

The fifth-year-average equivalent availability of all nuclear plants, greater than 400 MW, varies from a low of 46.2% for 800-899 MW plants to 71.8% for 500-599 MW plants. The corresponding ranges in annual average equivalent availability of Pressurized Water Reactor plants and Boiling Water Reactor plants are 69.2%-70.9% and 46.2%-70.6%, respectively.

Table 4.93

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 400 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
First	26	61.0	17	66.3	43	63.1
Second	24	70.1	12	60.7	36	66.9
Third	10	70.4	7	60.1	17	66.1
Fourth	6	79.2	4	63.4	10	72.9
Fifth	4	70.3	3	62.5	7	66.9
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart include units of different design, utilization, vintage, etc.						

Table 4.94

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 400 to 499 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
First	3	78.1	—	—	3	78.1
Second	3	79.8	—	—	3	79.8
Third	2	74.4	—	—	2	74.4
Fourth	2	93.0	—	—	2	93.0
Fifth	2	69.2	—	—	2	69.2
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart includes units of different design, utilization, vintage, etc.						

Table 4.95

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 500 to 599 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
First	5	69.2	3	69.3	8	69.2
Second	5	70.0	2	78.4	7	72.4
Third	3	85.6	1	72.2	4	82.2
Fourth	1	80.8	—	—	—	8.8
Fifth	1	71.8	—	—	—	71.8

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.96

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 600 to 699 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
First	1	40.7	4	79.6	5	71.8
Second	1	72.6	2	74.3	3	73.8
Third	1	85.9	2	58.8	3	67.8
Fourth	1	85.2	3	66.0	4	70.8
Fifth	—	—	2	70.6	2	70.6

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.97

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 700 to 799 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
First	3	62.3	—	—	3	62.3
Second	3	71.5	—	—	3	71.5
Third	1	74.1	—	—	1	74.1
Fourth	1	82.1	—	—	1	82.1
Fifth	1	70.9	—	—	1	70.9

[†] Source: SDC analysis of EEI data supplied by FEA
Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.98

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 800 to 899 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
First	9	56.8	6	65.8	15	60.4
Second	8	65.4	5	61.8	13	64.0
Third	3	46.0	4	57.7	7	52.7
Fourth	1	41.2	1	55.5	2	48.3
Fifth	—	—	—	46.2	1	46.2
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data to develop chart includes units of different design, utilization, vintage, etc.						

Table 4.99

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: 900 to 999 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
First	2	61.5	—	—	2	61.5
Second	1	76.0	—	—	1	76.0
Third	—	—	—	—	—	—
Fourth	—	—	—	—	—	—
Fifth	—	—	—	—	—	—
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart includes units of different design, utilization, vintage, etc.						

Table 4.100

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.						
Size: Greater Than 1000 MW						
Year of Commercial Operation	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)	Number of Unit Years	Average Equivalent Availability [†] (%)
First	3	44.9	4	51.6	7	48.8
Second	3	68.8	3	38.0	6	53.4
Third	—	—	—	—	—	—
Fourth	—	—	—	—	—	—
Fifth	—	—	—	—	—	—
[†] Source: SDC analysis of EEI data supplied by FEA Note: The data used to develop chart includes units of different design, utilization, vintage, etc.						

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.5 Plant Heat Rate

Nuclear power plants have operated at an average annual net heat rate of 11220 Btu/Kwh during the period 1971-1974 (see Table 4.101). This includes all the nuclear plants in the U.S. for which data exists in the FPC "Cost and Annual Production Expenses" Supplement for 1971, 1972, 1973 and 1974. A 102 Unit-year sample is the basis of this national average of 11220 Btu/Kwh.

Nuclear plants in California have operated at an average heat rate of 10487 Btu/Kwh during the same four (4) year period. This figure is based on the 4 unit-year average of one nuclear plant. The FPC "Cost and Annual Production Expenses" supplement contained data on this one plant only. The four year national average heat rate is higher for plants in the U.S. than it is for the one plant in California.

Average annual heat rates for all the plants in the U.S. have varied from year to year. The maximum range of the variation of annual average heat rates for all plants in the U.S. is 409 Btu/Kwh while, and for the one California plant, it is 414 Btu/Kwh.

Annual average heat rates for all plants in the U.S. have steadily increased during the period 1971-1974, as shown in Table 4.101. The five-year-average heat rate of 11220 Btu/Kwh is increased by the higher average heat rates of later years.

The annual average heat rate for the one California plant also shows a similar trend. The five-year-average heat rate of 10487 Btu/Kwh is also increased by the higher average of later years.

Annual average heat rates for all the size ranges have varied during the 1971-1974 period as shown in Tables 4.103 through 4.111. A five-year-average heat rate for each size range is also included in these tables. In general the annual average heat rates of all sizes have increased over the 1971-1974 period. Except for isolated instances, the annual average heat rates, as shown by the tables are predominantly between 11000 Btu/Kwh and 12000 Btu/Kwh.

Nuclear power plants 700-799 MW in size exhibit the maximum annual average heat rate of 12851 Btu/Kwh. The minimum annual average heat rate of 10376 Btu/Kwh is exhibited by nuclear plants 900-999 MW in capacity.

Table 4.101

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit Years	Average Heat Rate [†] (net)
1971	13	10897
1972	22	11136
1973	29	11276
1974	38	11306
1971-1974	102	11220
[†] Source: SDC Analysis of FPC Data Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 4.102

NUCLEAR STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Period	Number of Unit Years	Average Heat Rate [†] (net)
1971	1	10304
1972	1	10387
1973	1	10537
1974	1	10718
1971-1974	4	10487
[†] Source: SDC Analysis of FPC Data Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.5 Plant Heat Rate (Continued)

Heat Rates of Alternate Nuclear Plant Designs

Heat Rates of nuclear plants can be studied by distinguishing between Pressurized Water Reactor (PWR) plants and Boiling Water Reactor (BWR) plants. As shown in Table 4.103, the four-year-average heat rate of Pressurized Water Reactor plants is significantly higher than that of Boiling Water Reactor plants (11394 Btu/Kwh vs. 10973 Btu/Kwh).

The annual average heat rates of PWR's and BWR's have changed during the four-year-period, 1971-1974. As shown in Table 4.103, both PWR's and BWR's have shown a steady increase in annual average heat rates. While the annual average heat rates of both designs were very close in 1971 (10835 Btu/Kwh for PWR's vs. 10968 Btu/Kwh for BWR's) the annual average heat rates for 1974 vary significantly (11464 Btu/Kwh for PWR's vs. 11117 Btu/Kwh for BWR's).

Tables 4.104 through 4.111 list the annual average heat rate and the four-year-average heat rate of Pressurized Water Reactor plants and Boiling Water Reactor Plants in the U.S. by plant sizes. Pressurized Water Reactors recorded an all time high heat rate of 14146 Btu/Kwh in 1973 for plants greater than 1000 MW. Boiling Water Reactor plants, on the other hand, recorded an all time high heat rate of 11933 Btu/Kwh in 1972 for 500-599 MW plants.

The best (lowest) heat rate (10376 Btu/Kwh) for any Pressurized Water Reactor plant was achieved by the 900-999 MW size plant in 1974. The best (lowest) heat rate (10388 Btu/Kwh) for any Boiling Water Reactor plant was achieved by the 600-699 MW size plants in 1972.

The lowest five-year-average heat rates are exhibited by the 600-699 MW capacity PWR's and the 900-999 MW capacity BWR's (10969 Btu/Kwh vs. 10376 Btu/Kwh).

To summarize, Boiling Water Reactor plants have historically attained lower heat rates than have Pressurized Water Reactor plants.

Table 4.103

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: All Sizes						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	7	10835	6	10968	13	10897
1972	11	11476	11	10800	22	11138
1973	18	11467	11	10964	29	11276
1974	24	11464	14	11117	38	11336
1971-1974	60	11394	42	10973	102	11220

† Source: SDC Analysis of FPC Data

Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 4.104

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: Less than 400 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	2	11164	2	11313	4	11239
1972	2	11758	2	11022	4	11390
1973	2	13338	2	11379	4	12359
1974	2	11645	2	11401	4	11523
1971-1974	8	11976	8	11279	16	11628

† Source: SDC Analysis of FPC Data

Note: The data used to develop chart includes units of different design, utilization, vintage, etc.

Table 4.105

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: 400 to 499 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	2	10517	--	--	2	10517
1972	2	10641	--	--	2	10641
1973	3	10944	--	--	3	10944
1974	3	10832	--	--	3	10832
1971-1974	10	10764	--	--	10	10764

† Source: SDC Analysis of FPC Data

NOTE: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.106

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: 500 to 599 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	1	10452	--	--	1	10452
1972	2	10785	1	11933	3	11168
1973	2	10934	1	11436	3	11101
1974	3	10871	1	11277	4	10972
1971	8	10813	3	11549	11	11013

† Source: SDC Analysis of FPC Data
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.107

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: 600 to 699 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	1	10935	3	10569	4	10661
1972	1	10937	4	10388	5	10498
1973	1	10877	4	10589	5	10647
1974	1	11128	4	10477	5	10607
1971-1974	4	10969	15	10502	19	10600

† Source: SDC Analysis of FPC Data
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.108

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: 700 to 799 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	1	11099	--	--	1	11099
1972	2	12851	--	--	2	12851
1973	3	11205	--	--	3	11205
1974	3	10988	--	--	3	10988
1971-1974	9	11487	--	--	9	11487

† Source: SDC Analysis of FPC Data
 Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.109

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: 800 to 899 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	--	--	1	11474	1	11474
1972	2	11611	4	10817	6	11082
1973	5	10488	4	11013	9	10699
1974	8	12018	5	11562	13	11843
1971-1974	15	11440	14	11186	29	11318

† Source: SDC Analysis of FPC Data

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.110

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: 900 to 999 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	--	--	--	--	--	--
1972	--	--	--	--	--	--
1973	--	--	--	--	--	--
1974	1	10376	--	--	1	10376
1971-1974	1	10376	--	--	1	10376

† Source: SDC Analysis of FPC Data

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 4.111

NUCLEAR STEAM ELECTRIC POWER UNITS IN THE U.S. †						
SIZE: Greater than 1000 MW						
Period	Pressurized Water Reactors		Boiling Water Reactors		All Power Plants	
	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)	Number of Unit Years	Average Heat Rate (Net)
1971	--	--	--	--	--	--
1972	--	--	--	--	--	--
1973	2	14146	--	--	2	14146
1974	3	12041	2	10921	5	11593
1971-1974	5	12883	2	10921	7	12322

† Source: SDC Analysis of FPC Data

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.6 Key Systems and Components

To identify the key systems and components of a nuclear plant that have impacted the historical attainability of higher levels of the four reliability and efficiency indices, it was necessary to review the data on historical failures, malfunctions, and off-specification performance of nuclear plant systems and components. Nuclear plant components/systems responsible for over 100 equivalent full power outage hours per calendar year are defined on key components/systems.

The primary source of nuclear plant data was the Edison Electric Institute (EEI) Equipment Availability Data Bank. This bank contains historical data by cause code headings. An EEI cause code heading is a title under which all the outage time due to either (1) a group of equipment, (2) similar multiple equipment, or (3) individual equipment, are assigned. Forced, maintenance and planned, full and partial outage times can be obtained from the data bank. Along with the outage times due to forced, maintenance and planned full outages, the Institute also provides an annual summary of all the outages by each cause code. This summary titled "Average Equivalent Full Power Outage Hours" is the sum of all the full (forced, maintenance and planned) outages and the partial outages equivalized to full outage hours.

No data was available on the historical malfunction or off-specification performance of nuclear plant components or systems, if no failure occurred and the plant did not undergo a partial or full outage condition. Failures leading to plant partial or full outages are reported to EEI, and are available as annual summaries through EEI.

EEI provided SDC with annual sorts of nuclear plant component/system data, by cause codes. Table 4.112 lists the cause codes that have been responsible for over one-hundred (100) equivalent full power outage hours per unit-year. In all thirty-one (31) cause codes have outage hours in excess of one-hundred (100) hours assigned to them.

Table 4.112

NUCLEAR STEAM ELECTRIC POWER PLANTS IN THE U.S.							
Size: 600 MW and Above							
EEI Cause Code	EEI Cause Code Title	Average Equivalent Full Power Outage Hours Per Unit-Year*					
		1971	1972	1973	1974	1975	Five Year Total 1971-1975
200	Reactor, General Code	1194	--	--	21	52	1267
201	Reactor Internals...	--	--	107	73	207	387
203	Reactor Coolant System...	36	473	115	99	160	883
204	Reactor " Recirculating...	9	84	215	238	291	837
205	Steam Generator...	--	20	495	298	130	943
207	Control Rods & Drives	72	6	64	51	103	296
208	Reactivity Limitation	--	--	64	19	130	213
209	Fuel Assembly Including...	310	47	14	155	124	650
210	Refueling	662	723	254	560	442	2641
228	Auxiliary System Valves...	56	18	25	29	10	138
229	Safety System Valves...	455	14	43	52	171	785
251	Radioactivity Discharge...	57	--	9	25	35	126
251	Reactor Protection...	20	22	7	18	34	101
263	Engineered Safeguards...	15	39	51	10	40	155
280	Core Physics Test	--	--	228	8	8	244
290	Operator Training...	34	--	14	140	4	192
299	Miscellaneous...	26	14	55	45	88	228
600	Turbine, General Code...	662	651	397	291	281	2282
622	Control, Turbine, and...	4	59	17	22	14	116
630	Vibration of Turbine...	765	--	6	117	8	896
631	Lube Oil System & Bearings	440	--	9	11	1	461
645	Moisture Removal Equipment	639	23	290	9	4	965
648	Inspection	--	1	--	1	155	157
700	Generator, General Code	--	4	109	329	85	525
705	Seal Oil System & Seals	--	--	--	--	142	142
715	Inspection	--	--	--	9	202	204
800	Condenser, General Code	--	356	140	141	391	1028
900	Other, General Code	--	--	81	153	278	512
911	??	183	110	--	--	--	293
911	Cooling Water Limitation	445	3	--	31	45	534
911	Maintenance Error	--	--	2	5	445	551
(All Others)		147	81	282	447	605	

* Source: EEI Special Analysis for SDC

Section 4.0 NUCLEAR STEAM ELECTRIC POWER PLANTS

Subsection 4.6 Key Components/System

It should be noted that the outage hours of Table 4.112 are a summary of both full and partial outages due to forced, maintenance and planned outages. These outage types are not identified separately as the objective was to identify the key components that have required the highest outage time regardless of outage type.

In many instances, simultaneous preventative maintenance and repairs are necessary on more than one component/system to remove the outage conditions and bring the plant back on line. In such cases the outage may be reported under more than one cause code. Table 4.113 is based upon EEI data and unit outage projection, based upon combining the individual cause codes should be made with caution.

The EEI cause codes with either high outage hours in 1974 and 1975, the latter years in the sample, or with a worsenign (increasing outage time) trend over the five year period, are significant cause codes and are listed in Table 4.113.

Table 4.113

Nuclear Steam Electric Power Plants in the U.S.								
Size: 600 MW & Above								
Key Components/Systems			Average Equivalent Full Power Outage Hours per Unit-Year					Five-Year Total (1971-1975)
Rank	EEI Cause Code	EEI Cause Code Title	1971	1972	1973	1974	1975	
1	209	Refueling	662	723	254	560	442	2641
2	600	Turbine, general	662	651	397	291	281	2282
3	200	Reactor, general	1194	-	-	21	52	1267
4	800	Condensar, general	-	356	140	141	391	1028
5	205	Steam Generator	0	20	495	298	130	943
6	204	Reactor Coolant Pump & Drive	9	84	215	238	291	837
7	700	Generator, general	-	4	109	329	85	525
8	900	Other, general	-	-	81	153	278	512

Section 5.0

GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.1 Introduction

The Geysers power station is the largest geothermal installation in the world. It is the only geothermal power station in the United States. There are eleven (11) plants (Table 5.1) currently in operation at the Geysers power station.

These plants vary in size from 11 MW to 110 MW. The smaller plants (1, 2, 3 and 4) were experimental plants and are plants on which the initial experience in the operation, maintenance and design of geothermal plants was obtained. Because of the experimental nature of these small plants they have not been included in the overall evaluation of geothermal power plants.

Six (6) large plants, Plant #5 through Plant #10, are each 55 MW, while Plant #11 is of 110 MW capacity. Although the plant size has been doubled for Plant #11 there has been no corresponding increase in the number of equipment (except for the turbine); the equipment comprising Plant #11 are sized larger than those of the 55MW size plant to handle the greater working fluid volume. This is the only change in the basic design of the 55MW plants. The data on the 110MW plant (#11) were studied separately from that of the 55MW plants; comparisons are made between the two sizes.

Table 5.2 describes the data base that has been used to evaluate the averages and ranges of the R&E indices. Using annual data from the date of commercial operation through the end of 1975, the number of plants considered and the number of unit-years in each size group are shown in Table 5.2.

Geothermal systems are divided into two general classes, namely 1) the vapor-dominated system, and 2) the liquid or water-dominated system. The steam fields at the Geysers are typical examples of a vapor-dominated system. At the Geysers an emission abatement program is being implemented that is expected to scrub ninety (90) percent of the hydrogen sulfide from the non-condensable gases. Data are not available to quantify the effects of the abatement program on any of the four reliability and efficiency indices. The abatement program had not yet been implemented or been operational for any length of time on any geothermal plant. The environmental control program requires hydrogen sulphide

Table 5.1

GEYSERS POWER STATION		
Plant #	Plant Capacity (MW)	Date of Commercial Operation
1	11	09/25/60
2	13	03/19/63
3	27	04/28/67
4	27	11/02/68
5	55	12/15/71
6	55	12/15/71
7	55	08/18/72
8	55	11/23/72
9	55	10/15/73
10	55	11/30/73
11	110	05/31/75
Source: Pacific Gas and Electric Co.		

Table 5.2

Plant Size	Number of Plants	Number of Unit-Years
55 MW	6	24
110 MW	1	1

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.1 Introduction (Continued)

abatement equipment on all new (projected) installations at the Geysers and to be retrofitted on all existing plants.

Geothermal units, based upon vapor dominated systems, have operated at an average capacity factor of 74.5%, an average equivalent availability of 76.8% and an operating availability of 83.3% during the period 1971-1975. The "estimated" five-year-average gross heat rate is 22826 BTU/KWH. The data used to develop these figures includes units of different size, age, and design vintage operating using a vapor-dominated geothermal fluid.

The annual average capacity factor, equivalent availability and operating availability have, in general, increased (improved) during the period 1971-1975. The "estimated" annual average gross heat rate has, on the other hand, decreased, (also an improvement) during this period.

Two unit sizes, 55MW and 110MW, comprise the data used to evaluate the historical averages of tables 5.3, 5.4 and 5.5. The data for the 110MW size is obtained from the one year of operation of a single unit. Based upon this limited 110MW size plant data, no conclusions can be made as to the effect of geothermal unit size on the four recommended reliability and efficiency indices.

The historical data does exhibit a marked increase in the values of each index with increase in utility experience. As the utility experience increased the indices for the second year equaled or exceeded the first five-year-average.

The historical values achieved by each index reflect the unit design maturity, its vintage, unit operational maturity (age) and the utility experience in the design, operation and maintenance of vapor-dominated geothermal units. No data projections are made, or are possible, for any of the four indices for liquid-dominated systems.

Table 5.3

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA				
Year	Number of Unit-Years	Average Capacity Factor (%)†	Average Equivalent Availability (%)†	Average Operating Availability (%)†
1971	2	36.75	42.5	49.0
1972	4	78.35	81.9	84.25
1973	6	72.68	77.7	80.53
1974	6	76.02	76.5	89.90
1975	7	83.41	83.0	89.30
1971-1975	25	74.52	76.8	83.30

Note: The data used to develop chart includes units of different size, age, vintage, etc.
†Source: SDC Analysis of Plant Data

Table 5.4

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA				
Size	Number of Unit-Years	Average Capacity Factor (%)†	Average Equivalent Availability (%)††	Average Operating Availability (%)†
55 MW	24	74.77	77.1	83.6
110 MW	1	68.50	69.1	75.6

Note: The data used to develop chart includes units of different age, vintage, etc.
†Source: SDC Analysis of Plant Data
††Average for the period 1971-1975

Table 5.5

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA			
Size (MW)	Heat Rate (Btu/KWh)		
	Design (Net)†	Design (Gross)†	Estimated†† Five Year Average (Gross)
55	21690	20910	22896
110	21376	20607	21156

Note: The data used to develop chart includes units of different age, vintage, etc.
†Source: Unit/Utility data
††Estimate based upon 1200 Btu/lb enthalpy steam

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.2 Plant Capacity Factor

Geothermal power plants have operated at an average capacity factor of 74.5%. This figure includes all geothermal plants greater than 54MW in operation during the period, 1971-1975. This is, thus, the lifetime average of the annual capacity factors of Units 5, 6, 7, 8, 9, 10 and 11. A 25 unit-year sample is the basis of this average.

The average capacity factor of all geothermal plants has steadily increased (improved) during the period 1971-1975. As shown in Table 5.6 the lowest average capacity factor was 36.75% in 1971, which increased to 83.41% in 1975.

The 55MW plants have shown a higher average lifetime capacity factor than the 110MW plant; 74.77% vs. 68.50% respectively. The lifetime capacity factor of 55MW plants is based upon the 24 unit-years of data on six plants, while the lifetime capacity factor of 110MW plant is based upon the first year of operation of a single unit.

Table 5.6

GEOTHERMAL STEAM ELECTRIC POWER PLANTS IN CALIFORNIA		
year	Number of Unit-Years	Average Capacity Factor (%) [†]
1971	2	36.75
1972	4	78.35
1973	6	72.68
1974	6	76.02
1975	7	83.41
1971-1975	25	74.52
[†] Source: SDC Analysis of Plant Data		

Table 5.7

GEOTHERMAL STEAM ELECTRIC POWER PLANTS IN CALIFORNIA		
Size	Number of Unit-Years	Average ^{††} Capacity Factor (%) [†]
55 MW	24	74.77
110 MW	1	68.50
[†] Source: SDC Analysis of Plant Data		
^{††} Average for the Period 1971-1975		

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.2 Plant Capacity Factor (Continued)

Operational Maturity (Age) and Capacity Factors

While the 55MW plants had operated for an average of four years each, by 1976, the 110MW plant had operated for only one year. It is more likely, then, that the 55MW plants have matured to operate at their optimum capacity factor than has the 110MW plant.

Table 5.8 lists the average capacity factors achieved by the power plants for each year of commercial operation. The six 55MW plants operated at an average capacity factor of 58.9% in the first year of operation. This average improved to over 80% in the following years, as the units matured.

The data available for the 110MW size is very limited. As shown in Table 5.8 the 110MW unit achieved a capacity factor of 68.5% in its first year. This is a marked increase over that achieved by the 55MW units in their first year of operation. It is reasonable to assume that the 110MW unit will improve with age, just as the 55MW units have, and will achieve the higher capacity factor of over 80%.

Table 5.8

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA				
Year of Commercial Operation	55 MW		110 MW	
	Number of Unit-Years	Average Capacity Factor (%) [†]	Number of Unit-Years	Average Capacity Factor (%) [†]
First	6	58.9	1	68.5
Second	6	80.6	-	-
Third	6	80.3	-	-
Fourth	4	77.3	-	-
Fifth	2	83.4	-	-
[†] Source: SDC Analysis of Plant Data				

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.2 Plant Capacity Factor (Continued)

Historical Capacity Factors and Utility Experience

The Geysers power station's eleven plants are maintained and operated by one investor-owned utility. The capacity factors achieved by the eleven plants reflect the experience and confidence of this one utility in designing, constructing, operating and maintaining geothermal power plants.

In 1960 when the first experimental unit (Plant #1) came into commercial operation, the utility had no "hands-on" experience. By the time Plant #5 went into operation the utility had over 26 unit-years of experience, based upon four power plants. This experience had increased to over 56 unit-years when Plant #11 went on-line. The increase in average capacity factors for the first year of commercial operation (Table 5.8) of the 55MW and the 110MW sizes reflects this increase in utility experience. As the experience increased from 26 unit-years to 56 unit-years, the average capacity factor correspondingly increased from 58.9% to 68.5%.

The increase of utility experience from 26 unit-years to 56 unit-years occurred during the period 1971-1975. During this period the utility was primarily operating only 55MW per plants. As the utility's experience with this one plant size improved, the average capacity factors show a marked improvement, namely, from 36.75% in 1971 to 76.02% in 1974 (as shown in Table 5.9). It is expected, then, that increased experience with the 110MW plants will also result in increased capacity factors for plants of this size.

Table 5.9

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Year	Average Capacity Factor (%) [†]	
	55 MW	110 MW
1971	36.75	--
1972	78.35	--
1973	72.68	--
1974	76.02	--
1975	85.90	68.5
[†] Source: SDC Analysis of Plant Data		

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.3 Plant Operating Availability

Geothermal power plants have achieved an average operating availability of 83.30%. This figure includes all geothermal plants in operation during the period 1971-1975, and greater than 54MW. This is, then, the lifetime average annual operating availability of Plants 5, 6, 7, 8, 9, 10 and 11. A 25 unit-year is the basis of this average.

The average operating availability of all geothermal plants has steadily improved (increased) during the period 1971-1975. As shown in Table 5.10, the lowest average operating availability was 49.0% in 1971 which increased dramatically to 89% plus by 1974 and 1975.

The 55MW size has shown a higher average lifetime operating availability than the 110MW size: 83.6% vs. 75.6% respectively. The average lifetime operating availability of the 55MW size is based upon 24 unit-years of data on six units, while the average lifetime operating availability of the 110MW size is based upon one year of operation of a single unit.

Table 5.10

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Year	Number of Unit Years	Average Operating Availability (%) [†]
1971	2	49.0
1972	4	84.25
1973	6	80.53
1974	6	89.90
1975	7	09.30
1971-1975	25	83.30
[†] Source: SDC Analysis of Plant Data		

Table 5.11

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size	Number of Unit Years	Average [†] Operating Availability (%) ^{††}
55 MW	24	83.6
110 MW	1	75.6
[†] Average over the period 1971-1975		
^{††} Source: SDC Analysis of Plant Data		

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.3 Plant Operating Availability (Continued)

Plant Operational Maturity (Age) and Operating Availability

While the 55MW size has operated for an average of four years for each plant (by 1976), the 110MW size has been in operation for just one year. It is, then, more likely that the 55MW size has matured to operate at its optimum operating availability, than has the 110MW size.

Table 5.12 lists the average operating availability achieved by the power plants for each year of commercial operation. The six 55MW plants achieved an average operating availability of 69.3% in the first year of operation. This average improved to over 89% in the following years, as the units matured.

The data available for the 110MW size is very limited. As shown in Table 5.12 the 110MW size achieved an operating availability of 75.6% in its first year. This is a marked increase over that achieved by the 55MW size in the first year of operation. It is reasonable to assume that the 110MW size will improve with age, just as the 55MW size has, and will achieve over 89% operating availability.

Table 5.12

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA				
Year of Commercial Operation	55 MW		110 MW	
	Number of Unit-Years	Average Operating Availability (%)	Number of Unit-Years	Average Operating Availability (%)
First	6	69.3	1	75.6
Second	6	85.8	-	-
Third	6	89.7	-	-
Fourth	4	89.9	-	-
Fifth	2	89.2	-	-
Source: SDC Analysis of Plant Data				

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.3 Plant Operating Availability (Continued)

UTILITY EXPERIENCE AND OPERATING AVAILABILITY

The Geyser power station's seven power plants are maintained and operated by one investor-owned utility. The operating availability of the eleven plants reflects the experience and confidence of this utility in designing, constructing, operating and maintaining geothermal power plants.

In 1960, when the first experimental plant (Unit #1) came on-line, the utility had no "hands-on" experience with geothermal power plants. On the other hand, by the time Plant #5 went on-line, the utility had over 26 unit-years of experience on four geothermal power plants. This experience had increased to over 56 unit-years when plant #11 went on-line. The increase in average operating availability for the first year of commercial operation (Table 5.12) of the 55MW and the 110MW size reflects this increase in utility experience. As this experience increased for 26 unit-years to 56 unit-years, the average operating availability also increased, from 69.3% to 75.6%.

The increase in utility experience occurred during the period 1971-1975. During this period, the utility was primarily operating and maintaining 55MW size power plants. As its experience with this one plant size increased, the average operating availability showed a marked improvement; namely, 49.0% in 1971 to 89.9% in 1974 (see Table 5.13). It is expected, then, that increase in experience in operating and maintaining 110MW size plants will result in increased operating availability for the 110MW size, also. The operating availability of 110MW size power plants is projected to reach 90%.

Table 5.13

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Year	Average Operating Availability (%) [†]	
	55 MW	110 MW
1971	49.0	—
1972	84.3	—
1973	80.5	—
1974	89.9	—
1975	91.6	75.6
[†] Source: SDC Analysis of Plant Data		

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.4 Plant Equivalent Availability

Geothermal power plants have operated at an average equivalent availability of 76.8% during the period 1971-1975. This figure includes all geothermal plants in operation during this period and greater than 54MW in capacity. Seven (7) plants are included in the sample, namely, Plant #5, #6, #7, #8, #9, #10 and #11. The average equivalent availability of 76.8% is the lifetime average of all these plants, through 1975. A 25 unit-year sample is the basis of this five year average value.

The average equivalent availability of all geothermal plants has steadily increased (improved) with time, during the period 1971-1975. As shown in Table 5.14 the lowest average equivalent availability was 42.5% in 1971, which increased to 83.0% in 1975.

The 55 MW plants have shown a higher lifetime average than the 110MW plants; 77.1% vs. 69.1 respectively. The lifetime average equivalent availability of 55MW plants is based upon the 24 unit-years of data on six plants. The average equivalent availability of 69.1 % for 110MW is based upon one year of operation of a single unit.

Table 5.14

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Year	Number of Unit-Years	Average Equivalent Availability (%) [†]
1971	2	42.5
1972	4	81.9
1973	6	77.7
1974	6	76.5
1975	7	83.0
1971-1975	25	76.8
[†] Source: SDC Analysis of Plant Data		

Table 5.15

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size	Number of Unit-Years	Average [†] Equivalent Availability (%) ^{††}
55 MW	24	77.1
110 MW	1	69.1
[†] Average Over the 5 Year Period 1971-1975		
^{††} Source: SDC Analysis of Plant Data		

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.4 Plant Equivalent Availability (Continued)

Operational Maturity (Age) and Equivalent Availability

While the 55MW size has operated for an average of four years for each plant (by 1976), the 110MW size has been in commercial operation for just one year. It is, thus, more likely that the 55MW size has matured to operate at its optimum level of equivalent availability, than has the 110MW size.

Table 5.16 lists the average equivalent availability of each of the plant sizes for each year of commercial operation. The six 55MW plants achieved an average equivalent availability of 65.2% in the first year of commercial operation. As these units matured, the average improved to 84.3% by the fifth year.

The data available for the 110MW unit is very limited. As shown in Figure 5.16 the 110MW size achieved an average equivalent availability of 69.1% in its first year of commercial operation. It is reasonable to assume that the 110MW size will improve further with age, as have the 55MW plants. It is feasible for the 110MW size to attain an annual average equivalent availability in the mid eighties (≈ 85%).

Table 5.16

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA				
Year of Commercial Operation	55 MW		110 MW	
	Number of Unit-Years	Average Equivalent Availability (%) [†]	Number of Unit-Years	Average Equivalent Availability (%) [†]
First	6	65.2	1	69.1
Second	6	81.9	—	—
Third	6	83.0	—	—
Fourth	4	75.2	—	—
Fifth	2	84.3	—	—
[†] Source: SDC Analysis of Plant Data				

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.4 Plant Equivalent Availability (Continued)

Utility Experience and Equivalent Availability

The Geysers power station's seven power plants are maintained and operated by a single investor-owned utility. The historical average equivalent availability of the eleven (11) plants is a measure of the experience and maturity of this utility's ability to design, construct, operate and maintain geothermal power plants.

The equivalent availability of geothermal plants is a strong function of the steam properties. Experience on one design type operating with steam of given properties cannot be directly translated to geothermal plants to be built and operated with steam of different properties. In other words, the experience gained by this utility is very valuable for similar vapor-dominated fields as the Geysers, but may not be equally applicable to power plants operating on wet steam.

In 1960, when the first experimental geothermal plant, Plant #1 came on-line, the utility had no hands-on experience with geothermal power plants. But by the time Plant #5 went into commercial operation the utility had over 26 unit-years of experience on four (4) geothermal power plants. This experience had increased to over 56 unit-years, when Plant #11 went commercial. The increase in average equivalent availability for the first year of commercial operation reflects this increase in experience. As the experience increased from 26 unit-years to over 56 unit-years, the average equivalent availability increased from 65.2% to 69.1%.

The increase in utility experience occurred during the period 1971-1975. During this period the utility was primarily operating and maintaining 55MW size plants. As its experience with this plant size improved the annual average equivalent availability of the 55MW size showed an increasing (improving) trend (see figure 5.17).

It can be expected that as the utility's experience with 110MW plants increase, their average equivalent availability will also increase. The average equivalent availability of new 110MW plants will exceed that for the first 110MW plant and it is feasible for the average equivalent availability of 110MW plants to eventually exceed 85%.

Table 5.17

GEOTHERMAL STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Year	Average Equivalent Availability (%) [†]	
	55 MW	110 MW
1971	42.5	—
1972	81.9	—
1973	77.7	—
1974	76.5	—
1975	85.3	69.1
[†] Source: SDC Analysis of Plant Data		

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.5 Plant Heat Rate

Neither gross heat rate nor net heat rate are computed for the Geyser units. The only performance related measure that is recorded is the gross steaming rate (lb/MW). The annual average gross steaming rates for the 55MW and the 110MW size units are listed in Table 5.18.

Knowing the average gross steaming rate and the average enthalpy of the geothermal steam, the gross heat rate can be readily computed. At the geyser units, however, the steam enthalpy is not monitored/recorded regularly. As a result, no representative data on the annual average enthalpy of the steam utilized is available.

The 55MW and 110MW geysers units were designed for steam with an enthalpy of 1200 BTU/lb. The design "net" and design "gross" heat rates for the two sizes are shown in Table 5.19 along with an estimated five year average gross heat rate, based on 1200 BTU/lb enthalpy steam.

The natural thermodynamic constraints placed on any steam electric power production cycle require the rejection of 60 to 70 percent of the energy produced. Because the geothermal plant operates at much lower temperatures, the thermodynamic efficiency is commonly half that of a modern central station; that is, it has an efficiency of conversion of approximately 16 to 17 percent. It must be remembered that this represents the net efficiency of the entire power cycle from production of steam through the well bores to conversion to electricity. For fossil fuel power plants and nuclear power plants the thermodynamic efficiency is only measured in terms of the conversion at the power plant and does not take into account the energy expended in the mining, processing, transportation, or waste handling required for other fuel types. These energy costs need to be added to the nuclear or fossil-fuel plant cycle costs for comparison of geothermal plants with other fossil-fuel or nuclear plants.

Table 5.18

GEOTHERMAL STEAM ELECTRIC POWER PLANTS IN CALIFORNIA					
	55MW			110MW	
Period	Number of Units	Average Steaming Rate (lb/MWH) [†]	Average Estimated Heat Rate ^{††}	Number of Units	Average Steaming Rate (lb/MWH) [†]
1971	2	20880	25056	-	-
1972	4	18890	22668	-	-
1973	6	18780	22668	-	-
1974	6	19560	22536	-	-
1975	6	18440	22128	1	17630
1971-1975	24	19080	22896	1	17630
[†] SDC analysis of Utility/Unit data ^{††} Estimate based upon 1200 BTU/lb enthalpy steam					

Table 5.19

GEOTHERMAL STEAM ELECTRIC POWER PLANTS IN CALIFORNIA			
Size (MW)	Heat Rate (BTU/KWH)		
	Design (net) [†]	Design (gross) [†]	Estimated # Five Year Average (gross) ^{††}
55	21690	20910	22896
110	21376	20607	21156
[†] Source: Unit/Utility data ^{††} Estimated based upon 1200 BTU/lb enthalpy steam			

Section 5.0 GEOTHERMAL STEAM ELECTRIC POWER PLANTS

Subsection 5.6 Key Systems/Components

To identify the key components, subsystems and systems that have resulted in a reduction in the historical level of each reliability and efficiency index, it was necessary to review the data on historical failures, malfunctions and off-specification performance of geothermal plant components, subsystems and systems.

The primary source of geothermal plant failure data was the geothermal plant operating utility. Their data bank contains information on the historical failures by EEI cause code headings. An EEI cause code heading is a title under which all the outages due to either (1) a group of equipment, (2) similar multiple equipment, or (3) individual equipment, are assigned.

No data was available on historical malfunction or off-specification performance of components, subsystems and systems if no failure occurred and if the geothermal plant did not undergo a partial or full outage condition.

Tables 5.20 and 5.21 list the EEI cause codes that have been responsible for 55MW & 110MW geothermal plant outages. Unit outage projections based upon combination of data of the cause codes in either of the tables should be made with caution; in instances where simultaneous preventative maintenance and repairs were done on more than one component/system to remove a unit outage condition, the same outage may have been reported under more than one cause code heading.

Table 5.20

GEOTHERMAL STEAM ELECTRIC POWER PLANTS IN THE U.S.							
Size: 55 MW							
EEI Cause Code	EEI Cause Code Title	Average Equivalent Full Power Outage Hours Per Unit-Year †					Five Year Total 1971-1975
		1971	1972	1973	1974	1975	
600	Turbine, General	5	109	738	321	518	1691 *
621	Governors	-	-	-	2	13	15
622	Control, Stop Valves	-	1	3	-	35	39
629	Buckets and Blades	-	-	164	913	140	1217 *
630	Vibration	-	2	18	8	15	43
631	Lube Oil System & Bearings	376	63	7	64	-	510 *
632	Control, Turbine	1	7	21	-	-	29
634	Blade Fouling	-	-	21	6	-	27
643	Piping	-	314	3	1	3	321 *
648	Inspection	-	-	13	-	-	13
699	Miscellaneous	1	3	1	-	2	7
703	Generator - Hydrogen Cooling System	-	-	1	-	-	1
709	Rotor Collector Rings	-	-	-	-	2	2
710	Brush Rigging	-	37	3	5	3	48
711	Generator - Main Lead	-	-	29	-	-	29
712	Exciter	-	-	2	-	3	5
713	Voltage Regulator	1	2	5	-	6	14
714	Control, Generator	12	-	-	-	-	12
799	Miscellaneous	-	3	9	17	1	30
800	Condenser, General	50	5	7	29	7	98
804	Condensate Pumps	-	36	57	106	30	229
805	Air Removal Pumps	1	-	-	-	1	2
806	Shell	-	2	-	-	-	2
807	Control, Condenser	221	117	15	27	15	395
808	Air Leakage	-	5	30	2	-	37
809	Expansion Joint	-	6	-	13	28	47
810	Inspection	-	-	1	-	-	1
812	Cooling Towers	-	56	127	142	154	479 *
899	Miscellaneous	-	20	19	44	37	120
900	Other, General	-	-	28	11	-	39
903	Main Transformer	-	15	25	-	-	40
904	Switchgear	-	-	-	-	-	1
909	Service Water Pumps	-	-	-	-	-	1
912	Cooling Water Limitation	-	-	17	-	-	17
914	Aux. Transformer	-	56	-	-	6	62
916	Error, Maintenance	-	-	-	25	-	25
930	Precipitators	316	-	5	37	21	379 *
931	??	22	79	159	162	155	577 *
999	External Cause	140	63	45	123	95	466 *

† Source: SDC Analysis of Utility/Plant Data

Table 5.21

GEOTHERMAL STEAM ELECTRIC POWER PLANTS IN THE U.S.		
Size: 110 MW		
EEI Cause Code	EEI Cause Code Title	Average Equivalent Full Power Outage Hours per Unit Year†
		1975
621	Governors, Turbine	5
622	Control, Valves	236
629	Buckets and Blades	10
630	Vibration, Turbine	71
631	Lube Oil System & Bearings	37
648	Inspection, Turbine	337
699	Miscellaneous, Turbine	39
712	Exciter, Generator	77
713	Voltage, Regulator	3
803	Circulating Water Pumps	2
805	Air Removal Pumps	14
807	Condenser Control	6
810	Inspection, Condenser	15
812	Cooling Towers	826
904	Switchgear	2
930	Precipitation	35
931	? ?	113
999	External Cause	19

† Source: SDC Analysis of Utility/Plant Data

SECTION 6.0

GAS TURBINE ELECTRIC POWER PLANTS

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.1 Introduction

Four indices of power plant reliability and efficiency, are recommended for use by the State of California, Energy Conservation and Development Commission, in the evaluation of utility AFC submittals for new gas turbine electric power plants. The indices are 1) Capacity Factor, 2) Operating Availability, 3) Equivalent Availability, and 4) Heat Rate.

To establish feasible ranges and averages for each of the above four indices, a review of historical data was necessary.

The period 1971-1975 is the primary basis for the evaluation of ranges and averages of Reliability and Efficiency Indices for gas turbines in operation in the United States and in the State of California. The time period was chosen as it covers the latest advances in gas turbine technology, effects of restrictive environmental controls, effects of increased regulation, etc. Also, a comprehensive data base was available for the gas turbines in operation during this period.

The primary source of U.S. annual average capacity factors, annual average operating availability and annual average equivalent availability was the Edison Electric Institute (EEI) Equipment Availability Data Bank. The data on gas turbines in the U.S. was extracted from the EEI data bank, by EEI in accordance with the analysis requirements set by SDC. Table 6.1 lists the number of plants EEI used to arrive at the annual summaries. As it is EEI's policy not to reveal the individual plant name or a plants' specific annual operating data, no lists of plants by name could be included for each year's analysis.

The primary source of annual average capacity factor, annual average operating availability and annual average equivalent availability for gas turbines in California was EEI data supplied to SDC by the FEA. The individual gas turbine data was assimilated by SDC to arrive at average ranges for each of the above three indices. The number of plants used to arrive at this average for the state of California are shown in Table 6.1.

Table 6.1

GAS TURBINES		
Year	Number of Units in the U.S. †	Number of Units in California ††
1971	25	17
1972	57	25
1973	85	27
1974	200	27
1975	198	27
† Source: EEI Special Analysis for SDC		
†† Source: SDC Analysis of EEI Data Supplied by FEA		

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.2

GAS TURBINES		
Year	Number of Units in the U.S. †	Number of Units in California †
1973	993	21
† Source: SDC Analysis of FPC Data		

NOTE. The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.1 Introduction (Continued)

The primary source of annual average Heat Rates of gas turbines was the Federal Power Commission's (FPC) "Gas Turbine Electric Plant Construction Cost and Annual Production Expenses Supplement for 1973" (as of this analysis, no supplement for any other year was available). Some individual plant heat rate data were obtained from California utilities but a comprehensive and representative heat rate data bank on California plants could not be compiled. The heat rate data base is limited to the year 1973 only. Table 6.2 lists the number of plants on which data were obtained from the FPC report.

Table 6.3 and 6.4 list the number of plants in the gas turbine data base for the U.S. and California by two size range classifications. These size ranges were chosen to better match plants of equivalent sizes. As described above, the data for computing the National (U.S.) averages was obtained from EEI while data for computing the State of California averages were obtained from the FEA.

The historical levels achieved for each index reflect the size of the plant, its design maturity, the experience of the operating utility, the age of the plant, the load demand to be satisfied by the plant, etc. To better define and assess the effect of each of these factors on the index levels achieved, individual gas turbine data are required for years prior to 1971. These data were not available, on individual plants.

The study of the effects of plant design maturity, utility experience and plant age on plant Heat Rate could not be accomplished, as a comprehensive and representative data base could not be compiled.

Only gas turbines 15MW in capacity and greater are scheduled for start-up in the state of California during the period 1980-1995.

Table 6.3

GAS TURBINES IN THE U.S.					
Size Range	Number of Units				
	1971	1972	1973	1974	1975
0 - 24 MW	23	38	63	131	147
25 MW & Above	2	19	22	69	51
† Source: EEI Special Analysis for SDC					

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.4

GAS TURBINES IN CALIFORNIA					
Size Range	Number of Units				
	1971	1972	1973	1974	1975
0 - 24 MW	13	22	23	23	23
25 MW & Above	4	3	4	4	4
† Source: SDC Analysis of EEI Data Supplied by FEA					

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANT

Subsection 6.1 Introduction (Continued)

Gas turbines have been operated at an average capacity factor 9.73%, have been maintained at an average equivalent availability of 81.2% and an average operating availability of 81.3%. The average net heat rate for gas turbines in operation in the U.S. was 16918 BTU/KWH for 1973. The data used to develop these averages includes units of different design, size, age and utilization, etc.

As a group, the average capacity factor, operating availability and equivalent availability of gas turbines has reduced during the period 1971-1975. This reduction represents an improvement in capacity factor (reduced use of expensive fuel oil) and a possible decline in equivalent availability and operating availability. These are mirrored by both size groups of gas turbines.

The reduction in utilization (capacity factor) of small gas turbines (less than 25MW) is greater than that of the larger size (25MW and above). The average reduction in equivalent availability and operating availability is, however, about the same (11%).

Table 6.5

GAS TURBINES IN THE U.S.				
Period	Number of Units-Years	Average Capacity Factor (%) [†]	Average Equivalent Availability (%) [†]	Average Operating Availability (%) [†]
1971	25	15.49	91.3	91.26
1972	57	16.40	86.6	86.60
1973	85	11.65	83.0	82.98
1974	200	10.56	81.0	81.19
1975	198	5.46	77.7	77.90
1971-1975	565	9.73	81.2	81.29
NOTE: The data used to develop chart includes units of different design, size, age, utilization, vintage, etc.				
[†] Source: EEI special analysis for SDC				

Table 6.6

GAS TURBINES IN THE U.S.				
Size Range	Number of Unit-Years	Average [†] Capacity Factor (%) ^{††}	Average [†] Equivalent Availability (%) ^{††}	Average [†] Operating Availability (%) ^{††}
Less than 25 MW	402	9.44	84.5	84.52
25 MW and Above	163	10.43	73.0	73.32
<p>NOTE: The data used to develop chart includes units of different design, age, utilization, vintage, etc.</p> <p>[†]Average over the five-year-period 1971-1975</p> <p>^{††}Source: EEI special analysis for SDC</p>				

Table 6.7

GAS TURBINES IN THE U.S.		
Range of Average Size of Gas Turbines	Number of Unit-Years	Average Heat Rate [†] (Net) for 1973
Less than 25 MW	597	16364
25 MW and Above	396	17753
All Gas Turbines	993	16918
<p>NOTE: The data used to develop chart includes units of different design, age, utilization, vintage, etc.</p> <p>[†]Source: SDC analysis of FPC data</p>		

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.2 Plant Capacity Factors

Gas turbines have operated on a national basis, with an average capacity factor of 9.73% during the period 1971-1975 (see Table 6.8). This includes the gas turbines in operation during this period, on whom capacity factor data were reported to EEI. A 565 unit-year sample was used to arrive at the national average of 9.73%.

Gas turbines in California have operated at an average capacity factor of 7.37% during the period 1971-1975 (see Table 6.9). This includes all gas turbines operated by five major California utilities (Pacific Gas and Electric Co., Southern California Edison Co., San Diego Gas and Electric Co., Sacramento Municipal Utility District and the City of Angeles Department of Water and Power) during this period and whose data were available in the FEA data base. A 123 unit-year sample was used to arrive at the average capacity factor of 7.37%.

The average capacity factor of the gas turbines in the state of California is lower than that on a national basis for the five year period 1971-1975.

As gas turbines utilize expensive fuel oil and are less efficient than other fossil fuel means of electric power generation, they are primarily used for peak demand (loads) only. The objective, then, is to use these types of plants only when absolutely necessary, which results in very low capacity factors.

The average capacity factor of gas turbines in the U.S. has, in general, declined during the period 1971-1975. This reducing trend is also mirrored by the gas turbines in California.

Tables 6.10 and 6.11 list the average capacity factors for the gas turbines in the U.S. and the state of California, respectively. The two size ranges, namely, less than 24MW and 25MW and greater, have operated at different average capacity factors during the period 1971-1975. On the national level, gas turbine capacity factors for the two sizes are very close - they differ by just one percentage point. However, gas turbines of the two size ranges, show a marked difference in capacity factors for the state of California.

Table 6.8

GAS TURBINES IN THE U.S.		
Period	Number of Unit-Years	Average Capacity Factor %
1971	25	15.49
1972	57	16.40
1973	85	11.65
1974	200	10.56
1975	198	5.46
1971-1975	565	9.73

Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.9

GAS TURBINES IN CALIFORNIA		
Period	Number of Unit-Years	Average Capacity Factor %
1971	17	8.02
1972	25	7.75
1973	27	10.66
1974	27	6.73
1975	27	3.97
1971-1975	123	7.37

Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.10

GAS TURBINES IN THE U.S.		
Size Range	Number of Unit-Years	Average Capacity Factor %
0-24 MW	402	9.44
25 MW & Above	163	10.43

† Average over the Five-Year Period 1971-1975
 †† Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.11

GAS TURBINES IN CALIFORNIA		
Size Range	Number of Units-Years	Average Capacity Factor (%)
0-24 MW	104	8.50
25 MW & Above	19	1.21

† Average over the Five-Year Period 1971-1975
 †† Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.12

GAS TURBINES IN THE U.S.		
Period	Average Capacity Factor (%)	
	0-24 MW	25 MW & Above
1971	15.44	16.06
1972	17.71	13.77
1973	10.79	14.12
1974	10.79	10.12
1975	4.57	7.80
1971-1975	9.44	10.43

Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.13

GAS TURBINES IN CALIFORNIA		
Period	Average Capacity Factor (%)	
	0-24 MW	25 MW & Above
1971	9.9	1.9
1972	8.6	1.5
1973	12.3	1.2
1974	7.8	0.6
1975	4.5	0.9
1971-1975	8.5	1.2

Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.2 - Plant Capacity Factors (Continued)

Large gas turbines in California have a lower average capacity factor than the smaller size range. On a national level the reverse is true, i.e. large gas turbine average capacity factors are higher.

Annual average capacity factors of gas turbines have changed during the period 1971-1975. Table 6.12 lists the annual average capacity factor and the five year average capacity factor for each of the two size ranges of gas turbines in the U.S. Table 6.14 lists, each size range, the maximum range in the variation of capacity factors during the period 1971-1975 and describes the type of change.

Table 6.13 lists the annual average capacity factor and the five year average capacity factor for each of the two size ranges of gas turbines in the state of California. Table 6.15 lists, for each size range, the maximum range in the variation of capacity factor during the 1971-1975 period, and describes the type of change.

The five year average capacity factor is reduced by the lower capacity factors of the later years. This is an apparent improvement in the utilization of gas turbines, with time, in both the U.S., and in particular, the state of California.

While the annual average capacity factors of the smaller size ranges are very close in 1975, the maximum variation is quite different. Average capacity factors of all the gas turbines less than 25MW in the U.S. have reduced twice as much as those for the gas turbines in the state of California.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.2 Plant Capacity Factors (Continued)

Historically, the average capacity factor for the large size (25MW and above) gas turbines have been very low in California and are less than 2%. On the other hand, the average capacity factors for the large size gas turbines in the U.S. have been over 16%, a difference of over eight times.

Table 6.14

GAS TURBINES IN THE U.S.		
Size Range (MW)	Maximum Variation in Capacity Factor (In Percentage Points)	Type of Change
0-24	13.14	Reduction
25 MW & Above	8.26	Reduction

NOTE: The data used to develop chart includes
units of different age, vintage, utilization, etc.

Table 6.15

GAS TURBINES IN CALIFORNIA		
Size Range (MW)	Maximum Variation in Capacity Factor (In Percentage Points)	Type of Change
0-24	7.8	Reduction
25 MW & Above	1.3	Reduction

NOTE: The data used to develop chart includes
units of different age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.3 Plant Operating Availability

Gas turbines have achieved a national average operating availability of 81.3% during the period 1971-1975. This includes all the gas turbines in the U.S. in operation between 1971 and 1975, and on whom Operating Availability data were reported to EEI. A 565 unit-year sample was used to arrive at the national average of 81.3%.

Gas turbines in California have achieved an average operating availability of 28.6% during the period 1971-1975, shown in Table 6.17. This includes all the gas turbines operated by the five major California utilities (Pacific Gas and Electric Co., Southern California Edison Co., San Diego Gas and Electric Co., Sacramento Municipal Utility District and the City of Los Angeles, Department of Water and Power) during this period, and on whom EEI data were available from the FEA. A 123 unit-year sample was used to arrive at the State average operating availability of 28.6%.

The average operating availability of gas turbines in the state of California was lower than that of gas turbines in the U.S. as a whole, for the five year period 1971-1975. The annual average operating availability for gas turbines in California was also lower.

As gas turbines are required only for meeting peak loads, the higher their operating availability, the better. A higher operating availability represents ability over a greater period of time to produce some electric power. From the five year average, and the annual average operating availability figures of Tables 6.16 and 6.17, it can be seen that the state of California can generate electric power from its gas turbines for lesser period of time than can the U.S. as a whole.

The annual average operating availability of gas turbines in the U.S., and the state of California has, in general, reduced during the period 1971-1975. Tables 6.18 and 6.19 list the average operating availability for each of the two size ranges of gas turbines in the U.S. and the state of California. These averages are over the five year period 1971-1975. The two size ranges show different average operating availability figures for both the U.S. and California.

Table 6.16

GAS TURBINES IN THE U.S.		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	25	91.26
1972	57	86.60
1973	85	82.98
1974	200	81.19
1975	198	77.90
1971-1975	565	81.29

Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.17

GAS TURBINES IN CALIFORNIA		
Period	Number of Unit-Years	Average Operating Availability (%)
1971	17	15.63
1972	25	40.88
1973	27	30.29
1974	27	26.31
1975	27	26.05
1971-1975	123	28.62

Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.18

GAS TURBINES IN THE U.S.		
Size Range	Number of Unit-Years	Average Operating Availability (%)
0-24 MW	402	84.52
25 MW & Above	163	73.32

Average over the Five-Year Period 1971-1975
Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.19

GAS TURBINES IN CALIFORNIA		
Size Range	Number of Unit-Years	Average Operating Availability (%)
0-24 MW	104	31.59
25 MW & Above	19	12.34

Average over the Five-Year Period 1971-1975
Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.20

GAS TURBINES IN THE U.S.		
Period	Average Operating Availability (%)	
	0-24 MW	25 MW & Above
1971	92.6	75.9
1972	89.2	81.4
1973	85.9	74.6
1974	85.5	73.0
1975	80.6	70.1
1971-1975	84.5	73.3

Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.21

GAS TURBINES IN CALIFORNIA		
Period	Average Operating Availability (%)	
	0-24 MW	25 MW & Above
1971	19.7	2.4
1972	46.2	1.9
1973	35.3	1.5
1974	30.7	1.1
1975	21.5	52.2
1971-1975	31.6	12.3

Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.3 Plant Operating Availability (Continued)

For gas turbines in the U.S., the five year average operating availability of both size ranges is quite close - they differ by about ten percentage points (10%). However, the gas turbine size exhibits a marked difference in average operating availability for the state of California.

On both the national level and the state of California, the large gas turbines are available for a shorter period of time than the smaller sizes.

Annual average operating availability of different sizes of gas turbines have changed during the period 1971-1975. Table 6.20 lists the annual average operating availability and the five year average operating availability for each of the two size ranges of gas turbines in the U.S. Table 6.22 lists, for each size range, the maximum variation of average operating availability during the period 1971-1975 and describes the trend of the change.

Table 6.21 lists the annual average operating availability and the five year average operating availability for each of the two size ranges of gas turbines in the state of California. Table 6.23 lists, for each gas turbine size range, the maximum variation of average annual operating availability during the 1971-1975 period and describes the five year changing trend.

The average operating availability of all gas turbines has, in general, reduced with time. This is true for the U.S. annual averages while the California annual averages have increased over the period 1971-1975.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.3 Plant Operating Availability (Continued)

Historically, the gas turbines in the U.S. have very close annual average operating availability figures for all sizes, and are in the high eighties (80%). Gas turbines in California, on the other hand, exhibit significantly different annual average operating availability figures for different sizes of gas turbines.

While the historical average operating availability figures can be used to depict historical levels achieved by gas turbines, defining feasible operating availability levels for future sizes of gas turbine is complicated by many factors. Some of the factors that need to be evaluated to assess their effect on gas turbine operating availability, by gas turbine size, are plant design maturity, plant operational maturity (age), utility experience, and utility economic dispatch.

Table 6.22

GAS TURBINES IN THE U.S.		
Size Range (MW)	Maximum Variation in Operating Availability (In Percentage Points)	Type of Change
0-24	12.0	Reduction
25 & Above	11.3	Reduction

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.23

GAS TURBINES IN CALIFORNIA		
Size Range (MW)	Maximum Variation in Operating Availability (In Percentage Points)	Type of Change
0-24	26.5	Increase
25 & Above	51.1	Increase

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.4 - Plant Equivalent Availability

Gas turbines have achieved a national level average Equivalent Availability of 81.2% during the period 1971-1975. This includes all the gas turbines in the U.S. in operation between 1971 and 1975, and on whom operating availability data were reported to EEI. A 565 unit-year sample was used to arrive at the national average of 81.2%.

Gas turbines in California have achieved an average Equivalent Availability of 28.8% during the period 1971-1975 as shown in Table 6.25. This includes all gas turbines operated by five major California utilities (Pacific Gas and Electric Co., Southern California Edison Co., San Diego Gas and Electric Co., Sacramento Municipal Utility District and the City of Los Angeles, Department of Water and Power) during this period and whose data were available in the FEA data base. A 123 unit-year sample was used to arrive at the state average equivalent availability of 28.8%.

The average equivalent availability of gas turbines in the state of California is significantly lower than gas turbines in the U.S., for the five year period 1971-1975. The annual average equivalent availability for gas turbines in California is also lower.

As gas turbines are required only for meeting peak loads, it may be viewed that the higher their equivalent availability the better. A higher equivalent availability represents ability over a greater period of time to produce some electric power. From the five year average and the annual average equivalent availability values of Tables 6.26 and 6.27, it can be seen that the state of California can generate electric power from its gas turbines for a lesser period of time than can the U.S. as a whole.

The annual average equivalent availability of gas turbines in the U.S. and the state of California has, in general, reduced during the period 1971-1975. Tables 6.26 and 6.27 list the average equivalent availability for each of the two size ranges of gas turbines in the U.S. and the state of California. These averages are over the five year period 1971-1975. The two size ranges show different average equivalent availability figures for both the U.S. and California.

Table 6.24

GAS TURBINES IN THE U.S.		
Period	Number of Unit-Years	Average Equivalent Availability (%) [†]
1971	25	91.3
1972	57	86.6
1973	85	83.0
1974	200	81.0
1975	198	77.7
1971-1975	565	81.2

[†] Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.25

GAS TURBINES IN CALIFORNIA		
Period	Number of Unit-Years	Average Equivalent Availability (%) [†]
1971	17	15.6
1972	25	40.8
1973	27	30.6
1974	27	26.8
1975	27	26.1
1971-1975	123	28.8

[†] Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.26

GAS TURBINES IN THE U.S.		
Size Range	Number of Unit-Years	Average [†] Equivalent Availability (%) [‡]
0-24 MW	402	84.5
25 MW & Above	163	73.0

[†] Average over the Five-Year Period 1971-1975
[‡] Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.27

GAS TURBINES IN CALIFORNIA		
Size Range	Number of Unit-Years	Average [†] Equivalent Availability (%) [‡]
0-24 MW	104	31.8
25 MW & Above	19	12.5

[†] Average over the Five-Year Period 1971-1975
[‡] Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.28

GAS TURBINES IN THE U.S.		
Period	Average Equivalent Availability (%) [†]	
	0-24 MW	25 MW & Above
1971	92.6	75.9
1972	89.2	81.4
1973	85.9	74.6
1974	85.5	72.6
1975	80.5	69.5
1971-1975	84.5	73.0

[†] Source: EEI Special Analysis for SDC

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Table 6.29

GAS TURBINES IN CALIFORNIA		
Period	Average Equivalent Availability (%) [†]	
	0-24 MW	25 MW & Above
1971	19.7	2.3
1972	46.2	1.6
1973	35.7	1.4
1974	31.0	2.6
1975	21.6	51.7
1971-1975	31.8	12.5

[†] Source: SDC Analysis of FEA Data

NOTE: The data used to develop chart includes units of different size, age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.4 Plant Equivalent Availability (Continued)

For gas turbines in the U.S. the five year average equivalent availability of both size ranges are quite close - they differ by about ten percentage points (10%). However, the gas turbine sizes exhibit a marked difference in average equivalent availability for the State of California.

On both the national level and the State of California, the large gas turbines are available for a shorter period of time than the smaller sizes, to generate the same amount of electric power.

Annual average equivalent availability of different sizes of gas turbines have changed during the period 1971-1975. Table 6.28 lists the annual average equivalent availability and the five year average equivalent availability for each of the two size ranges of gas turbines in the U.S. Table 6.30 lists, for each size range, the maximum variation of average equivalent availability during the period 1971-1975 and describes the trend of the change.

Table 6.26 lists the annual average equivalent availability and the five year average equivalent availability for each of the two size ranges of gas turbines in the State of California. Table 6.31 lists, for each gas turbine size range, the maximum variation of average annual equivalent availability during the 1971-1975 period and describes the five year change trend.

The annual average equivalent availability of all gas turbines has, in general, reduced with time. This is true for the U.S. annual averages while the California annual averages have increased over the period 1971-1975.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.4 Plant Equivalent Availability (Continued)

Historically, the gas turbines in the U.S. have very close annual average equivalent availability figures for all sizes, and are in the high eighties (80%+). Gas turbines in California, on the other hand, exhibit very different annual average equivalent availability figures for different size gas turbines.

While the historical average equivalent availability figures can be used to depict historical levels achieved by gas turbines, defining feasible levels of future sizes of gas turbine equivalent availabilities, is complicated by many factors. Some of the factors that need to be evaluated to assess their effect on gas turbine equivalent availabilities, is complicated by many factors. Some of the factors that need to be evaluated to assess their effect on gas turbine equivalent availability by gas turbine size are, amongst others, plant design maturity, plant operational maturity (age), utility experience and utility economic dispatch.

Table 6.30

GAS TURBINES IN THE U.S.		
Size Range (MW)	Maximum Variation in Equivalent Availability (In Percentage Points)	Type of Change
0-24	12.1	Reduction
25 & Above	11.9	Reduction

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.31

GAS TURBINES IN CALIFORNIA		
Size Range (MW)	Maximum Variation in Equivalent Availability (In Percentage Points)	Type of Change
0-24	26.5	Increase
25 & Above	50.3	Increase

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.5 Plant Heat Rate

Table 6.29 and 6.30 list the average heat rates for 1973 for gas turbines in the U.S. and the State of California. The 1973 data on plant heat rate was obtained from the Federal Power Commission (FPC) "Gas Turbine Electric Plant Construction Cost and Annual Production Expenses" supplement for 1973. This report lists average heat rates for each gas turbine station. It was assumed, for the purpose of this analysis, that the average heat rate value provided in the report was valid for each gas turbine at the station. The average size of the gas turbine was obtained by dividing the total installed capacity (MW) at the station by the number of gas turbines at the station. This average size was then used to arrive at the average heat rates for the two size ranges.

Gas turbines in the U.S. have operated at a lower heat rate than have gas turbines in the State of California (16918 BTU/KWH vs. 17573 BTU/KWH). Also, the smaller gas turbines exhibit a lower annual average heat rate than do the large gas turbines.

Table 6.32

GAS TURBINES IN THE U.S.		
Range of Average Size of Gas Turbines	Number of Unit-Years	Average Heat Rate [†] (Net) for 1973
Less than 25 MW	597	16364
25 MW & Above	396	17753
All Gas Turbines	993	16918
[†] Source: SDC Analysis of FPC Data		

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Table 6.33

GAS TURBINES IN CALIFORNIA		
Range of Average Size of Gas Turbines	Number of Unit-Years	Average Heat Rate [†] (Net) for 1973
Less than 25 MW	21	17573
25 MW & Above	(No Data)	(No Data)
[†] Source: SDC Analysis of FPC Data		

NOTE: The data used to develop chart includes units of different age, vintage, utilization, etc.

Section 6.0 GAS TURBINE ELECTRIC POWER PLANTS

Subsection 6.6 Key Systems/Components

To identify the key components that have resulted in a reduction in the historical level of each reliability and efficiency index, it was necessary to review the data on historical failures, malfunctions and off-specification performance of gas turbines.

The primary source of gas turbine plant failure data was the Edison Electric Institute Equivalent Availability data bank. Their data bank contains information on the historical failures by Cause Code headings. An EEI cause code heading is a title under which all the outages due to either (1) a group of equipment, (2) similar multiple equipment, or (3) individual equipment, are assigned.

No data was available on historical malfunction or off-specification performance of components, if no failure occurred and if the gas turbine did not undergo a partial or full outage condition.

Tables 6.34 and 6.35 list the EEI cause codes that have been responsible for gas turbine outages. Unit outage projections based upon combination of data of the cause codes in either of the tables should be made with caution: in instances where simultaneous preventative maintenance and repairs were done on more than one component to remove a unit outage condition, the same outage may have been reported under more than one cause code heading.

Table 6.34

GAS TURBINE ELECTRIC POWER PLANTS IN THE U.S.							
Size: 25 MW and Above							
EEI Cause Code	EEI Cause Code Title	Average Equivalent Full Power Outage Hours Per Unit-Year*					Five Year Total 1971-1975
		1971	1972	1973	1974	1975	
300	Gas Turbine...	—	75	—	142	311	528
301	Inlet Air Ducts & Vanes	81	—	1	62	1	145
302	Compressor	18	1	385	124	70	598
304	Fuel Supply System	68	271	18	113	190	660
305	Ignition System	9	32	109	32	8	190
306	Combustion Chamber	149	111	454	260	486	1460
307	Turbine (high pressure)	9	—	82	244	391	726
309	Exhaust Chamber...	43	146	52	40	26	307
311	Regenerators	—	—	—	246	174	420
313	Load Shaft & Bearings	—	42	148	—	95	285
317	Lube Oil System	122	12	11	54	18	417
322	Starting Motor	17	62	—	49	1	129
325	Control & Instrumentation	219	113	102	112	107	653
326	??	—	—	—	64	54	118
348	Inspection (see code 502)	—	—	72	84	368	524
399	Miscellaneous...	1024	94	5	181	13	1317
702	Air Cooling System	—	30	139	1	1	171
712	Exciter	41	3	—	33	64	141
903	Main Transformer	13	4	151	44	33	245
910	Computer	362	43	40	44	8	497

* Source: EEI Special Analysis for SDC

Table 6.35

GAS TURBINE ELECTRIC POWER PLANTS IN THE U.S.							
Size: Below 25 MW							
EEI Cause Code	EEI Cause Code Title	Average Equivalent Full Power Outage Hours Per Unit-Year*					Five Year Total 1971-1975
		1971	1972	1973	1974	1975	
300	Gas Turbine...	22	68	95	242	134	562
304	Fuel Supply System	87	81	33	38	21	260
305	Ignition System	22	20	31	34	2	109
306	Combustion Chamber	42	220	134	66	126	588
307	Turbine (high pressure)	45	—	8	93	196	342
308	Low Pressure Turbine	—	—	—	—	13	13
309	Exhaust Chamber...	48	33	17	17	41	156
313	Load Shaft & Bearings	5	11	70	37	53	176
314	Compressor Shaft...	—	—	115	—	12	127
317	Lube Oil System	20	7	157	29	57	270
322	Starting Motor	19	117	79	52	71	338
324	Turning Gear & Motor	31	5	29	18	38	121
325	Control & Instrumentation	67	57	86	109	53	372
348	Inspection (see code 542)	—	6	81	78	92	257
349	Miscellaneous...	—	—	41	116	85	242
399	Miscellaneous...	62	37	7	26	313	445
900	Other, General Code...	—	—	5	69	53	127
910	Switchgear	16	28	12	27	56	139
999	External Cause...	26	12	62	47	77	224

*Source: EEI Special Analysis for SDC

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Section 7.0

COMBINED CYCLE ELECTRIC POWER PLANTS

Section 7.0 COMBINED CYCLE ELECTRIC POWER PLANTS

Combined cycle plants, wherein gas turbines, heat-recovery boilers and steam turbines are matched to provide an optimum electric generation system, have been, and on most occasions still are, designed to meet specific utility requirements.

Combined cycle plants have been designed for two kinds of operation, from mid-range service to those for peaking service only.

Two off-the-shelf package plants are currently available in the United States; the General Electric "STAG" system and the Westinghouse "PACE" system.

The data available on combined cycle plants is severely limited. As most of the plants have been designed to meet the specific requirements of each utility, the historical data cannot be combined to arrive at averages or ranges for each of the recommended indices. The index averages and ranges obtained is very dependent upon the plant design and its specific application/use by the utility.

Table 7.1 lists some of the rough estimates gleaned by SDC from telephone conversations with utilities around the country. These figures are in most cases "best estimates" and have not been substantiated by rigorous analysis. No industry group (EEI etc.) collects any historical data on combined cycle plants, individually. The Federal Power Commission (FPC) notes the existence of combined cycle plants but does not publish historical data on the four recommended indices, either.

Table 7.1

COMBINED CYCLE ELECTRIC POWER PLANTS	
Index	Range of Estimates
Capacity Factor (%)	50 - 90
Equivalent Availability (%)	53 - 95
Operating Availability (%)	60 - 95
Heat Rate (net)	9400 - 12,400

SECTION 8.0

GAS FIRED STEAM ELECTRIC POWER PLANTS

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.1 Introduction

Four indices of power plant reliability and efficiency are recommended for use by the State of California, Energy Conservation and Development Commission, in the evaluation of utility AFC submittals for new power plants. These indices are 1) Capacity Factor, 2) Operating Availability, 3) Equivalent Availability and 4) Heat Rate.

No gas fired plants are planned to be sited in the state of California during the period 1980-1995. Thus, projections of feasible ranges of the reliability and efficiency indices, for new gas fired plants, are not made. The results of analysis of available historical data on the indices is, however, included in this section.

The analysis to determine the historical levels achieved, of the reliability and efficiency indices, by gas fired plants was based upon the data available for the period 1971-1975. Data were analysed at the national level and for the state of California. Table 8.1 lists the number of units on which data was analysed for each of the five years, 1971, 1972, 1973, 1974 and 1975, to determine the ranges and averages of capacity factor, operating availability and equivalent availability.

The principal source of annual average capacity factor, annual average operating availability and annual average equivalent availability of national data was the Edison Electric Institutes's (EEI) Equipment Availability Data Bank. Annual summaries for each of these three indices were purchased by SDC from EEI. Table 8.1 lists the number of units EEI used to arrive at the annual summaries. As it is EEI's policy is not to reveal the individual plants comprising these data summaries, a list of the plants included in each year's analysis is not available.

The principal source of data on oil plants in California was the EEI data supplied by FEA. Table 8.1 lists the number of units on whom data were analysed by SDC.

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANT

Subsection 8.1 Introduction (Continued)

The number of units included by the EEI in the national historical data summaries are less than these identified by SDC as having operated on oil fuel in California in 1971 and 1972. The reason why less units are included in the EEI analysis for these years could not be ascertained.

The primary source of annual average heat rates of existing gas fired steam electric plants was the Federal Power Commission's (FPC) "Steam Electric Plant Construction Cost and Annual Production Expenses Supplements." Very few plants were operated during the time period 1971-1975 on gas fuel alone. A secondary major fuel was oil. The heat rate averages and ranges are also presented for "oil and gas" fired units. The results of this analysis are presented in subsection 8.5. The heat rate data results are based on 652 units for 1973. Data on other years were not evaluated.

The plants were separated into six ranges based upon their maximum dependable capacity. These six ranges were 60-89MW, 90-129MW, 130-199MW, 200-389MW, 390-599MW, and 600MW-and-greater. Plants less than 60MW were not included in this analysis.

Table 8.1

GAS FIRED STEAM ELECTRIC POWER UNITS		
YEAR	Number of Units*	
	U.S. [†]	CALIFORNIA ^{††}
1971	30	1
1972	32	1
1973	33	44
1974	33	39
1975	33	39
*Number of units in data base for computation of CF, OA and EA historical ranges and averages		
[†] Source: EEI special analysis for SDC		
^{††} Source: SDC analysis of EEI data supplied by FEA		

Section 8.1 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.1 Introduction (Continued)

The historical data on CF, EA, and OA of gas fired plants were analysed for each of the six ranges to determine averages and ranges of these three indices as follows:

1. Average values for California and National gas fired plant data,
2. Average values by each of six discrete size classifications.

The averages were computed for each of the years 1971, 1972, 1973, 1974 and 1975; an average for the period 1971-1975 was also computed.

No new gas fired units are projected for siting and startup in California. Details of the analysis of national gas fired unit data and gas units in California is provided in the following section. It is recognized that the historical values achieved of the three indices by a gas fired plant are subject to many factors, e.g., differences in unit design maturity, vintage, unit age, utility experience, etc. As no gas fired new units are proposed to be sited in California, no attempt was made to analyze the data to evaluate the effects of these factors on the indices.

Analysis results of U.S. gas fired power plant data on the four recommended indices can be summarized as follows:

- 1) Gas fired units greater than 60MW have operated at an average capacity factor of 56.6%, average equivalent availability of 84.5% average operating availability of 85.3% during the five-year period 1971-1975. The data used to develop these figures includes units of of different size, design, vintage and utilization.
- 2) The annual average capacity factor has declined more than equivalent availability and operating availability which have remained about constant over the five-year study period (1971-1975). These trends are exhibited by the size ranges of all units in the U.S.

Table 8.2

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)	Average Equivalent Availability [†] (%)	Average Operating Availability [†] (%)
1971	30	58.23	83.7	84.36
1972	32	58.27	82.8	83.35
1973	33	59.72	88.1	88.62
1974	33	56.33	84.3	85.70
1975	33	50.60	83.6	84.50
1971-1975	161	56.59	84.5	85.32
NOTE: The data used to develop chart includes units of different size, design, age, vintage, utilization, etc.				
[†] Source: EEI special analysis for SDC				

Table 8.3

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Size Range	Number of Unit-Years ^{††}	Average [†] Capacity Factor ^{††} (%)	Average [†] Equivalent Availability ^{††} (%)	Average [†] Operating Availability ^{††} (%)
60-89 MW	13	35.27	88.6	88.76
90-129 MW	20	45.75	85.9	86.10
130-199 MW	18	69.57	88.3	88.90
200-389 MW	67	54.93	83.6	84.80
390-599 MW	34	66.29	85.0	85.53
600 MW & Above	9	60.95	73.2	74.48
NOTE: The data used to develop chart includes units of different design, age, vintage, utilization, etc.				
[†] Average over the five-year period 1971-1975				
^{††} Source: EEI special analysis for SDC				

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.2 Plant Capacity Factor

Gas fired power plants have operated at a national average capacity factor of 56.6% during the period 1971-1975 (see Table 8.4). This includes all gas fueled plants in operation in the U.S. during the five-year period 1971-1975, and on which data was available from EEL. A 161 unit-year sample is the basis of this national average of 56.6%.

Gas fired plants in California have operated at an average capacity factor of 48.3% during the same 1971-1975 period. This five year average capacity factor is based on a 124 unit-year sample (see Table 8.5). The five year average capacity factor for gas fired plants in the state of California is lower than the average of all gas fired plants in the U.S.

Average annual capacity factors for gas fired plants in the U.S. and the state of California have varied from year to year. The maximum range of variation of average annual capacity factors for all U.S. plants is 9.1% while that for California plants is 26.9%. Annual average capacity factors of gas fired plants in California have, in general, steadily declined over the years. As shown in Table 8.5, the five year average of 48.3% is influenced (reduced) by the low average capacity factor of later years. For plants on a national basis, a similar reduction is apparent from Table 8.4.

From national gas fired plant data, it appears that the average annual capacity factor is, generally, proportional to the plant size. Table 8.6 presents the average capacity factors for each MW size range for the period 1971 through 1975. The highest average of 69.6% was achieved by the 130-199MW group.

Gas fired plants in the state of California also show average capacity factors varying with size. The largest plants exhibit lower average capacity factors as shown in Table 8.7. The Table lists the average five year capacity factors for California's gas fired plants by each size range.

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	30	58.23
1972	32	58.27
1973	33	59.72
1974	33	56.33
1975	33	50.60
1971-1975	161	56.59
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 8.5

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	1	27.6
1972	1	40.6
1973	44	54.53
1974	39	43.80
1975	39	46.76
1971-1975	124	48.28
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 8.6

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years ^{††}	Average [†] Capacity Factor ^{††} (%)
60-89 MW	13	35.27
90-129 MW	20	45.75
130-199 MW	18	69.57
200-389 MW	67	54.93
390-599 MW	34	66.29
600 MW & above	9	60.95
[†] Average over the five year period 1971-1975		
^{††} Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.7

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size Range	Number of Unit-Years ^{††}	Average [†] Capacity Factor ^{††} (%)
60-89 MW	17	67.32
90-129 MW	23	40.40
130-199 MW	37	45.79
200-389 MW	30	48.63
390-599 MW	8	40.71
600 MW & above	9	49.63
[†] Average over the five year period, 1971-1975		
^{††} Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS
Subsection 8.2 Plant capacity Factors (Continued)

Annual average capacity factors of U.S. plants in all the size ranges have changed during the 1971-1975 period as shown in Tables 8.8 through 8.13. The highest annual average capacity factor (81.8% in 1971) is recorded for the 130-199MW size range (Table 8.10). The lowest annual average capacity factor (26.7% in 1971) is recorded for the 60-89MW size range (Table 8.8). Except for isolated instances, the annual average capacity factors, as shown by these tables are predominantly less than 70%.

Table 8.8

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	3	26.7
1972	3	30.7
1973	3	31.0
1974	2	48.8
1975	2	47.9
1971-1975	13	35.3
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.9

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	4	46.7
1972	4	56.3
1973	4	53.7
1974	4	45.0
1975	4	27.3
1971-1975	20	45.8
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 130-194 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	3	81.8
1972	3	80.1
1973	4	71.1
1974	4	72.3
1975	4	48.2
1971-1975	18	69.6
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.11

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 200-309 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	12	58.6
1972	13	57.1
1973	13	58.2
1974	15	49.9
1975	14	52.7
1971-1975	67	54.9
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.12

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 190-199 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	7	70.4
1972	7	61.0
1973	7	68.9
1974	6	69.7
1975	7	62.0
1971-1975	34	66.3
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.13

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	1	39.9
1972	2	69.1
1973	2	70.0
1974	2	65.0
1975	2	50.2
1971-1975	9	61.0
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.2 Plant Capacity Factor (Continued)

Annual average capacity factors of California plants, of all size ranges, have changed during the 1971-1975 period as shown in Tables 8.14-8.19. The highest annual average capacity factor (76.9% in 1973) is recorded by 60-89MW size range (Table 8.14). The lowest annual average capacity factor (27.6% in 1971) was also recorded for the 60-89MW size range (Table 8.14). Except for isolated instances, the annual average capacity factors, as shown by these tables, are predominantly less than 60%.

Table 8.14

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	1	27.6
1972	1	40.6
1973	5	76.9
1974	5	71.3
1975	5	67.0
1971-1975	17	67.3
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.15

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 90-120 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	—	—
1972	—	—
1973	9	45.4
1974	7	36.3
1975	7	38.1
1971-1975	23	40.4
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	—	—
1972	—	—
1973	15	51.8
1974	11	41.6
1975	11	41.8
1971-1975	37	45.8
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.17

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	—	—
1972	—	—
1973	10	54.1
1974	10	44.2
1975	10	47.6
1971-1975	30	48.6
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.18

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	—	—
1972	—	—
1973	2	58.0
1974	3	29.2
1975	3	40.7
1971-1975	8	40.7
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.19

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 600 MW & above		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	—	—
1972	—	—
1973	3	57.4
1974	3	36.7
1975	3	54.8
1971-1975	9	49.6
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.3 Plant Operating Availability

Gas fired power plants have operated at a national average operating availability of 85.3% during the period 1971-1975 (see Table 8.20). This includes all gas fueled plants in operation in the U.S. during the five-year period 1971-1975, and on which data was available from EEI. A 161 unit-year sample is the basis of this national average of 85.3%

Gas fired plants in California have operated at an average operating availability 84.8% during the same 1971-1975 period. This five year average operating availability is based on a 124 unit-year sample (see Table 8.21). The five year average operating availability for gas fired plants in the state of California is slightly lower than the average of all gas fired plants in the U.S.

Average annual operating availability for gas fired plants in the U.S. and the state of California have varied from year to year. The maximum range of variation of average annual operating availability for all U.S. plants is 5.3% while that for California plants is 13.1%. Annual average operating availability of gas fired plants in California have, in general, steadily declined over the years. As shown in Table 8.21, the five year average of 84.8% is influenced (reduced) by the low average operating availability of later years. For plants on a national basis, a similar reduction is apparent from Table 8.20.

From National gas fired plant data, it appears that the average annual operating availability is, generally, inversely proportional to the plant size. Table 8.22 presents the average operating availability for each MW size range for the period 1971 through 1975. The highest average of 88.9% was achieved by 130-199MW group.

Gas fired plants in the state of California exhibit an average operating availability varying with size. The largest plants exhibit lower average operating availability as shown in Table 8.23. It lists the average five year operating availability for California's plants by each size range.

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	30	84.36
1972	32	83.35
1973	33	88.62
1974	33	85.70
1975	33	84.50
1971-1972	161	85.32
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 8.21

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	1	79.5
1972	1	92.6
1973	44	86.51
1974	39	83.53
1975	39	84.23
1971-1975	124	84.85
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 8.22

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years ^{††}	Average [†] Operating Availability ^{††} (%)
60-89 MW	13	88.76
90-120 MW	20	86.10
130-199 MW	18	88.90
200-389 MW	67	84.80
390-599 MW	34	85.53
600 MW & above	9	74.48
[†] Average over the five year period, 1971-1975		
^{††} Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.23

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size Range	Number of Unit-Years ^{††}	Average [†] Operating Availability ^{††} (%)
60-89 MW	17	92.09
90-129 MW	23	92.42
130-199 MW	37	87.64
200-389 MW	30	82.40
390-599 MW	8	57.33
600 MW & above	9	73.00
[†] Average over the five year period 1971-1975		
^{††} Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.3 Plant Operating Availability (Continued)

Annual average operating availability of U.S. gas fired plants, in all the size ranges have changed during the 1971-1975 period as shown in Tables 8.24 through 8.29. The highest annual average operating availability (96.6% in 1974) is recorded for the 130-199MW size range (Table 8.26). The lowest annual average operating availability (55.7% in 1971) is recorded for the 600MW & above size range (Table 8.29). Except for isolated instances, the annual average operating availability, as shown by these tables, lies in the range 70-90%.

Table 8.24

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	3	92.5
1972	3	95.4
1973	3	89.6
1974	2	92.3
1975	2	68.4
1971-1975	13	88.8
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.25

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	4	82.8
1972	4	85.9
1973	4	88.8
1974	4	87.1
1975	4	85.9
1971-1975	20	86.1
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	3	81.2
1972	3	86.6
1973	4	87.3
1974	4	96.6
1975	4	90.3
1971-1975	18	88.9
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.27

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	12	85.0
1972	13	82.1
1973	13	91.1
1974	15	81.5
1975	14	84.8
1971-1975	67	84.8
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.28

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	7	86.1
1972	7	78.2
1973	7	89.7
1974	6	88.8
1975	7	85.8
1971-1975	34	85.5
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.29

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	1	55.7
1972	2	81.4
1973	2	69.6
1974	2	76.7
1975	2	79.6
1971-1975	9	74.5
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.3 Plant Operating Availability (Continued)

Annual average operating availability of California plants of all size range plants have changed during the 1971-1975 period as shown in Tables 8.30-8.35. The highest annual average operating availability (94.2% in 1974) is recorded by the 60-89MW size range (Table 8.30). The lowest annual average operating availability 47.3% in 1974) was recorded for the 390-599MW size range (Table 8.34). Except for isolated instances, the annual average operating availability, as shown by these tables, range between 70% and 30%.

Table 8.30

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	1	79.5
1972	1	92.6
1973	5	93.7
1974	5	94.2
1975	5	90.8
1971-1975	17	92.1
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.31

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	—	—
1972	—	—
1973	9	93.6
1974	7	91.7
1975	7	91.6
1971-1975	23	92.4
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	—	—
1972	—	—
1973	15	87.1
1974	11	89.0
1975	11	87.0
1971-1975	37	87.6
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.33

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	—	—
1972	—	—
1973	10	82.8
1974	10	83.7
1975	10	80.7
1971-1975	30	82.4
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.34

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	—	—
1972	—	—
1973	2	65.2
1974	3	47.3
1975	3	62.1
1971-1975	8	57.3
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.35

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	—	—
1972	—	—
1973	3	76.8
1974	3	62.2
1975	3	80.0
1971-1975	9	73.0
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.4 Plant Equivalent Availability

Gas fired power plants have operated at a national average equivalent availability of 84.5% during the period 1971-1975 (see Table 8.36). This includes all gas fueled plants in operation in the U.S. during the five-year period 1971-1975, and on which data was available from EEI. A 161 unit-year sample is the basis of this national average of 84.5%.

Gas fired plants in California have operated at an average equivalent availability of 80.9% during the same 1971-1975 period. This five year average equivalent availability is based on a 124 unit-year sample (see Table 8.37). The five year average equivalent availability for gas fired plants in the state of California is lower than the average of all gas fired plants in the U.S.

Average annual equivalent availability for gas fired plants in the U.S. and the state of California have varied from year to year. The maximum range of variation of average annual equivalent availability for all U.S. plants is 5.3% while that for California plants is 14.1%. Annual average equivalent availability for California plants have, in general, steadily declined over the years. As shown in Table 8.37, the five year average of 80.9% is influenced (reduced) by the low average equivalent availability of later years. For national plants, a similar reduction is apparent from Table 8.36.

From national gas fired plant data, it appears that the average annual equivalent availability is, generally, independent of the plant size. Table 8.38 presents the average equivalent availability for each MW size range for the period 1971 through 1975. The highest average of 88.6% was achieved by the 60-89MW group.

Gas fired plants in the state of California exhibit average equivalent availability varying with plant size. The largest plants exhibit lower average equivalent availability as shown in Table 8.39. The table lists the average five year equivalent availability for California's gas fired plants by each size range.

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	30	83.7
1972	32	82.8
1973	33	88.1
1974	33	84.3
1975	33	83.6
1971-1975	161	84.5
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 3.37

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	1	79.5
1972	1	92.3
1973	44	83.9
1974	39	80.1
1975	39	78.2
1971-1975	124	80.9
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 8.38

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years ^{††}	Average [†] Equivalent Availability ^{††} (%)
60 - 89 MW	13	88.6
90-129 MW	20	85.9
130-199 MW	18	88.3
200-389 MW	67	83.6
390-599 MW	34	85.0
600 MW & Above	9	73.2
[†] Average over the five year period, 1971-1975		
^{††} Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.39

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size Range	Number of Unit-Years ^{††}	Average Equivalent Availability ^{††} (%)
60 - 89 MW	17	86.4
90-129 MW	23	90.1
130-199 MW	37	85.0
200-389 MW	30	77.9
390-599 MW	8	52.3
600 MW & Above	9	66.0
[†] Average over the five year period, 1971-1975		
^{††} Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.4 Plant Equivalent Availability (Continued)

Annual average equivalent availability of U.S. plants, in all the size ranges, have changed during the 1971-1975 period as shown in Tables 8.40 through 8.45. The highest annual average equivalent availability (95.3% in 1972) is recorded for the 60-89MW size range (Table 8.40). The lowest annual average equivalent availability (53.5% in 1971) is recorded for the 600MW and above size range (Table 8.45). Except for isolated instances, the annual average, as shown by these tables lie within the range 70% - 80%.

Table 8.40

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	3	92.5
1972	3	95.3
1973	3	89.6
1974	2	91.6
1975	2	68.3
1971-1975	13	88.6
[†] Source: EEL special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.41

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	4	82.7
1972	4	85.9
1973	4	88.8
1974	4	87.1
1975	4	85.0
1971-1975	20	85.9
[†] Source: EEL special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	3	81.2
1972	3	86.6
1973	4	86.9
1974	4	94.7
1975	4	89.9
1971-1975	18	88.3
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.43

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	12	83.9
1972	13	81.1
1973	13	90.4
1974	15	79.5
1975	14	83.7
1971-1975	67	83.6
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.44

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	7	85.7
1972	7	77.6
1973	7	89.1
1974	6	88.3
1975	7	84.9
1971-1975	34	85.0
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.45

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	1	53.5
1972	2	81.1
1973	2	68.3
1974	2	74.9
1975	2	78.2
1971-1975	9	73.2
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.4 Plant Equivalent Availability (Continued)

Annual average equivalent availability of California plants, of all size ranges, have changed during the 1971-1975 period as shown in Tables 8.46-8.51. The highest annual average equivalent availability (93.9% in 1973) is recorded by the 60-89MW size range (Table 8.46). The lowest annual average equivalent availability (45.1% in 1974) was recorded for the 380-599MW size range (Table 8.50). Except for isolated instances, the annual average equivalent availability, as shown by these tables, for California gas fired plants lies between 70% and 90%.

Table 8.46

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	1	79.5
1972	1	92.3
1973	5	93.6
1974	5	93.9
1975	5	71.9
1971-1975	17	86.4
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.47

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	—	—
1972	—	—
1973	9	92.6
1974	7	89.8
1975	7	87.1
1971-1975	23	90.1
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.48

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	—	—
1972	—	—
1973	15	85.6
1974	11	85.4
1975	11	83.9
1971-1975	37	85.0
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.49

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	—	—
1972	—	—
1973	10	78.2
1974	10	78.2
1975	10	77.2
1971-1975	30	77.9
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.50

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 380-599 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	—	—
1972	—	—
1973	2	59.1
1974	3	45.1
1975	3	54.9
1971-1975	8	52.3
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 8.51

GAS FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	—	—
1972	—	—
1973	3	68.1
1974	3	56.7
1975	3	73.3
1971-1975	9	66.0
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.4 Plant Heat Rate

The primary source of annual average heat rate data on existing gas fired power plants, in the U.S., was the Federal Power commission's (FPC) "Steam Electric Plant Construction Cost and Annual Production Expense Supplements". This publication contains, heat rate data by each plant station and not by individual units comprising the power plant. No data was available on individual units for plants in the U.S.

Heat Rate data available from the FPC publication for plants in operation in 1973 was analyzed to arrive at historical averages and ranges of heat rate. For the year 1973, 24 power plants were identified that used only gas as fuel. The plants varied from one unit plants to those madeup of six units. A total installed capacity of 8356.1MW was shared between these twenty-four stations by a total of sixty-seven (67) units. The average heat rate for each unit was 12385 BTU/KWH for 1973. As the heat rate data was available only at the station level it was not possible to analyze the heat rates for each of the six established plant size ranges.

Gas was a fuel used by plants, other than the 24 analyzed above, along with oil. Data or heat rates of plants using gas and oil as fuel was analyzed. The results are shown in Table 8.52.

Table 8.52

GAS FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Fuel	Number of Units	Average Heat Rate ⁺ (BTU/net KWH) (1973)
Gas only	67	12384
Gas & Oil	583	12101
<p>Note: The data used to develop chart includes units of different size, age, design, utilization, etc.</p> <p>+Source: SDC analysis of FPC data</p>		

Section 8.0 GAS FIRED STEAM ELECTRIC POWER PLANTS

Subsection 8.5 Key Component/Systems

Data on the components and systems of gas fired plants have historically been responsible for reduced capacity factors, equivalent availability and operating availability (plant power reductions or plant outages) were reviewed to arrive at a listing of the key components and systems.

The primary source of gas fired plant outages or power reduction data was the Edison Electric Institute (EEI) Equipment Availability Task Force Data Bank. This data bank contains, information on the historical failures by Cause Code Headings. An EEI Cause Code Heading is a title under which all the outages due to either 1) a group of equipment, 2) similar multiple equipment, or 3) individual equipment, are assigned.

No data was available on historical malfunction or off-specification performance of components/systems if no plant partial or full outage occurred.

The period 1971-1975 was chosen for identification of key components and systems. No component/system data on plants using gas only as fuel as available through EEI.

SECTION 9.0

OIL FIRED STEAM ELECTRIC POWER PLANTS

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.1 Introduction

Four indices of power plant reliability and efficiency are recommended for use by the state of California, Energy Conservation and Development Commission, in the evaluation of utility AFC submittals for new power plants. These indices are 1) Capacity Factor, 2) Operating Availability, 3) Equivalent Availability and 4) Heat Rate.

No oil fired plants are planned to be sited in the state of California during the period 1980-1995. Thus, projections of feasible ranges of the reliability and efficiency indices for new oil fired plants are not made. The results of analysis of available historical data on the indices is, however, included in this section.

The analysis to determine the historical levels achieved, of the reliability and efficiency indices, by oil fired plants was based upon the data available for the period 1971-1975. Data were analysed at the national level and for the state of California. Table 9.1 lists the number of units on which data was analysed for each of the five years, 1971, 1972, 1973, 1974 and 1975, to determine the ranges and averages of capacity factor, operating availability and equivalent availability.

The principal source of annual average capacity factor, annual average operating availability and annual average equivalent availability of national data was the Edison Electric Institute's (EEI) Equipment Availability Data bank. Annual summaries for each of these three indices were purchased by SDC from EEI. Table 9.1 lists the number of units EEI used to arrive at the annual summaries. As it is EEI's policy not to reveal the individual plants comprising these data summaries, a list of the plants included in each year's analysis is not available.

The principal sources of data on oil plants in California was the EEI data supplied by FEA. Table 9.1 lists the number of units on whom data were analyzed by SDC.

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.1 Introduction (Continued)

The number of units included by EEI in the National historical data summaries for the historical analysis are less than these identified by SDC as having operated on oil fuel in California in 1971 and 1972. The reason why less units are included in the EEI analysis for these years could not be ascertained.

The primary source of annual average heat rates of existing oil fired steam electric plants was the Federal Power Commission's (FPC) "Steam Electric Plant Construction Cost and Annual Production Expenses Supplements." Few plants were operated during the time period 1971-1975 on oil fuel alone. A secondary major fuel was natural gas. The heat rate averages and ranges are, thus, presented for "oil and gas" fired units together. The results of the analysis are included in subsection 9.5.

The plants were separated into six ranges based upon their maximum dependable capacity. These six ranges were 60-89MW, 90-129MW, 130-199MW, 200-389MW, 390-599MW and 600MW-and-greater. Plants less than 60MW were not included in this analysis.

Table 9.1

OIL FIRED STEAM ELECTRIC POWER UNITS		
Year	Number of Units*	
	U.S.†	California††
1971	28	54
1972	32	56
1973	34	21
1974	39	27
1975	46	27
†Source: EEI special analysis for SDC		
††Source: SDC analysis of California utility/unit data		
*Number of units in data base for computation of CF, OA and EA averages		

Section 9.0 - OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.1 - Introduction (Continued)

The historical data on CF, EA, and OA, of oil fired plans were analysed, for each of the six size ranges, to determine averages and ranges of these three indices as follows:

1. Average values for California and National oil fired plant data,
2. Average values by each of six discrete size classifications for National data and California plants.

The averages were computed for each of the years 1971, 1972, 1973, 1974 and 1975; an average for the period 1971-1975 was also computed.

No new oil fired units are projected for siting and startup in California. Details of the analysis of national oil fired unit data, and oil fired units in California is provided in the following sections. It is recognized that historical values achieved of these indices by an oil fired plant are subject to many factors, e.g., differences in unit design maturity, vintage, age utility experience, etc. As no new units are proposed to be sited in California, no attempt was made to analyze the data to evaluate the effects of these factors on the indices.

Analysis results of U.S. oil fired power plant data on the recommended indices can be summarized as follows:

- 1) Oil fired power units greater than 60MW have operated at an average capacity factor of 59.2% average equivalent availability of 78.5%, average operating availability of 83.4% during the five-year period 1971-1975. The data used to develop these figures includes units of different size, design, age, vintage and utilization.
- 2) The annual average capacity factor has declined more than equivalent availability and operating availability which have remained about constant over the five-year study period (1971-1975). These trends are exhibited by all the size ranges of oil fired units in the U.S.

Table 9.2

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)	Average Equivalent Availability [†] (%)	Average Operating Availability [†] (%)
1971	28	65.46	80.9	82.49
1972	32	64.47	82.3	84.70
1973	34	63.66	82.9	85.45
1974	39	58.06	79.3	82.82
1975	46	49.30	70.5	74.23
1971-1975	179	59.20	78.5	83.40

NOTE: The data used to develop chart includes units of different size, design, age, vintage, utilization, etc.

[†]Source: EEI special analysis for SDC

Table 9.3

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.				
Size Range	Number of Unit-Years ^{††}	Average [†] Capacity Factor (%) ^{††}	Average [†] Equivalent Availability ^{††} (%)	Average [†] Operating Availability ^{††} (%)
60-89 MW	18	72.96	90.9	91.36
90-129 MW	52	66.44	88.6	88.93
130-199 MW	28	40.52	70.4	72.79
200-389 MW	23	58.20	64.2	70.20
390-599 MW	44	59.72	76.0	81.12
600 & Above	14	52.18	78.5	77.10

NOTE: The data used to develop chart includes units of different design, age, vintage, utilization, etc.

[†]Average over the five-year period 1971-1975

^{††}Source: EEI special analysis for SDC

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.2 Plant Capacity Factor

Oil fired power plants have operated at a national average capacity factor of 59.2% during the period 1971-1975 (see Table 9.4). This includes all oil fueled plants in operation in the U.S. during the five-year period 1971-1975, and on which data was available from EEI. A 179 unit-year sample is the basis of this national average of 59.2%.

Oil fired plants in California have operated at an average capacity factor of 45.2% during the same 1971-1975 period. This five year average capacity factor is based on a 185 unit-year sample (see Table 9.5). The five-year average capacity factor for oil fired plants in the state of California is lower than the average of all oil fired plants in the U.S.

Average annual capacity factors of oil fired plants in the U.S. and the state of California have varied from year to year. The maximum range of variation of average annual capacity factors for all U.S. plants is 16.2% while that for California plants is 19.2%. Annual average capacity factors of oil fired plants in California have, in general, steadily declined over the years. As shown in Table 9.5, the five year average of 45.2% is influenced (reduced) by the low average capacity factor of later years. For plants on a national basis, a similar reduction is apparent from Table 9.4.

From national oil fired plant data, it appears that the average annual capacity factor is, generally, inversely proportional to the plant size. Table 9.6 presents the average capacity factors for each MW size range for the period 1971 through 1975. The highest average of 72.96% was achieved by the 60-89MW group.

Oil fired plants in the state of California also show average capacity factors varying with size. The smallest and largest plants exhibit lower average capacity factors as shown in Table 9.7. It lists the average five year capacity factors for California's oil fired plants by each size range.

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.

Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	28	65.46
1972	32	64.47
1973	34	63.66
1974	39	58.06
1975	46	49.30
1971-1975	179	59.20

[†]Source: EEI special analysis for SDC

Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 9.5

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA

Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	54	46.52
1972	56	53.01
1973	21	51.46
1974	27	33.25
1975	27	33.07
1971-1975	185	45.15

[†]Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.

Table 9.6

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.

Size Range	Number of Unit Years ^{††}	Average [†] Capacity Factor (%) ^{††}
60-89 MW	18	72.96
90-129 MW	52	66.44
130-199 MW	28	40.52
200-389 MW	23	58.20
390-599 MW	44	59.72
600 & above	14	52.18

[†]Average over the five year period 1971-1975
^{††}Source: EEI special analysis for SDC

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Table 9.7

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA

Size Range	Number of Unit-Years ^{††}	Average [†] Capacity Factor (%) ^{††}
60-89 MW	28	33.01
90-129 MW	22	30.37
130-199 MW	68	46.75
200-389 MW	40	55.54
390-599 MW	14	52.23
600 MW & Above	13	47.26

[†]Average over the five year period 1971-1975
^{††}Source: SDC analysis of EEI data supplied by FEA

Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.2 Plant Capacity Factors (Continued)

Annual average capacity factors of U.S. plants in all the size ranges, have changed during the 1971-1975 period as shown in Tables 9.8 through 9.13. The highest annual average capacity factor (81.2% in 1975) is recorded for the 60-89MW size range (Table 9.8). The lowest annual average capacity factor (25.2% in 1975) is recorded for the 130-199MW size range (Table 9.10). Except for isolated instances, the annual average capacity factors, as shown by these tables are predominantly less than 70%.

Table 9.8

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	4	76.33
1972	5	74.66
1973	4	68.17
1974	3	66.49
1975	2	81.24
1971-1975	18	72.96
†Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.9

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 90-129 MW		
Period	Number of Unit-Years	Average Capacity Factor (%)
1971	9	66.8
1972	9	68.5
1973	11	69.1
1974	11	68.2
1975	12	60.6
1971-1975	52	66.4
†Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.10

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	5	47.6
1972	5	46.7
1973	5	49.2
1974	5	43.1
1975	8	25.2
1971-1975	28	40.5
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.11

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	4	65.8
1972	4	66.2
1973	4	55.5
1974	6	53.9
1975	5	53.2
1971-1975	23	58.2
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.12

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	4	74.0
1972	7	63.0
1973	8	66.0
1974	12	57.9
1975	13	51.5
1971-1975	44	59.7
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.13

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 600 MW and above		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	2	68.1
1972	2	67.1
1973	2	68.2
1974	2	41.3
1975	2	40.2
1971-1975	6	52.2
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.2 Plant Capacity Factor--(Continued)

Annual average capacity factors of California plants, of all size ranges, have changed during the 1971-1975 period as shown in Tables 9.14-9.19. The highest annual average capacity factor (66.9% in 1973) is recorded by the 200-389MW size range (Table 9.17). The lowest annual average capacity factor (4.3% in 1975) was recorded for the 60-89MW size range (Table 9.14). Except for isolated instances, the annual average capacity factors, as shown by these tables, are predominantly less than 60%.

Table 9.14

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	6	56.8
1972	7	58.5
1973	5	24.3
1974	5	6.3
1975	5	4.3
1971-1975	28	33.0
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.15

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	9	32.0
1972	9	37.7
1973	—	—
1974	2	9.0
1975	2	11.6
1971-1975	22	30.4
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.16

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	21	45.7
1972	21	52.3
1973	6	57.3
1974	10	40.7
1975	10	37.0
1971-1975	68	46.8
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.17

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	11	51.0
1972	11	60.3
1973	6	66.9
1974	6	48.5
1975	6	50.8
1971-1975	40	55.5
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.18

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	4	54.7
1972	4	58.4
1973	2	60.7
1974	2	42.6
1975	2	43.1
1971-1975	14	53.2
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.19

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 600 MW and Above		
Period	Number of Unit-Years [†]	Average Capacity Factor [†] (%)
1971	1	48.0
1972	4	56.2
1973	2	46.4
1974	2	32.7
1975	2	43.7
1971-1975	13	47.3
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.3 Plant Operating Availability

Oil fired power plants have operated at a national average operating availability of 83.4% during the period 1971-1975 (see Table 9.20). This includes all oil fueled plants in operation in the U.S. during the five-year period 1971-1975, and on which data was available from EEI. A 179 unit-year sample is the basis of this national average of 83.4%.

Oil fired plants in California have operated at an average operating availability of 83.6% during the same 1971-1975 period. This five-year average operating availability is based on a 185 unit-year sample (see Table 9.21). The five-year average operating availability for oil fired plants in the state of California equals the average of all oil fired plants in the U.S.

Average annual operating availability of oil fired plants in the U.S. and the state of California have varied from year to year. The maximum range of variation of average annual operating availability for all U.S. plants is 11.2% while that for California plants is 12.9. Annual average operating availability of oil fired plants in California have, in general, steadily declined over the years. As shown in Table 9.21 the five year average of 83.6% is influenced (reduced) by the low average operating availability of recent years. For plants on a national basis, a similar reduction is apparent from Table 9.20.

From national oil fired plant data, it appears that the average annual operating availability is, generally, inversely proportional to the plant size. Table 9.22 presents the average operating availability for each MW size range, for the period 1971 through 1975. The highest average of 91.4% was achieved by the 60-89MW group.

Oil fired plants in the state of California also show average operating availabilities varying with size. The larger plants exhibit lower average operating availabilities as shown in Table 9.23. It lists the average five year capacity factors for California's oil fired plants by each size range.

TABLE 9.20

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit Years [†]	Average Operating Availability [†] (%)
1971	28	82.49
1972	32	84.70
1973	34	85.45
1974	39	82.82
1975	46	74.23
	179	83.40
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 9.21

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Period	Number of Unit Years [†]	Average Operating Availability [†] (%)
1971	54	87.88
1972	56	83.60
1973	21	81.90
1974	27	75.01
1975	27	84.86
	185	83.60
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 9.22

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit-Years ^{††}	Average [†] Operating Availability ^{††} (%)
60-89 MW	18	91.36
90-129 MW	52	88.93
130-199 MW	28	72.79
200-389 MW	23	70.20
390-599 MW	44	81.12
600 MW & Above	14	77.10
[†] Average over the five year period 1971-1975		
^{††} Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.23

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size Range	Number of Unit-Years ^{††}	Average [†] Operating Availability ^{††} (%)
60-89 MW	28	84.03
90-129 MW	22	88.46
130-199 MW	68	87.94
200-389 MW	40	79.35
390-599 MW	14	78.83
600 MW & Above	13	69.79
[†] Average over the five year period 1971-1975		
^{††} Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.3 Plant Operating Availability (Continued)

Annual average operating availability of U.S. oil fired plants, in all the size ranges, have changed during the 1971-1975 period as shown in Tables 9.24 through 9.29. The highest annual average operating availability (95.7% in 1975) is recorded for the 60-89 MW size range (Table 9.24). The lowest annual average operating availability (57.7% in 1975) is recorded for the 130-199 MW size range (Table 9.26). Except for isolated instances, the annual average operating availability as shown by these tables are predominantly less than 90%.

Table 9.24

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	4	89.9
1972	5	93.1
1973	4	91.5
1974	3	87.3
1975	2	95.7
1971-1975	18	91.4
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.25

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	9	85.3
1972	9	89.8
1973	11	90.9
1974	11	89.8
1975	12	88.4
1971-1975	52	88.9
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.26

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	5	78.6
1972	5	79.4
1973	5	86.4
1974	5	70.9
1975	8	57.7
1971-1975	28	72.8
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.27

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	4	76.4
1972	4	81.6
1973	4	68.3
1974	6	67.6
1975	5	60.7
1971-1975	23	70.2
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.28

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	4	81.3
1972	7	80.5
1973	8	83.9
1974	12	86.4
1975	13	74.8
1971-1975	44	81.1
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.29

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	2	79.3
1972	2	74.9
1973	2	81.5
1974	2	91.6
1975	6	70.8
1971-1975	14	77.1
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.3 Plant Operating Availability (Continued)

Annual average operating availability of California plants of all size ranges, have changed during the 1971-1975 period, as shown in Tables 9.30-9.35. The highest annual average operating availability (96.7% in 1975) is recorded by the 60-89 MW size range (Table 9.30). The lowest annual average operating availability (59.8% in 1974) was also recorded for the 60-89 MW size range (Table 9.30). Except for isolated instances, the annual average operating availability, as shown by these tables, are predominantly less than 90%.

Table 9.30

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	7	94.5
1972	6	87.4
1973	5	76.8
1974	5	59.8
1975	5	96.7
1971-1975	28	84.0
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.31

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	9	91.0
1972	9	90.4
1973	—	—
1974	2	74.5
1975	2	82.5
1971-1975	22	88.5
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	21	91.7
1972	21	87.9
1973	6	90.2
1974	10	83.4
1975	10	83.3
1971-1975	68	88.0
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.33

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	11	75.0
1972	11	80.6
1973	6	80.0
1974	6	76.9
1975	6	86.8
1971-1975	40	79.4
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.34

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	4	80.7
1972	4	79.6
1973	2	89.5
1974	2	76.3
1975	2	65.4
1971-1975	14	78.8
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart included units of different design, age, utilization, vintage, etc.		

Table 9.35

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Operating Availability [†] (%)
1971	3	63.7
1972	4	73.3
1973	2	67.7
1974	2	64.7
1975	2	79.1
1971-1975	13	69.8
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.4 Plant Equivalent Availability

Oil fired power plants have operated at a national average equivalent availability 78.5% during the period 1971-1975 (see Table 9.36). This includes all oil fueled plants in operation in the U.S. during the five-year period 1971-1975, and on which data was available from EEI. A 179 unit-year sample is the basis of this national average of 78.5%.

Oil fired plants in California have operated at an average equivalent availability 81.5% during the same 1971-1975 period. This five year average equivalent availability is based on a 185 unit-sample (see Table 9.37). The five year average equivalent availability for oil fired plants in the state of California is higher than the average of all oil fired plants in the U.S.

Average annual equivalent availability for oil fired plants in the U.S. and the state of California have varied from year to year. The maximum range of variation of average annual equivalent availability for all U.S. plants is 12.4% while that for California plants is 11.6%. Annual average equivalent availability of oil fired plants in California have, in general, steadily declined over the years. As shown in Table 9.36, the five year average of 81.5% is influenced (reduced) by the low average equivalent availability of latter years. For plants on a national basis, a similiar reduction is apparent from Table 9.36.

From national oil fired plant data, it appears that the average annual equivalent availability is, generally, inversely proportional to the plant size. Table 9.38 presents the average equivalent availability for each MW size range for the period 1971 through 1975. The highest average of 90.9% was achieved by the 60-89 MW group.

Oil fired plants in the state of California also show average equivalent availability varying with size. The plants exhibit values of average equivalent availability as shown in Table 9.39. It lists the average five year equivalent availability for California's oil fired plants by each size range.

Table 9.36

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	28	80.9
1972	32	82.3
1973	34	82.9
1974	39	79.3
1975	46	70.5
1971-1975	179	78.5
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 9.37

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	54	84.12
1972	55	83.82
1973	21	79.30
1974	27	72.55
1975	27	82.07
1971-1975	184	81.48
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different size, age, design, utilization, vintage, etc.		

Table 9.38

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Size Range	Number of Unit Years ^{††}	Average [†] Equivalent Availability ^{††} (%)
60 - 89 MW	18	90.9
90 - 129 MW	52	88.6
130 - 199 MW	28	70.4
200 - 389 MW	23	64.2
390 - 599 MW	44	76.0
600 MW & Above	179	78.5
[†] Average over the five year period, 1971-1975		
^{††} Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.39

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Size Range	Number of Unit-Years ^{††}	Average Equivalent Availability ^{††} (%)
60-89 MW	27	83.1
70-129 MW	22	87.3
130-199 MW	68	86.6
200-389 MW	40	77.0
390-599 MW	14	74.8
600 MW & Above	13	62.5
[†] Average over the five year period, 1971-1975		
^{††} Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.4 Plant Equivalent Availability (Continued)

Annual average equivalent availability of U.S. Plants of all the size ranges, have changed during the 1971-1975 period as shown in Tables 9.40 through 9.45. The highest annual average equivalent availability (94.5% in 1975) is recorded for the 60-89 MW size range (Table 9.40). The lowest annual average equivalent availability (53.9% in 1975) is recorded for the 200-389 MW size range (Table 9.43). Except for isolated instances, the annual average as shown by these tables are predominantly less than 90%.

Table 9.40

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 60-89 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	4	89.4
1972	5	92.8
1973	4	90.8
1974	3	87.3
1975	2	94.5
1971-1975	18	90.8
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.41

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	9	85.1
1972	9	89.3
1973	11	90.9
1974	11	89.6
1975	12	87.8
1971-1975	52	88.6
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.42

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	5	76.8
1972	5	77.9
1973	5	85.2
1974	5	67.5
1975	8	54.4
1971-1975	28	70.4
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.43

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	4	73.4
1972	4	75.5
1973	4	60.6
1974	6	61.6
1975	5	53.9
1971-1975	23	64.2
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.44

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	4	78.6
1972	7	76.5
1973	8	80.2
1974	12	79.9
1975	13	68.9
1971-1975	44	76.0
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.45

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	2	74.5
1972	2	69.5
1973	2	73.5
1974	2	89.5
1975	6	66.8
1971-1975	14	72.5
[†] Source: EEI special analysis for SDC		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.4 Plant Equivalent Availability (Continued)

Annual average equivalent availability of California plants of all size ranges, have changed during the 1971-1975 period as shown in Tables 9.46-9.51. The highest annual average equivalent availability (96.1% in 1975) is recorded by the 60-89 MW size range (Table 9.46). The lowest annual average equivalent availability (51.8% in 1974) was recorded for the 600 MW and above size range (Table 9.51). Except for isolated instances, the annual average capacity factors, as shown by these tables, are predominantly less than 90%.

Table 9.46

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 60-89 MW		
Period	Number of Unit-Years	Average Equivalent Availability (%)
1971	6	93.5
1972	6	87.3
1973	5	76.4
1974	5	59.3
1975	5	96.1
1971-1975	27	83.1
Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.47

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 90-129 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	9	89.05
1972	9	89.54
1973	—	—
1974	2	74.4
1975	2	82.5
1971-1975	22	87.3
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 130-199 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	21	90.1
1972	21	86.7
1973	6	88.4
1974	10	82.1
1975	10	82.5
1971-1975	68	86.6
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.49

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 200-389 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	11	73.3
1972	11	78.8
1973	6	78.9
1974	6	74.2
1975	6	81.6
1971-1975	40	77.0
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.50

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 390-599 MW		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	4	73.9
1972	4	77.5
1973	2	86.8
1974	2	71.9
1975	2	61.2
1971-1975	14	74.8
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Table 9.51

OIL FIRED STEAM ELECTRIC POWER UNITS IN CALIFORNIA		
Unit Size: 600 MW & Above		
Period	Number of Unit-Years [†]	Average Equivalent Availability [†] (%)
1971	3	62.1
1972	4	70.8
1973	2	52.9
1974	2	51.8
1975	2	66.7
1971-1975	13	62.5
[†] Source: SDC analysis of EEI data supplied by FEA		
Note: The data used to develop chart includes units of different design, age, utilization, vintage, etc.		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.5 Plant Heat Rate

The primary source of annual average heat rate data on existing oil fired power plants, in the U.S., was the Federal Power Commission's (FPC) "Steam Electric Plant Construction Cost and Annual Production Expense" supplements. This publication contains heat rate data by each plant station and not by individual units comprising the power plant. No data was available on individual units for plants in the U.S.

Heat Rate data available from the FPC publication for plants in operation since 1973 was analyzed to arrive at historical averages and ranges of heat rate data. For the year 1973, 66 power plants were identified that used only oil as fuel. A total of two hundred and sixty (260) units were shared between these sixty-six (66) stations. The average heat rate for each unit was 12447 BTU/KWH for 1973. As the heat rate data was available only at the station level it was not possible to analyze the heat rates for each of six established plant size ranges.

Oil was a fuel used by plants, other than those analyzed above, along with gas. Data on heat rates of plants using gas and oil as fuel was analyzed. The results are shown in Table 9.52.

Table 9.52

OIL FIRED STEAM ELECTRIC POWER UNITS IN THE U.S.		
Fuel =	Number of Units	Average Heat Rate ⁺ (BTU/KWH) (1973)
Oil only	260	12447
Oil & Gas	583	12101
<p>Note: The data used to develop chart includes units of different size, age, design, utilization, etc.</p> <p>+ Source: SDC Analysis of FPC data</p>		

Section 9.0 OIL FIRED STEAM ELECTRIC POWER PLANTS

Subsection 9.5 Key Components/Systems

Data on components/systems of oil fired plants that have historically been responsible for reduced capacity factors, equivalent availability and operating availability (plant power reduction and/or plant outages) were reviewed to arrive at a listing of the key components and systems. Components/systems responsible for over 100 equivalent full power outage hours, per unit year, are listed as key components/systems.

The primary source identified of oil fired plant outage and power reduction data was the Edison Electric Institute (EEI) Equipment Availability Task force data bank. This data bank contains information on the historical failures by Cause Code Headings. An EEI Cause Code Heading is a title under which all the outages due to either 1) a group of equipment, 2) similar multiple equipment, and 3) individual equipment, are assigned.

No data was available on historical malfunction as off-specification performance of components/systems if no partial or full outage occurred.

The period 1971-1975 was chosen for identification of key components and systems. Data was received on 600MW and above oil fired plants only. Table 9.53 lists the EEI cause codes along with the Average Equivalent full power outage hours per unit-year that were assigned to each code.

OIL FIRED STEAM ELECTRIC POWER PLANTS IN THE U.S.							
Size: 600 MW and Above							
EEI Cause Code	EEI Cause Code Title	Average Equivalent Full Power Outage Hours Per Unit-Year *					Five Year Total 1971-1975
		1971	1972	1973	1974	1975	
100	Boiler, General	931	692	683	117	290	2713
101	Water Walls	74	287	64	29	118	572
102	Generating Tubes	—	33	—	—	71	104
103	Superheater	—	—	353	302	59	714
108	Air Preheater...	34	108	67	—	20	229
110	Forced Draft Fans	12	11	279	—	10	312
117	Valves and Piping...	141	—	7	—	11	159
121	Pulverizers	62	—	—	—	86	148
123	Fuel Handling Equipment	4	1	—	—	236	241
126	Boiler Casing...	61	32	—	—	12	105
128	Boiler Circulating...	46	—	56	8	14	124
130	Precipitator-Electrical	117	—	—	—	—	117
139	Air Heater Fouling	94	182	83	—	—	359
199	Miscellaneous...	152	3	—	—	—	155
600	Expander Turbine...	794	995	—	4	—	1793
672	Control, Turbine...	63	40	—	—	45	148
630	Vibration of Turbine...	—	—	—	—	197	197
700	Generator...	472	647	—	—	19	1165
712	Exciter	—	—	193	—	2	195
800	Condenser...	297	1	23	1	—	322
802	Tube Failure	18	3	153	—	6	180
803	Circulating Water Pumps	184	106	—	82	24	396
900	Other, General Code...	24	674	28	—	72	798
901	Feedwater Heaters...	106	16	131	60	35	368
903	Main Transformers	13	67	—	114	1	195
905	Boiler Feed Pumps...	18	352	38	—	60	468
925	Starting System Failure	—	122	—	—	—	122
* Source: EEI Special Analysis for SDC							