UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
PENNSYLVANIA POWER & LIGHT COMPANY	)	
and	)	Docket Nos. 50-387 50-388
ALLEGHENY ELECTRIC COOPERATIVE, INC.	)	
(Susquehanna Steam Electric Station, Units 1 and 2)	)	

AFFIDAVIT OF ROBERT H. KOPPE
IN SUPPORT OF APPLICANTS' ANSWER
TO NRC STAFF'S MOTION
FOR SUMMARY DISPOSITION OF
CONTENTION 14

County of Boulder)
: ss.
State of Colorado)

Robert H. Koppe, being duly sworn according to law, deposes and says as follows:

1. I am Manager of Reliability and Safety Projects for the S. M. Stoller Corporation and give this Affidavit in support of Applicants' Answer to NRC Staff's Motion for Summary Disposition of Contention 14. A summary of my professional qualifications and experience is attached as Exhibit "A" to my Affidavit.

2. I have reviewed the Affidavit of Raghaw Prasad, dated August 31, 1981, and the Statement of Material Facts As To Which There Is No Genuine Issue To Be Heard, both of which were attached to the NRC Staff Motion for Summary Disposition of Contention 14, dated September 10, 1981. Mr. Prasad assumes a 60% capacity factor, which is lower than the average capacity factors cited in the two reports which

he references: (1) a 65% capacity factor estimated for an 1100 MW boiling water reactor (Esterling, Robert C., NUREG/CR-1881, "Statistical Analysis of Power Plant Capacity Factors through 1979" (December, 1980)); and (2) an average capacity factor of 61.8% for all operating nuclear reactors in the United States up to the end of January 1981 (NUREG-0020, "Licensed Operating Reactor Status Report," vol. 5, no. 2 (February, 1981)).

3. Based upon my analysis, set forth below, of boiling water reactors of a design similar to the Susquehanna units, I conclude that the NRC Staff's assumed 60% capacity factor is conservative. Based on my analysis, I have concluded that capacity factors of about 60% for the first four years of operation and 70% thereafter are prudent estimates for the performances of the Susquehanna units. My best estimate of Susquehanna unit capacity factors for planning purposes is about 65% in the first commercial year, 55% in Year 2, 60% in Year 3, 65% in Year 4, and 70% or better in subsequent years.

4. During my investigation I found no evidence that would indicate a tendency for the Susquehanna unit performance to decline with age. Also, I expect that the performances of the Susquehanna units should be somewhat better than that of the presently operating BWR-3 and BWR-4 units because of the solving of past problems and reduced likelihood of new problems.

I. INTRODUCTION

A. Discussion of Objective

5. There are a number of indices which provide useful measures of the performance of generating units. One of the most common and useful of these indices is the capacity factor. When we are looking at the economics of a

generating unit, the capacity factor is an important measure of unit performance, and it is with capacity factor that I will be concerned in this Affidavit.

6. When a generating unit is designed and built, it is intended to be able to operate consistently at any power up to some maximum. This power level which is the maximum at which a unit could run consistently is called the design net electrical rating of the unit. Because of seasonal variations in condenser cooling water temperatures, the actual maximum output of a unit may be somewhat above or below the design power level on any particular day. Nonetheless, the design net electric rating of a unit is equal to the average power which the unit would produce throughout the year if all equipment were working correctly and if the unit were continuously run at its maximum capability.* It should be obvious that a given unit can produce no more than some maximum amount of power in a year. It can only produce that maximum output if all equipment works perfectly throughout the year and if the power is always wanted. The actual output of a unit for a year will probably never be equal to the maximum theoretically possible. A unit may fail to produce some power due to refueling; due to equipment maintenance or failure; due to restrictions imposed by regulatory bodies or due to lack of need for the power.

7. For a given time period, the capacity factor for a unit is simply the ratio of the power that it did produce to that which it theoretically could have produced (multiplied by 100 to yield a percent). If a unit actually did run

* Note that there are some problems defining the design rating for individual units. Many units have changed designs either during construction or during operation and thereby have ended up with two or more design ratings. This question is addressed further in the Appendix.

perfectly for a year and required no maintenance or refueling, its capacity factor for that year would be 100%. A unit which did not run at all for a year would have a zero percent capacity factor. In a case where a unit ran perfectly for nine months and was shut down for three months, its capacity factor for that year would be 75%.

8. As a measure of generating unit performance, capacity factors have one drawback. That is, they do not tell how much of the power which was not produced was lost because of considerations external to the unit such as demand for power and economics. Because of their low incremental costs, nuclear units have usually been operated at the maximum power output possible. Therefore, almost all of the reductions of unit capacity factors below 100% have been due to scheduled maintenance, refueling, unscheduled outage of equipment in the units, or because of regulations affecting the units. There have been a few exceptions and when considering the performance of individual units, one must be careful to account for these nonplant causes of reduction in capacity factor. In general, however, the capacity factors of nuclear units are direct indicators of the performance of those units.

9. My Affidavit will be concerned with projections of capacity factors for the Susquehanna units. These units will each have a Boiling Water Reactor (BWR) supplied by the General Electric Company (GE). Presently, there are 26 nuclear units utilizing BWRs in commercial operation in the United States. Of these 26 reactors, 25 were supplied by General Electric. Five of these 25 General Electric units (Dresden 1, Humboldt Bay, Big Rock Point, Nine Mile Point 1, and Oyster Creek 1) are more than nine years old and have reactors of early designs, which differ in significant ways from BWRs of more current

design. Dresden 1, Humboldt Bay, and Big Rock Point have reactors designated Model BWR-1 while Nine Mile Point and Oyster Creek are Model BWR-2. The Susquehanna units are BWR-4s. Only the GE BWR-3 and BWR-4 type units were considered to predict the performances of the Susquehanna units. These units are listed in Table 1. Together these 20 units have accrued about 130 unit-years of commercial operating experience through December, 1980.

10. Predicting the future is seldom easy. Usually, we start with our past experience, try to see what changes will take place in the future, and try to estimate what the effects of these changes will be. For generating units, the ideal predicting situation would be if we were building a unit that was identical to a large group of units which had already been operating for 15 or more years. In that case, we could be confident that the future unit would perform as the past units if it were operated by similar crews under similar conditions. The actual situation is far from the ideal in this regard. Generating unit design has been evolving very rapidly, and many problems which affected operating units a few years ago have already been eliminated or their impacts greatly reduced today. The Susquehanna units are BWR-4 type units and are similar in many ways to the 13 other BWR-4s that are presently in commercial operation. They will have the benefit of a number of years of operating experience with these units and other BWRs. Thus, one would expect that the Susquehanna units would perform at least as well and probably better than today's BWR-4 units. New undiscovered problems, unique events, and new regulatory actions however could reduce the effects of these improvements.

11. It should be obvious from the preceding that one cannot simply average the performance of a group of units now operating and say that the

Table 1

LIST OF 20 GENERAL ELECTRIC BWR-3s AND BWR-4s
IN COMMERCIAL OPERATION AS OF DECEMBER, 1980

Plant	BWR Class	Date of Commercial Operation	Full Months of Commercial Operation	Design Electric Rating (MWe net)
Dresden 2	BWR-3	6/72	102	794
Millstone Point 1	BWR-3	3/71	117	660
Monticello	BWR-3	7/71	113	545
Dresden 3	BWR-3	1/72	108	794
Pilgrim 1	BWR-3	12/72	96	668
Quad Cities 1	BWR-3	2/73	94	789
Quad Cities 2	BWR-3	3/73	93	789
Vermont Yankee	BWR-4	11/72	97	514
Peach Bottom 2	BWR-4	7/74	77	1065
Browns Ferry 1	BWR-4	8/74	77	1065
Cooper Station	BWR-4	7/74	78	778
Duane Arnold	BWR-4	2/75	71	515
Browns Ferry 2	BWR-4	3/75	70	1065
Peach Bottom 3	BWR-4	12/74	72	1065
Hatch 1	BWR-4	12/75	60	786
Fitzpatrick	BWR-4	7/75	65	821
Brunswick 2	BWR-4	11/75	61	821
Browns Ferry 3	BWR-4	3/77	46	1065
Brunswick 1	BWR-4	3/77	45	821
Hatch 2	BWR-4	9/79	15	784

performance of a unit in the future will be the same. Any intelligent attempt to use past experience to predict the performance of Susquehanna or other future units must consider the designs of individual operating units; the ways in which those designs have affected the performance of the units; and the ways in which the design of Susquehanna relates to the designs of present units. In the following sections of my Affidavit I will make these considerations.

B. Recent Significant Incidents

12. Since early 1979, a number of events have had a significant impact on nuclear units. In March of 1979, five reactors were required to shut down (if they were operating) because of an inadequacy in a Stone and Webster computer code for calculating stress on the units' pipes. A number of other problems involving the design of the seismic pipe supports at nuclear units resulted in NRC Inspection and Enforcement Bulletins 79-02, 07, and 14 and required outages at many units for inspections and repairs later in 1979 and on through 1980. Also in March of 1979, Three Mile Island 2 experienced a reactor accident, and subsequently a number of units with Babcock and Wilcox reactors were shut down to make design improvements. Design modifications to o her units besides those with Babcock and Wilcox reactors were also required.

13. Also in 1979 a generic cracking problem in the PWR feedwater system pipes and nozzles was discovered. This problem resulted in NRC Inspection and Enforcement Bulletin 79-13. Later in the same year another cracking problem was discovered in the discs of Westinghouse low pressure turbines. Many units with these turbines were required by the NRC to shut down and inspect these turbine discs. If cracks were then found the disc and multiple stages of turbine blading were usually removed, and the unit was returned to power at a reduced output rating.

14. Fortunately for the BWR-3 and BWR-4 units only Cooper has a turbine manufactured by Westinghouse. These BWR units as a group were therefore relatively unaffected by the cracking in Westinghouse turbines and in the PWR feedwater system and the shutdowns of the Babcock and Wilcox units after the Three Mile Island accident. Many of these BWR units, however, experienced losses due to the seismic pipe support design problems and also due to three BWR generic problems discovered in 1980.

15. In 1980 all the BWR-3 and BWR-4 units were required to perform tests of their scram system. These shutdowns were required by the NRC following a problem with the scram discharge volume at Browns Ferry (refer to NRC Inspection and Enforcement Bulletin 80-17). Also in 1980 many BWRs repaired problems discovered in the jet pump supports (refer to NRC Inspection and Enforcement Bulletin 80-07) and installed a new safety relief valve discharge device (called a T-quencher). These problems and NRC requirements to inspect and/or modify equipment significantly influenced the performance of BWR units in 1980. These effects are further discussed in Section IV of this Affidavit.

16. These incidents were unique occurrences that should not contribute to any losses in the future. In the past, other unique events have affected nuclear units, and the subsequent losses are included in the data used in this Affidavit. The fact that such problems are still taking place is indicative of the learning mode that the nuclear industry is still going through. My projections for the Susquehanna units effectively allow for a continuing level of new and/or unique problems, and I believe that this allowance is both necessary and reasonable.

C. Affidavit Organization

17. In Section II of this Affidavit I examine the overall performance of the BWR-3 and BWR-4 units. This data has been derived from unit operating statistics through December 31, 1980. In Section III a detailed breakdown of the causes of all outages and power reductions is presented for BWR-3 and BWR-4 data also through December, 1980. Section IV projects the expected performance of the Susquehanna units. Section V examines the effects of unit age on performance and Section VI presents my conclusions.

II. GROSS UNIT STATISTICS

18. There are three methods of looking at overall unit performance: (1) the unweighted average of all units; (2) the average of all units weighted by unit lifetime; and (3) the composite unit average. In the following three sections I will discuss each of the three methods in turn and present results of analyses using each method. The aggregated capacity factors determined by these three methods are presented in Table 2 for the data through December, 1980.

A. Unweighted Average

19. In this method, the lifetime average statistics for each unit are added and divided by the number of units. Equal weight is thereby given to all units. If there were a large number of units which had operated through a significant period of time, this average could correctly represent the performance of these units. As it is, many of the 20 units studied have operated commercially for relatively brief periods of time; so this method is biased in favor of the average performance of immature units. Because the performance during the immature years for most units is not as good as the performance in subsequent years, this method incorrectly suggest low numbers for average capacity factors.

B. Weighted Average

20. In this method, each unit's statistics are multiplied by the number of years of operation. The results are added and divided by the total years of operation for all units. Therefore, each unit-year of operation is given equal weight. As a result, a weighted average yields a measure of total performance to date. This method is also presently dominated by experience accrued during the break-in period for the units, and subject to the same criticism as the unweighted average.

Table 2

GROSS UNIT CAPACITY FACTORS FOR BWR-3s AND BWR-4s THROUGH DECEMBER, 1980

	Capacity Factors (%) of BWR-3s and BWR-4s
Unweighted Average	58.6
Weighted Average	59.3
Composite Unit Average	
Commercial Years 1-4	54.4
Commercial Years 5-10	66.9
Commercial Years 1-10	61.9

C. Composite Unit Average

21. In this method, the statistics of the first 12 months of commercial operation (regardless of calendar year) are averaged for all units.

22. This average is called the first year performance for a composite unit. The second 12-month statistics for all units which operated two or more years are then averaged, and this number is called the second-year performance for a composite unit. This process is continued for each year of operation.

23. Because many BWR-3 and BWR-4 units are still relatively new, the experience for these units is still dominated by the data from early years following the start of commercial operations. Using composite unit data that is aggregated by commercial year of experience allows the experience to be examined on a year-by-year basis and reduces the impact of the first few, or immature years. The composite unit method is, therefore, the best representation of the average performance as a function of the age for the units now operating.

III. GENERAL ELECTRIC BWR-3 AND BWR-4 UNIT PERFORMANCE

24. Capacity factor losses for BWR-3 and BWR-4 units through December, 1980 are presented in Table 3 as a function of commercial year of operation for each of 15 problem/component categories. A discussion of the principal problems associated with each category follows:

A. Refueling Operations

25. This classification for capacity factor losses accounts for refueling shutdowns and the operations directly involved with refueling, such as: vessel head removal, failed fuel detection, and vessel closure. In some instances, other work besides refueling operations became curtailing or the critical path job for the outage. To the extent that these other curtailing jobs were identified, their associated losses were attributed to other appropriate problem/component categories. It is likely, however, that because of poor reporting detail of the refueling outages, not all such curtailing repair and maintenance work was identified. Refueling outage losses, therefore, are somewhat overestimated and include some losses from other outage work.

26. Refueling outages have been the largest single source of capacity factor losses at nuclear units. Composite average losses from refueling at BWR-3 and BWR-4 units have been about 11.9%. The average capacity factor losses due to refueling outages is zero in the first year of commercial operation because none of the 20 operating BWR-3 and BWR-4 units refueled in that year.

B. Fuel Problems

27. This classification for capacity factor losses includes all problems associated with fuel performance. Major contributors to losses in this category

Table 3

CONTRIBUTIONS TO LOSSES IN CAPACITY FACTOR (%)
BWR-3 AND BWR-4 DATA THROUGH DECEMBER, 1980

	Year of Commercial Operation										Composite Average of Years 1-10
	1	2	3	4	5	6	7	8	9	10	
Refueling Operations	0.0	12.2	10.6	17.8	11.9	11.0	11.0	13.3	10.8	20.8	11.9
Fuel Problems	11.5	11.1	8.0	6.3	5.4	3.5	2.8	3.6	1.7	0.8	5.5
Recirculation Pump Problems	2.1	1.2	2.4	0.4	0.7	1.6	0.4	0.8	2.0	0.2	1.2
Control Rod & Drive Problems	0.3	0.6	0.6	0.7	0.1	0.4	0.3	0.3	0.7	0.3	0.4
Spurious Reactor Protection System Trips	0.6	0.2	0.2	0.0	0.2	0.2	0.1	0.1	0.2	0.0	0.2
Other NSSS Problems	8.8	7.9	11.0	11.2	8.4	5.8	3.7	3.1	8.9	3.9	7.3
Condensate & Feedwater	3.1	3.7	2.7	2.0	2.2	2.3	1.4	1.8	0.9	5.5	2.6
Main Turbine Problems	1.6	1.7	1.7	0.7	0.8	1.7	2.0	0.6	0.8	0.3	1.2
Main Generator & Electrical System Problems	2.0	0.7	0.7	1.6	1.6	0.5	0.7	4.0	0.2	0.0	1.1
Other Balance of Plant Problems	2.4	0.7	2.0	1.4	1.0	1.2	1.1	0.9	0.3	0.0	1.1
Thermal Efficiency Losses	1.2	1.8	1.9	1.4	1.6	1.7	1.8	0.9	0.6	0.3	1.3
Nonplant Related Problems	0.6	0.6	0.3	0.6	3.2	2.0	3.0	2.3	7.5	0.6	2.1
Startup Testing	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Unique Events	6.5	7.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
Other Problems	1.5	1.2	0.8	0.6	0.7	0.9	0.7	0.7	0.5	0.1	0.8
Total Capacity Factor Loss*	42.7	51.3	43.8	44.8	36.7	32.8	29.0	32.4	34.9	32.6	38.1
Unit-Years Experience	20.0	19.3	19.0	18.6	17.0	14.3	9.3	7.6	3.6	1.2	

* The numbers do not add up due to rounded off.

for BWR-3 and BWR-4 units have been: fuel cladding failures, power loading rate restrictions (that is, preconditioning limits) to minimize fuel failures, poison curtain vibration problems, Local Power Range Monitor (LPRM) vibration problems, and regulatory restrictions on local power levels in the reactor core.

28. Fuel failures at BWR units were largely caused by internal hydriding of the zircalloy cladding and by pellet-clad interactions. This latter phenomenon was principally a consequence of rapid local power spiking. To mitigate this problem, Preconditioning Interim Operating Management Recommendations (PCIOMR) or preconditioning limits were implemented which restricted the rate at which a unit could increase power. Subsequently, fuel failures have not been a major outage causing problem at BWR units.

29. The 8x8 fuel for the Susquehanna units will operate at a lower peak power rating than much of the fuel contributing to the BWR-3 and BWR-4 data base. This lower duty fuel should result in less restrictive preconditioning limits and smaller losses due to these requirements.

30. The vibration problems with the poison curtains and with the LPRMs at BWR units resulted in damage to the fuel channels. The only BWR units that were affected by poison curtain vibrations were Pilgrim and Vermont Yankee. BWR-4 units after Vermont Yankee no longer use poison curtains. This problem has been corrected at the two affected units and no losses have occurred since 1974.

31. The LPRM vibration problem was more widespread. Every BWR-4 that was operating when the problem was discovered in 1975 experienced some

losses as a result. The NRC required many of these units to operate at reduced power levels until modifications could be made and the fuel channels inspected and replaced where necessary. The immediacy of the problem prevented many units from delaying these lengthy repairs until their next refueling outage. As a result, losses for BWR-4 units were about 14.8% and 7.5% in 1975 and 1976, respectively. The problem has been corrected, however, and there have been no losses since 1976.

C. Recirculation Pump Problems

32. This classification for capacity factor losses includes outages for repairs to recirculation pump seals, drives, motor generator sets, and other recirculation pump problems.

33. More than two-thirds of the losses attributed to recirculation pump problems in the first commercial year were due to pump seal problems. Much of these losses occurred at the two BWR-4 units with Bingham pumps. The other BWR-3 and BWR-4 units, which with one exception have Byron Jackson pumps, have had better experience. Seal performance on both types of pumps has also generally improved following the backfitting of a seal purge injection system. The Susquehanna units will have Byron Jackson recirculation pumps with a seal purge injection system.

34. Problems with motor-generator sets which control the speed of the recirculation pumps have also been common and persistent. All 19 BWR-3 and BWR-4 units that have operated longer than three months have experienced some losses because of this problem. However, outages have typically been short.

D. Control Rods and Drive Problems

35. This classification for capacity factor losses includes outages for repair of control rods and control rod drives and losses resulting from the generic "inverted control rod" problem.

36. Losses due to control rod and control rod drive problems at BWR-3 and BWR-4 units have not been very consequential. There have been no failures that have resulted in any lengthy shutdowns, and most of the outage hours resulted from a generic QA problem in which inverted control rods were inadvertently approved for use. When the problem surfaced in 1973 and 1974, six units were required to shut down and perform tests. The problem has since been corrected, and there have been no losses in recent years due to inverted control rods.

E. Spurious Reactor Protection System Trips

37. This classification includes losses due to problems with the reactor control and protection systems and trips of the unit not attributable to other components or systems.

38. Losses from spurious reactor protection system trips have been small. Most of the outage hours for this problem are in the first few years of commercial operation and diminish in subsequent years as the units' operating experience increases.

F. Other NSSS Problems

39. This classification for capacity factor losses includes outages attributable to nuclear system problems not categorized under fuel problems, recirculation pump problems, control rod and drive problems, or spurious reactor

protection system trips. In general, this classification includes the reactor vessel and its associated internals, instrumentation, valves, piping, and other equipment up to and including the first isolation valve. In addition, this classification includes other equipment which is primarily associated with the nuclear portion of the unit, such as: the Emergency Core Cooling System, the Emergency Feedwater System, the Residual Heat Removal System or Shutdown Cooling System, the Containment Systems, the Safety Electrical Systems, and the Radioactive Waste Treatment and Discharge Systems.

40. Outages caused by inspections and repairs of reactor coolant system pipes account for a large portion of these losses. Although much of this experience is recent, it does appear that utilities with BWR units are becoming better able to detect a problem in the piping before it develops into a serious crack, and more of these inspections and repairs are being performed as noncurtailing work during other outages. In addition, the Susquehanna units have implemented design and procedural modifications intended to reduce the likelihood of problems with reactor coolant system piping.

41. Problems with reactor coolant system safety-relief valves and with main steam isolation valves (MSIVs) have also contributed to losses in this category, chiefly in commercial years 1 through 3. Many of the problems with the safety-relief valves have resulted from failures of the valves to reseat or leakage past the valve seat. Design differences of the safety-relief valves installed at the Susquehanna should preclude similar problems.

42. Losses due to problems with various safety systems are also grouped in this category. Snubber inspections, torus support problems, and leak rate testing of the containment have all resulted in losses.

G. Condensate and Feedwater System Problems

43. This classification includes load reductions and outages due to problems with the equipment associated with the feedwater, and condensate systems such as failure, inspection, or repair of the main condenser, feedwater pumps or valves, feedwater heaters, feedwater controls, and interconnecting pipe.

44. Problems with condenser tubes and maintaining the condenser vacuum account for more than a quarter of the total composite losses for this category. Leaks in feedwater heaters also represent a large portion of the composite losses while problems with feedwater pumps, condensate pumps, and piping have contributed smaller amounts.

H. Main Turbine Problems

45. This classification for capacity factor losses includes load reduction and outages attributable to the main turbine and its associated equipment, such as: turbine blading and vibration/balancing problems, turbine bearings, turbine lubrication systems, turbine controls, and turbine control and stop valves.

46. The losses in the first three commercial years due to main turbine problems are principally the result of turbine valve problems at a number of BWR-3 units, a water induction-caused blade failure that occurred at Browns Ferry 2, and cracks discovered in the rotor disc of the low pressure turbine at Cooper. (Cooper is the only operating BWR unit in this report's data base with a Westinghouse turbine; Susquehanna will utilize a GE turbine-generator system.) The remainder of the losses in this category are mainly from control system problems and to a lesser extent attributable to other turbine valve problems and testing.

I. Main Generator and Electrical System Problems

47. This classification for capacity factor losses includes load reductions and outages due to problems with the main generator, its auxiliary systems, or the unit electrical systems. Included in this category are problems with the generator exciter, the generator cooling/inerting system, the unit transformers, switchgear, and buses.

48. The relatively large losses for this category in the first, fourth, and eighth commercial years are mainly the result of a few failures that caused lengthy outages. Repairs of damages due to generator shorts at Brunswick 1 and Quad Cities 1 and 2 contributed most of losses in commercial years 1 and 4, while a failure in the Dresden 3 unit's main transformer accounted for most of the losses in commercial year 8. Other losses were caused by less consequential problems with the generator instrumentation and controls, generator cooling systems, exciter, buses, switchgear, and safety electrical systems.

J. Other Balance of Plant Problems

49. This classification for capacity factor loss includes load reductions and outages due to problems with the main steam system equipment and other miscellaneous systems such as moisture separator/reheaters, main steam valves, instrumentation and piping, instrument and service air systems, circulating and service water systems, and miscellaneous auxiliary systems.

50. The relatively large losses for this category are largely the result of problems with the off-gas system. Lengthy outages took place at Quad Cities 2 in commercial year 1, at Cooper in commercial year 2, and at Hatch 1 in commercial year 3. In addition, many units shut down to install an augmented

off-gas system as a backfit to the original design. The Susquehanna units will incorporate these design improvements to the off-gas system.

51. Also contributing to the losses in this category have been temperature restrictions on circulating water system at the Quad Cities units and problems with the moisture separator-reheaters. Neither of these problems should significantly affect the Susquehanna units.

K. Thermal Efficiency Losses

52. Thermal efficiency losses are those losses incurred from operating below the unit's design thermal efficiency. It is the difference between the expected unit capacity factor for a known reactor thermal output and the actual capacity factor determined from the actual net electrical output. There may be many sources of thermal efficiency losses, the most significant of which are:

- Operations at reduced power levels and frequent outages which necessitate less than optimally efficient unit operation
- Excessive use of steam by unit auxiliary loads or because of leaks
- Operation with degraded equipment (e.g., missing turbine blades or with leaking tubes in the condenser or feedwater heaters)
- Overestimates of the core thermal power

53. Thermal efficiency losses at BWR units have remained somewhat unchanged over the composite commercial years listed in Table 3. This level of thermal efficiency losses will probably persist in the future.

L. Nonplant Related Problem

54. This classification includes capacity factor losses due to items which were not directly related to the unit equipment, but rather were caused by out-of-plant considerations or occurrences. Items in this classification include load reductions and outages due to weather, system demand, load following, extension of core life by power reductions, and other deratings or shutdowns dictated by economics or by transmission system considerations when the unit was capable of operation.

55. Nonplant related problems also generally do not decrease as unit age increases. For BWR-3 and BWR-4 units, these losses actually increase in commercial years 5 through 7 as the frequency of load following and coast downs to refuelings were increased. Reporting of these economy-related power reductions and shutdowns is not perfect, and some such outages are probably attributed to the category of other unidentified losses. As a result, the losses due to nonplant related problems are probably slightly underestimated.

M. Startup Testing

56. This classification includes capacity factor losses due to testing associated with the programmed initial rise-to-power. The magnitude of the loss of capacity due to this classification is almost entirely dependent upon the unit condition when it was initially placed into commercial operation. For those units which have completed the initial rise-to-power testing, little or no losses exist for this classification. However, those units which were placed into commercial operation during the initial rise-to-power testing will incur such startup testing losses. As expected, all such losses at BWR-3 and BWR-4 units took place during the first commercial year of operations.

N. Unique Events

57. This classification includes the capacity factor losses due to unique occurrences which do not generically affect many units and should be categorized separately rather than being aggregated with the previous categories.

58. The only unique occurrence included in this category is the cable fire at the Browns Ferry plant. This fire resulted in the shutdown of Browns Ferry 1 for 36% of its first commercial year and all of its second year, and the shutdown of Browns Ferry 2 for essentially all of its first commercial year.

C. Other Problems

59. This classification includes capacity factor losses due to load reductions and outages which could not be classified into one of the above 14 classifications due to inadequacies in the reported data. These unidentified problems have resulted in moderate and fairly consistent losses.

IV. EXPECTATIONS FOR THE SUSQUEHANNA UNITS

60. Future units such as Susquehanna 1 and 2 will avoid many of the problems that have affected present day units. Design and procedural changes should preclude, or greatly reduce, any future losses due to such past problems as fuel densification, early fuel failures, poison curtain vibrations, LPRM vibrations, feedwater sparger vibrations, feedwater nozzle cladding cracking, CRD return line nozzle cracking, the Browns Ferry cable fire, pipe support analysis problems, torus modifications, installation of augmented off-gas systems, and inverted control rods. Other problems such as reactor coolant system pipe crack inspections and repairs, recirculation pump seal failures, fuel thermal limits, safety/relief valve problems, and preconditioning limits will continue to result in unit shutdowns or power reductions, but losses of output should be considerably reduced below historical levels.

61. It is possible that new problems will result in unanticipated losses in the future; however, it is unlikely that these losses will be as large as those caused by past problems in BWR-3s and BWR-4s. The improvement that was realized when some of these problems were solved is evident in the capacity factors in Table 4 for the years 1975 through 1979 (before 1975, BWR-3 and BWR-4 unit experience was more limited). These capacity factors in Table 4 were calculated by averaging the capacity factors for each operating BWR unit during each year. If a unit was in commercial operations for less than the full year, its capacity factor was weighted by this fraction of a full year of experience.

Table 4

CAPACITY FACTORS FOR BWR-3 AND BWR-4 UNITS

Year	1975	1976	1977	1978	1979	1980
Capacity Factor (%)	48.0	53.4	59.4	66.6	67.1	60.2

62. The relatively poorer performances in 1980 was primarily due to the large number of NRC required outages. It is expected that BWR-3 and BWR-4 unit performance in subsequent years will return to and exceed the 1979 level. The performances of the Susquehanna units, however, should be unaffected by the problems that caused an increase in unit losses in 1980. Furthermore, the predictions made for the Susquehanna unit performance indices include large contingencies for the discovery of new problems after the Susquehanna units have begun operation.

63. Table 5 presents the historical BWR-3 and BWR-4 unit capacity factors using data through the end of 1980. Composite unit capacity factors are also listed for early or immature unit years of operation and for later or mature unit operations. The immature years have been chosen as the first four years of commercial operation while mature experience is taken from commercial year 5 and thereafter.

64. These unit capacity factors given in the top-most line in Table 5 include the historical losses associated with all the past problems at BWR-3 and BWR-4 units. There are literally dozens of problems which have affected present day BWRs that will not occur at the Susquehanna units. Two such problems that have caused large losses in the past but have since been solved by design modifications such that no future losses should occur are the early problem with fuel failures and the problem with LPRM vibrations. Historical losses at BWR-3 and BWR-4 units from these two problems are also given in Table 5.

65. Adjusting the capacity factors for these two past problems and for historical load following and other power reductions for economic reasons gives a better idea of how a modern BWR-4 unit could be expected to perform. These

Table 5

HISTORICAL BWR-3 AND BWR-4 CAPACITY FACTORS

	Year of Commercial Operation										Composite Capacity Factors	
	1	2	3	4	5	6	7	8	9	10	Immature Years 1-4	Mature Years 5-10
Unit Capacity Factors	57.3	48.7	56.2	55.2	63.3	67.2	71.0	67.6	65.1	67.4	54.4	66.9
Load-Following and Losses for Economic Reasons	0.5	0.5	0.2	0.6	3.1	1.8	2.9	2.3	7.5	0.6	0.5	3.0
Early Fuel Failure Losses	1.3	0.5	1.3	1.7	1.4	0.0	0.0	1.2	0.0	0.0	1.2	0.4
LPRM Problem Losses	4.4	2.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
Adjusted Capacity Factors	63.5	52.4	58.4	57.5	67.8	69.0	73.9	71.1	72.6	68.0	58.1	70.3
Unit-Years of Experience	20.0	19.3	19.0	18.6	17.0	14.3	9.3	7.6	3.6	1.2		

adjusted capacity factors are given in Table 5. Still included in these adjusted capacity factors are the losses from the many early problems that affected BWR units, but are no longer sources of continued losses. These problems include:

- o The Browns Ferry cable fire and associated modifications
- o Poison curtain vibrations
- o Fuel densification
- o Feedwater sparger vibrations
- o Nozzle cladding cracking
- o Jet pump support problems
- o Installation of augmented off-gas systems
- o Westinghouse turbine cracking
- o Inverted control rod replacements and tests
- o Recirculation pump seal problems
- o Fuel preconditioning and thermal limits
- o Reactor coolant pipe cracks
- o Torus support and design problems
- o Main steam safety-relief valve operation problems
- o Main steam isolation valve problems
- o Moisture-separator reheater tube failures
- o Early pipe support problems
- o Safety-relief valve discharge pipe modifications
- o Scram discharge volume testing

66. All of the above problems have strongly affected the past performance of BWR units. Most of these problems are associated with the startup of the BWR-3 and

BWR-4 unit design and of the many components that comprise the units. Modifications or improved operating procedures have reduced these losses and as a result performances have improved with time as is evident in Tables 4 and 5.

67. The Susquehanna units contain reactor systems and turbine generators (the equipment responsible for most unit outages) which are essentially identical to those in 20 BWR-3 and BWR-4 units which have now been operating for up to ten years. Any new design problems at Susquehanna must, therefore, result from one of the relatively minor differences between Susquehanna and operating BWR-3 and BWR-4 units or must now exist in these units, but be still undiscovered. While the existence of such problems is not impossible (and some almost certainly exist), their likelihood is reduced as experience continues to be accrued.

68. Adjusting the historical capacity factors for all of these problems would yield projected capacity factors on the order of 80%. While I fully expect that capacity factors of at least 75% will be achieved in the future, I believe that this may take another five or ten years. In the meantime, units that are presently commencing operations, like the Susquehanna units, can anticipate some lingering of past problems and some occurrence of new problems. All-in-all, I believe that the Susquehanna units can realistically expect capacity factors of about 65% in commercial year 1, 55% in Year 2, 60% in Year 3, 65% in Year 4, and about 70% or better in the subsequent years. These capacity factors include a large contingency for future problems. The actual performance of Susquehanna will certainly differ from these from one year to the next; however, I believe these are the best possible estimates in view of what we know today.

V. EFFECT OF AGING

69. In the preceding section of this Affidavit I discussed expectations for the performances of the Susquehanna units. Historical performances of BWR-3 and BWR-4 units were used as a basis for these projections. These units have accrued up to ten years of operating experience since the start of commercial operations until the end of 1980. My expectations for the Susquehanna units in subsequent years of operations are discussed in the following paragraphs.

70. In general, I would expect that refueling and maintenance outages and problems with moving components such as valves and pumps would reach an equilibrium state after a few years of operation. Also, most problems resulting from vibration, thermal cycling, or chemical attack would be expected to show up in early years of operation. Therefore, any decrease in unit performance in later commercial years would be expected to come from unit changes required by regulatory bodies, from long-term fatigue or corrosion failure of static components, or from displacement of the unit by newer units.

71. There are only five commercial General Electric BWRs in the United States with 11 or more years of operating experience--namely, Dresden 1, Humboldt Bay, Big Rock Point, Oyster Creek, and Nine Mile Point 1. The first three of these units are classified as BWR-1 units by GE. Oyster Creek and Nine Mile Point 1 are BWR-2s. All the other GE reactors that are in commercial operation in the U.S. are the more modern BWR-3 and BWR-4 designs.

72. All five of the older GE BWRs have had performances in their later years which are consistent with their earlier years' performance. Since the beginning of 1975 and until the end of 1980, or in the case of Dresden 1 and Humboldt Bay until

their shutdowns to make safety system modifications, the average capacity factor for the three BWR-1 units (Dresden 1, Humboldt Bay, and Big Rock Point) has been about 54.4%. This compares with an average lifetime capacity factor for these units of about 54.6% calculated up until the same end dates. The two BWR-2 units, Oyster Creek and Nine Mile Point 1, have had an average capacity factor since 1975 of about 64.8% as compared with a lifetime average capacity factor of about 61.8% for these two units.

73. It is apparent from examining the individual performances of these five units that wear-out has not been a factor in their losses. Instead, both BWR-1 and BWR-2 units have experienced outages caused by random failures of equipment and by generic BWR problems like those with fuel leaks, fuel densification, feedwater sparger cracking, and pipe inspections. The three BWR-1 units have had somewhat worse performances because changing NRC requirements have also necessitated some prolonged power reductions or outages until their older safety system designs could be modified to meet newer standards. In addition, prior to its shutdown in October, 1978, Dresden 1 was shut down or operated at reduced power levels for reasons of economy or because of a lack of maintenance priority.

74. Recent (post-1974) performance of the two BWR-2 units, however, has been very similar to that of the newer BWR-3 and BWR-4 units. Composite unit average capacity factors for these latter two classes of units are presented in Table 2 of this Affidavit. Also, the older BWR-3 units do not exhibit any wear-out problems which would result in decreasing capacity factors in their later commercial years. The five BWR-3s with more than seven years of commercial operation as of December, 1980, have an average lifetime capacity factor of about 64.5% and an average factor since 1975 of about 68.1%. None of these units shows signs of diminished performance

as they grow older. The older PWR units have also generally performed well in their later commercial years despite some lengthy outages attributable to regulatory required modifications.

75. There is, therefore, nothing in the data to date that would indicate that unit performance will tend to decline with unit age. Wear-out caused losses have not been observed at the oldest BWRs or PWRs, and although changing regulatory requirements have affected the performances of BWR-1 units, it should not have a major impact on future units such as Susquehanna 1 and 2.

VI. CONCLUSIONS

76. Based on the preceding I have concluded that:

a. The performance of Susquehanna should be somewhat better than that of the BWR-3 and BWR-4 units because of the solving of past problems and reduced likelihood of new problems.

b. There is nothing in the data to date which would indicate any tendency of unit performance to decline with age.

c. Capacity factors of 60% for four years and 70% thereafter are suitable for cost benefit analyses where reasonable (best) estimates are desired. My best estimate of Susquehanna unit capacity factors for planning purposes is about 65% in Year 1, 55% in Year 2, 60% in Year 3, 65% in Year 4, and 70% or better in subsequent years.

d. The NRC Staff's assumed 60% capacity factor for Susquehanna conservatively underestimates the expected capacity factor.

Robert H Koppe

Robert H. Koppe

Sworn to and subscribed before me this 27th day of September, 1981.

State of Colorado)
: ss.
County of Boulder)

Kay H. Sealy

Notary Public My Commission Expires July 23, 1

APPENDIX

I. DATA SOURCE

The sources of the basic operating statistics and reasons for loss of output for this Affidavit were the individual monthly and/or semiannual reports issued by utilities for the period from the date of commercial operation through December 31, 1980, and the "Operating Units Status Reports" (Gray Books) issued by the United States Atomic Energy Commission (Nuclear Regulatory Commission) for the period from May 1, 1974 through the present. This information was supplemented by other unit operating reports and by many contacts with reactor vendors and utilities.

II. CAPACITY FACTOR DEFINITION AND METHOD OF CALCULATION

In the course of obtaining the basic operating statistics from the reported data, many inconsistencies were identified in the manner in which statistics were reported, including differing definitions of capacity factors. In order to calculate the basic operating statistics in a consistent manner, only the following monthly operating statistics were used from the utility monthly and/or semiannual reports or the "Operating Units Status Reports."

1. Net electric energy generated during the month.
2. Gross thermal energy generated during the month.

   Date of commercial operation for each unit was taken from "Operating Units Status Report."

For any unit which was declared commercial on the first day of a month, commercial operation was considered to start on that day. For units which were declared commercial on any other day of the month, commercial operation was considered to start on the first day of the following month. Capacity factors were calculated for each month of commercial operation, and yearly values were obtained from simple averages of the appropriate 12 months. Of course, these years often did not correspond to calendar years. The last year of commercial data for many units consists of less than 12 complete months. Data for a period less than one complete year was weighted by the number of hours represented. Capacity factors were calculated as follows:

$$\text{Capacity Factor} = \frac{(\text{Net Electric Energy generated during period}) \times (100)}{(\text{Total Hours in Period}) \times (\text{Plant Rating})}$$

There is considerable confusion as to the use of rated output, maximum dependable capacity (MDC) or some other number in calculating capacity factors. Part of the problem is that when a unit operates at full power with all equipment working, net electric output will vary as condenser cooling water temperature varies. The colder the condenser cooling water, the more power is produced by the unit. This effect is quite noticeable in units which are cooled by bodies of water with large seasonal temperature variations. In some units, maximum electric output at full power may vary 5% to 6% between winter and summer. Units in moderate climates and units using cooling towers experience smaller variations. In order to calculate capacity factor, the total output (MWH electric (net)) is divided by the hours in the period times the unit rated power. Ideally, the rated power for each unit would be a fixed number for that unit which would be calculated by standard methods. Unfortunately, unit ratings have often been calculated using different seasonal cooling conditions and differing fouling factors, leakage rates, design margins, etc. A number of units were initially designed for once-through cooling and were later changed to some form of closed cooling. Many units were designed to operate initially at a specific reactor power but were provided with turbines which could provide higher power in the event that license power would be increased at a later date. These units have two ratings; an initial rating and a "stretch" rating. Some units have operated for a time at their initial rating and then increased to their stretch rating, while others have remained at their initial ratings. As a result, some units have many different design ratings and valid arguments can be made for using any one of them.

It is a purpose of my studies to evaluate the performance of equipment in operating units to learn what I can about what might be expected from future units. For this purpose, the most appropriate measure of performance of a unit is the capacity factor based on the rating of the unit as it was actually built and licensed. For each unit I have endeavored to determine the design electric rating (DER) based on average seasonal conditions using the current reactor licensed power and the actual cooling system in operation. If a unit's cooling system or licensed power rating change, I change the design electric rating accordingly. Generally, ratings in recent Gray Books appear to correctly reflect the current license ratings and current cooling systems. The DERs listed in Table 1 agree with the DERs in the December, 1980, Gray Book with the exception of Duane Arnold, Hatch 1, and Pilgrim 1. These three DERs were adjusted slightly because the units were operating with average maximum capabilities that were different from listed DERs.

Capacity factors given in the "Operating Units Status Reports" have been based on both "design rating" and "Maximum Dependable Capacity" (MDC). Capacity factors based on MDC are published in the Gray Books to allow comparison with Edison Electric Institute figures on fossil-fueled units, which are all based on MDC. Since a unit's MDC is almost always based on summer conditions, it is usually lower than the design rating and therefore results in higher capacity factors.

III. CALCULATING AND APPORTIONING CAPACITY FACTOR LOSSES

Capacity factory losses take two forms--shutdown and operation at partial power. Calculations of percentage loss of capacity are done as follows:

For a unit shutdown, the percentage loss of capacity factor is:

$$\frac{\text{(hours shutdown)} \times (100)}{\text{(hours in the period)}}$$

For operation at partial power, the percentage loss of capacity factor is:

$$\frac{\text{(hours at part power)} \times (100) \times \text{(MW reduction)}}{\text{(hours in the period)} \times \text{(unit rating))}}$$

For each unit, each outage and each period of operation at reduced power was examined and a percentage loss of capacity factor was calculated. The capacity factor loss was then assigned to one of the 15 categories using the following ground rules:

- o If several operations were performed during an outage but one operation was clearly much more significant than the others, the entire outage was assigned to the most significant operation. Otherwise, the outage was divided equally among the several operations.
- o When there was more than one restriction on unit power at the same time, the entire loss of capacity was assigned to the more limiting restriction.

Utilities are required to list each outage, its duration, and cause in their reports to NRC. Consequently, it was straightforward to calculate capacity factor losses and assign causes. For a few units, outage times were given as reactor outage times rather than generator outage times. For these units I used available data including the reactor outage time, the power histograms, and verbal descriptions of operations to approximate generator outage times.

Considerably more trouble was encountered with periods of operation at reduced power. Until September, 1974, there was no requirement for systematic reporting of reduced power operation. Thus, the amount of information in available reports varies considerably. Many contacts with unit operating personnel resulted in a considerable increase in understanding of periods of reduced power operation. However, whenever the cause was not completely clear, the capacity factor losses were assigned to the "other" category. In more recent years, reporting of reasons for power reductions has improved considerably. Nonetheless, it was still necessary to assign some losses to "other."

RESUME
of
ROBERT H. KOPPE

Mr. Koppe joined SMSC in 1974 as Manager of Reliability and Safety Projects. While at SMSC, Mr. Koppe has directed the Company's ongoing projects related to analyzing the performance and improving productivity of nuclear and fossil power generating units. This work as included:

- Various studies for EPRI directed toward development of a National Data System for unit and component reliability data for power plants. This work has led to detailed specifications of data to be collected and analyses to be performed by the National Data System.
- Development of SMSC's computer program and data base on causes of outages and deratings at U.S. nuclear units.
- Analyses of nuclear and fossil plant operating experience to determine problem areas, effects of problems on unit performance and variations of problems as a function of design, age, etc.
- Applications of operating experience data to selection of equipment venders and to design improvement programs.

Mr. Koppe also directs a project which SMSC is undertaking for the Nuclear Safety Analysis Center. This involves analysis of operating experience at all U.S. nuclear units to identify and examine events with potential significant economic or safety implications. Mr. Koppe has also assisted other clients in the development of Safety Analysis Reports (SARs) and in reviewing the design of nuclear facilities relative to operability and radiological safety.

Prior to joining SMSC, Mr. Koppe was Manager of the Nuclear Engineering Division and was responsible for licensing and safety analysis for Consolidated Edison's nuclear projects. The design and engineering related to the safety of these projects was under his direction. This work included design review and licensing for the Indian Point 2 and 3 turnkey units, and design review of changes and retrofit modifications and additions to the three Indian Point units. He also directed the efforts of engineers within his division to supply modifications, analysis, and engineering support for the nuclear portion of the Indian Point 1 and 2 units during operation.

Mr. Koppe received his B.S. degree from the State University of New York at Syracuse in 1965 and his M.S. in Nuclear Engineering from Ohio State University in 1966. He completed course work toward a Ph.D. in Nuclear Engineering at the Massachusetts Institute of Technology.

EXHIBIT A

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
PENNSYLVANIA POWER & LIGHT COMPANY	)	
	)	
and	)	Docket Nos. 50-387
	)	50-388
ALLEGHENY ELECTRIC COOPERATIVE, INC.	)	
	)	
(Susquehanna Steam Electric Station,	)	
Units 1 and 2)	)	

CERTIFICATE OF SERVICE

This is to certify that copies of the foregoing "Applicants' Answer to NRC Staff Motion for Summary Disposition of Contention 14", and "Affidavit of Robert H. Koppe in Support of Applicants' Answer to NRC Staff's Motion for Summary Disposition of Contention 14", were served by deposit in the U.S. Mail First Class, postage prepaid, this 29th day of September, 1981 to all those on the attached Service List.

Matias F. Travieso-Diaz

Matias F. Travieso-Diaz

Dated: September 29, 1981

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
PENNSYLVANIA POWER & LIGHT COMPANY	)	
	)	
AND	)	Docket Nos. 50-387
	)	50-388
ALLEGHENY ELECTRIC COOPERATIVE, INC.	)	
	)	
(Susquehanna Steam Electric Station,	)	
Units 1 and 2)	)	

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