#26 DPU 1509

COMMONWEALTH OF MASSACHUSETTS

DEPARTMENT OF PUBLIC UTILITIES

RE: Performance Standards for Boston Edison Company G.L. Ch. 164 94G	)	D.P.U. 1509

Testimony of

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on Behalf of

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I. Introduction

Interest in assessing the prudence of electric utility fuel costs has increased over the last several years, as a result of increases in fuel prices, the expansion of fuel adjustment mechanisms, and large utility construction investments intended to control fuel costs.[1] This interest has been manifest in investigations of fuel purchasing and stockpiling, baseload plant outages, and of unit and system fuel efficiency.[2]

Until recently, regulation of fuel costs was primarily positive or descriptive in nature. That is, the principle questions addressed were those relating to what had actually occurred: Did the utility actually incur this cost? Should this cost be treated as a fuel cost? Should it be expensed, capitalized, or amortized?

The fuel cost adjustment mechanisms introduced in the mid-1970's were primarily intended to protect the utilities from the very rapid increases in fossil fuel costs which characterized that period. The emphasis in regulation and legislation was still positive, defining the types of actual fuel expenses which were to be included in the adjustment mechanisms. The issues of the propriety or prudence of the expenses often were neglected; indeed, some of this early legislation has been interpreted as prohibiting review of the prudence of such expenses.[3]

More recently, the focus has been expanded from what the utility did spend for fuel, to what the utility should have spent for fuel. The interests and responsibilities of regulators have thus been extended to include normative or prescriptive issues.[4] Commissions have investigated the quantities of fuel which utilities have purchased, the form of the contracts under which fuel is purchased, and the prices paid. Regulators have also examined utilities' provisions for power purchases, sales and interchange, and the fuel efficiency and availability of major generating units. When a utility's performance in any of these areas has been found to be below the norms the commission considered reasonable, the utility has generally been required to assume a portion of the extra costs. This cost-sharing may occur through denied or delayed fuel cost recovery, through denial of some O&M expense (such as for plant repair, or for the fuel manager's salary), through reduction in rate base (removal of a poorly-performing plant or of excess fuel stocks), or through a reduction in the return on equity.

Considering the magnitude of fuel costs, and the ability of individual fuel-related events to substantially increase rates, it is surprising that more work has not been done on setting normative standards for fuel cost control. This paper explores methods for correcting that deficiency, particularly in the areas of plant availability and efficiency.

This paper is organized as follows. The second section describes the currently most common form of plant performance review. Section III provides a more comprehensive framework for describing performance targets and discusses some alternative approaches. Section IV describes a comprehensive comparative analysis, while Section V considers the application of the several performance-setting methodologies to various types of plants, in a range of regulatory structures and circumstances.

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I. INTRODUCTION and QUALIFICATIONS

Q. Mr. Chernick, would you please state your name, position, and office address.

A. My name is Paul L. Chernick. I am employed by Analysis and Inference, Inc., as a Research Associate. My office address is 10 Post Office Square, Suite 970, Boston, Massachusetts 02109.

Q. Please describe briefly your professional education and experience.

A. I have received a S.B. degree from the Civil Engineering Department of the Massachusetts Institute of Technology in June, 1974, and a S.M. degree from the same school in February, 1978 in Technology and Policy. I have been elected to membership in the civil engineering honorary society Chi Epsilon, to membership in the engineering honorary society Tau Beta Pi, and to associate membership in the research honorary society Sigma Xi. I am the author of several publications, which are listed in my resume, attached as Appendix A.

My professional experience includes over three years as a Utility Rate Analyst for the Utilities Division of the Massachusetts Attorney General. In this capacity, I was involved in review and analysis of utility proposals on a number of topics, particularly load forecasting, capacity planning, and rate design. One of my first major projects for the Attorney General was an investigation of the 1977-78 maintenance outages and associated derating of the Pilgrim I power plant.

My current position with Analysis and Inference, Inc. has involved a number of utility-related projects. These include a study of nuclear decommissioning insurance for the NRC, analyses of gas and electric rate designs, nuclear power cost estimation, and design of conservation programs.

Q. Have you testified previously as an expert witness?

A. Yes. I have testified a number of times before this Department and before the Massachusetts Energy Facilities Siting Council. In addition, I have testified before the Massachusetts Division of Insurance, the Atomic Safety and Licensing Board of the Nuclear Regulatory Commission, and before the utility commissions of Texas, New Mexico, Illinois, New Hampshire, Connecticut, and the District of Columbia. My resume, which is attached as Appendix A to this testimony, lists my previous testimony.

I testified on power plant performance standards in Boston Edison's previous review, DPU 1048. I have also testified on nuclear capacity factors in a number of proceedings, including DPU 20055, DPU 20248, NHPUC DE 81-312, Illinois Commerce Commission 82-0026, and NMPSC 1794.

Q. Please describe the subject matter and purpose of your testimony.

A. My testimony discusses what I believe to be certain weaknesses and failings of the performance standards proposed by Boston Edison Company (BECo.). First, I describe the principles and concepts upon which power plant performance should be based. Second, I discuss BECo.'s derivation of standards, and explain why this approach is inappropriate to the purpose of this proceeding. Third, I discuss BECo.'s method for comparing its units to other units. This method is not used to derive the standards, but is offered in support of their reasonableness. Finally, I propose standards to be used in this proceeding, and some methods for developing more acceptable standards for the next performance standard proceeding.

II. Principles of Power Plant Performance Standard-Setting

Q. What basic approaches can be taken to establishing standards for power plant performance?

A. There are three basic types of alternative approaches. First, each unit's performance standard can be determined by a self-referent standard, based on the unit's past performance, such as:

- o The unit will perform at least as well as its best past performance.
- o The unit will perform at least as well as its average past performance.
- o The unit will perform at least as well as its worst past performance.

Such standards are inherently stricter for those units with good performance histories than for those with poor past performance. This is hardly a fitting reward for those utilities which have historically taken the greatest care in plant operation. In fact, it penalizes the best past performers and rewards the worst. There is generally no compelling reason for believing that the unit's history is representative of an appropriate level of performance (neither extraordinary nor inadequate), so self-referent standards are not likely to be useful in identifying efficient and cost-effectiveness operations. Self-referent standards are also inherently inapplicable to new units. If applied on a rolling basis (e.g., if the standard in any year is determined by performance in the preceding three years), serious and perverse incentive problems may be created. There may be special circumstances in which self-referent standards are desirable, but these can be expected to be quite rare.

Second, standards can be based on <u>comparative</u> analyses, which aggregate the experience of many units. This approach would include such standards as:

- The unit will perform as well as the average comparable unit.
- The unit will perform as well as the average <u>competently run</u> unit.
- The unit will perform better than half (or any other percentage) of the comparable units.

The comparisons may simply average data from a set of units which share some common characteristics, or they may involve more complex statistical analysis. Simple comparisons are generally performed on a set of very similar units, as it is difficult to justify direct comparisons between units which are known to vary in any relevant manner. The differences which are relevant are those which can be expected to affect performance: vintage, age, operating, pressure, size, fuel type, and so on. The resulting data sets tend to be small, and the comparability of the units is almost always subject to some dispute. Various statistical techniques, such as multiple regression, may mitigate these limitations; they permit several descriptive variables to be incorporated simultaneously, which facilitates the merging of data from a greater variety of units.

Third, standards may be based on absolute measures of proper performance, such as:

- o The unit will perform as was promised, or expected.
- o The unit will perform as well as the utility has assumed for other purposes, such as rate design, setting small power producer rates, and capacity planning.
- o The unit will perform well enough to justify its fixed costs.

These various absolute standards have considerable intuitive appeal. The first example suggests that, when the utility (and hence, the ratepayers) buy a generating unit, it should get what it (and they) expected. The second example suggests the standards applied in a plant performance standard review, where overoptimistic projections cause problems for the utility, should be the same as those used in proceedings where overoptimistic projections cause problems for ratepayers, such as capacity planning and rate design. The last example suggests that, regardless of what the utility expected, or predicted, or should have expected for the unit, the real issue is whether the unit is paying its own way.

The various kinds of standards are appropriate for different situations. Using pre-operational expectations to set performance standards is intrinsically appealing: if a utility sets out to build a plant which will operate in a particular manner, it should be able to explain why the actual plant is significantly different than the expected one. Similarly, utilities should not be allowed to change their stories to suit their positions in different proceedings, projecting wonderful operating results if they are allowed to build the plants of their choice; assuring regulators that good generating performance will make marginal costs so low that declining blocks are justified, conservation is counter productive, and small power producers are unnecessary; and then denying that it is realistic to expect performance at those levels. On the other hand, there may be performance factors and units for which expectations and representations are either unavailable or otherwise of limited usefulness. In such cases, the cost-effectiveness standard may be particularly appealing: this standard asks only that the ratepayers be better off with the plant than without it, but this may be all that can be expected from new (and especially from exotic) generating units. For most generating units, some form of comparative analysis is also possible.

Q. What type of performance standard is appropriate for BECo's major generating units in this proceeding?

A. Table 1 summarizes my recommendations for approaches to setting major performance standards for BECo's stem units and entitlements.

Methods for Standard-Setting

Unit	Factor	Comparative	Expectations	Other Filings	Breakeven
Pilgrim	CF	1	3	1	
Conn. Yankee	CF	1		1	
Mass. Yankee	CF			1	
Pt. Lepreau	CF	3	2		1
Mystic 4,5,6	EAF	1	2	2	
	HR	1		2	
Mystic 7	EAF	1		2	
	HR	1	1	2	
New Boston 1,2	EAF	1	2	2	
	HR	1		2	
Canal 1	EAF	1		2	
	HR	1	1	2	
Wyman 4	EAF	1	1	2	
	HR	1	1	2	
Coleson Cove	EAF	1	1	2	
	HR	1	1	2	
Potter 2	EAF	3	1	2	
	HR	3	1	2	

Table 1: Applicability of Various Methods of Setting Performance Standards.

Notes: 1 is highest applicability.

Blanks are not available or not appropriate.

I have generally rated the comparative methodologies as very promising, except for Pt. Lepreau, for which the comparison group is quite limited. Only nine other Canadian-built HWR's are operating; excluding one which is only 206MW in size, there are 59 years of experience with these plants, but only eight years of first-year experience. Depending on the extent and nature of the data, the relevant comparative studies may range from simple averages to complex statistical analyses.

Pre-operational expectations and representations are quite valuable as sources of heat rate standards, especially for newer units. These sources are also available for Pt. Lepreau and Pilgrim reliability, but is not clear that there was enough data in the early 1970's to allow for serious projections of Pilgrim's availability. This is even more true for Connecticut Yankee, and I do not know of pre-operation reliability projections for the fossil units.

The use of projections from other proceedings is especially appropriate for the nuclear units, since BECo was so willing to predict high nuclear capacity factors for Pilgrim 2, when ratepayer funds were at risk. If BECo believed that those capacity factor projections were reasonable, it can hardly argue that projections from the same source should not be applied to its existing light water reactors. In general, the Commission can probably best encourage accurate projections by requiring BECo to tell the same story for all purposes. BECo projections are also available for various sizes and types of oil-fired units, and for BECo's specific units, for a variety of proceedings.

It is important to remember that the performance standards to be set in this proceeding serve a particular function. The standards will not establish the performance level at which the utility will automatically incur a penalty for any operation of its system which falls below the standards. Instead, the standards will simply flag performance which requires some scrutiny or explanation. Thus, a higher standard would be appropriate for this screening purpose than might be appropriate if there were automatic financial consequences when the utility failed to meet the standard. When several sources of standards are available, I would therefore tend to recommend standards from the higher end of the range.

III. BECo's Approach

Q. How has BECo's approach to standard-setting changed since its previous filing in DPU 1048?

A. There has been very little progress. BECo still proposes to:

1. Set standards exclusively from the performance of the individual unit (i.e., self-referent standards),
2. Set standards on the basis of only three years' data,
3. Set standards below the average of past performance, and
4. Remove outages of arbitrary length from the reliability standards.

BECo has improved its approach slightly by moving the standards closer to the mean of past performance, by dropping its suggestion that the standards should vary with actual outages, and by making an effort to link its self-referent standards to comparative and absolute sources.

Q. How has BECo made this link, and does this eliminate the problems with self-referent standards which you have discussed?

A. BECo compares its units' average performance in the 1980-82 period with the performance of allegedly comparable groups of units, and attempts to reconcile its oil-unit heat rates with their design heat rates. I will comment only on the application of the comparisons at this point; I will discuss the choice of the comparison groups below.

Even if BECo's comparisons were apt, the application of the comparisons are inappropriate. BECo finds that its units did not perform at the same level as other utilities' units: for some important factors (Pilgrim CF, overall oil EAF) BECo did worse, for others (oil heat rates, some individual unit EAF's) BECo did better than the selected comparison group. BECo maintains that its individual unit performance is acceptable for use in standard setting because none of the differences are statistically significant and because certain results indicate

> "Pilgrim is performing well above average."
>
> "Pilgrim has performed in an exceptional manner."
>
> "Exhibit BE-13...indicates favorable performance of our generating units, compared to other power plants."

BECo can not have it both ways. Either the differences are significant or they are not. If Pilgrim's FOR is "well below the average" at a difference of .50 standard deviations, then its AF is also well below average with a .68 standard deviation difference.

If the differences are important, some explanation is clearly in order. If the differences are not significant, then it is hard to see why BECo considers its own-plant data to be preferable to industry figures. If Pilgrim CF experience is about the same as the national average, why not base the standards on the national experience? If the 3.6 point difference between Pilgrim and national experience is not significant, why not set standards so they average 3.6 points above the national average? The effect of BECo's methodology in this particular situation is to accept Pilgrim's poor performance as the starting point for developing standards.

Q. Please describe briefly why it is inappropriate for BECo to use self-referent standards.

A. As I discussed above, self-referent standards are not useful in determining efficient performance. The fuel clause statute (Ch. 164, §94G) requires that the performance program "provide for the efficient and cost-effective operation of individual generating units" and that the company use "all reasonable means to procure the lowest possible costs."

It is difficult for me to interpret this language as allowing units which have performed poorly in the past to continue performing poorly.

Q: Has BECo proposed that the targets for its units be set at their historic levels?

A: No. BECo has proposed setting the targets a standard deviation below the mean of the last three years' performance. Thus, substandard plants would be allowed to deteriorate further, and exceptional plants (if BECo has any) would be allowed to drift back towards or below past average performance, without any explanation being required. As I explained in my testimony last year, BECo's method has no particular statistical meaning or relevance, since it produces neither a confidence interval for the true mean, nor a prediction interval for a particular year's experience. Setting targets one standard deviation below the mean is certainly better than setting them two standard deviations below the mean, as BECo proposed last year. However, it is still equivalent to the worst 30% of past performance, or about the worst year in the last three. This is an extremely modest standard, and hardly represents optimal performance.

Q: Has BECo used all of the data available in setting its standards?

A: No. BECo rejects all data from other utilities' units, from its own units of similar size and design, and even from the subject unit before 1980. BECo has the 1979 data readily available, since it was used in DPU 1048, but chose not to include it in the current standards. BECo's defense of this behavior is limited to the claim that "the use of most recent historical data would best represent the current conditions under which the units are to be operated," or that the last three years "represent recent performance and conditions." Unless BECo can show that external conditions in 1979 were significantly more different from those to be expected over the next year than were the conditions in 1980-82, there is no reason to exclude that data. I see no reason to believe that the major factors affecting performance (NEPOOL's capacity mix, ocean water temperatures, environmental restrictions) changed markedly between 1979 and 1980. Thus, BECo is simply asking that each unit's performance target be based on its recent performance, so that units which have deteriorated since 1979 are held to a progressively lower standard, and those which have improved are held to a higher standard.

This approach is not helpful in setting performance standards, since it has no connection with cost-effective performance. Coupled with the proposal that standards always be set <u>below</u> past performance, this short retrospective horizon permits units to deteriorate significantly and repeatedly without ever triggering an investigation. Any self-referent standard automatically forgives BECo for poor performance at past levels; in addition, BECo is essentially asking to be forgiven for any future deterioration, so long as it is slow.

Q: You have explained that BECo's self-referent standards are very weak, and would allow significantly suboptimal performance to escape investigation. Are BECo's performance standards based entirely on this limited, self-referent analysis?

A: No. The reliability standards are modified by entirely unsubstantiated and arbitrary outage projections. These projections do not seem to be related in any way to historical experience, either with the particular unit or nationally, nor to BECo's own projections of typical outages. Table 2 compares BECo's projected outages in this case to its representations in its 1982 Cost of Service Information filing with FERC in compliance with PURPA §133. The two sources agree closely in some instances, but the current projections show a different split between the New Boston units, a large increase in Mystic 7 maintenance, and a doubling of Pilgrim's maintenance outage.

Thus, BECo is asking in part (for non-outage periods) to be held only to its recent performance, and in part (for outage periods) to be held to whatever standard BECo wishes to propose for the particular purposes of this case. If the Commission allows BECo to continue setting performance targets in this manner, it is not clear that the targets will

	BECO's Assumptions for 8/1/83 to 7/31/84	Typical Projection from BECO (1982)
PILGRIM	86 days	42
MYSTIC 4	39 days	42
MYSTIC 5	44 days	35
MYSTIC 6	____	84
MYSTIC 7	46 days	14
NEW BOSTON 1	44 days	70
NEW BOSTON 2	46 days	21

Table 2: Comparison of BECO's current maintenance assumptions with past assumptions.

have any meaning or usefulness: certainly, they will not be performing the purpose described in the fuel clause statute.

Q: Are there other problems in BECo's implementation of its method?

A: Yes, there are several problems. First, BECo does not include all of its units. Except for Pt. Lepreau, BECo does not propose standards, or even provide historical data, for any of its units for which it is not the primary owner. I can see no reason for exempting any of these units from the standard-setting process. Once a variance has occurred, and in prescribing relief, this Department may wish to recognize the nature of BECo's entitlement in the unit as shareholder (the Yankee plants), joint owner (Wyman #4), life-of-unit buyer (Canal #1), or intermediate-term buyer (Coleson Cove, Potter, and Pt. Lepreau); the nature of the variance, the size of and value of the entitlement, BECo's efforts to warn or assist the operator, and the relative size and expertise of the parties. In order for any regulatory action to be taken, however, standards first must be set so that variances can be detected.

As Table 3 illustrates, BECo's choices of units to include and exclude does not seem to follow any obvious pattern. The Canal 1 purchase is for more capacity and a longer period than the Pt. Lepreau purchase, yet Pt. Lepreau is included

UNIT	MW	BECo 1982 FERC Form 1 % of MWH	BECo 1982 FERC Form 1 % of $	Mid-1983: DPU 1009-L Exh. BE-8 % of MWH	Mid-1983: DPU 1009-L Exh. BE-8 % of $
Included					
Mystic 4	136)			2.98%	6.22%
Mystic 5	135)	8.33%	13.99%	0.48%	0.89%
Mystic 6	144)				
Mystic 7	592	22.65%	28.10%	17.49%	27.11%
New Boston 1	380)			17.11%	25.46%
New Boston 2	380)	32.65%	44.50%	14.92%	21.92%
Pilgrim	505 [a]	19.75%	2.96%	29.55%	5.51%
Pt. Lepreau	100 [b]	5.58%	0.59%	5.96%	0.77%
Jets	232	0.04%	0.15%	0.36%	1.37%
Excluded					
Mass Yankee	14.3 [c]	0.67%	0.17%	0.92%	0.26%
Conn Yankee	55.3 [c]	3.44%	0.91%	3.47%	1.19%
Canal 1	142	5.63%	6.71%	6.40%	8.70%
Potter 2	29-65 [d]	0.10%	0.22%	0.06%	0.18%
Wyman	36	0.53%	0.89%	0.15%	0.25%
Coleson Cove	18	0.63%	0.81%	0.14%	0.18%

Table 3: Contribution of BECo Units to Energy Supply and Fuel Expense.

Notes:
a. MW rating listed excludes life-of-unit sales to other utilities.
b. Pt. Lepreau energy and cost added to 1982 as if unit operated at 80% capacity factor.
c. Capacity from BECo filing with MEFSC.
d. Varies from month to month.

and Canal is excluded. Canal is also projected to be the fourth largest contributor to BECo's fuel bill. Each of the excluded units provided more energy and cost more in fuel than all the jets put together, and some units cost more than Pt. Lepreau. One of the excluded units (Wyman) involves a direct BECo ownership interest, while one of the included units (Pt. Lepreau) does not.

BECo should expand the group of units for which it reports performance and sets goals. This applies particularly to the Yankee plants, and to Canal 1. As I noted last year, it would make sense for one utility to take responsibility for presenting standards and data for each plant, and for the other owners (or holders of entitlements) to accept the results of the lead utility's standard-setting proceedings and quarterly reviews. Thus, BECo's proceedings might set standards and reach conclusions on the reasonableness of Pilgrim performance which would be applied to Eastern Edison and Commonwealth Electric, and the results of Commonwealth cases for Canal could apply to BECo. Table 4 lists the units in which both BECo and other utilities possess entitlements, and suggests lead utilities for each. In addition to the units listed in Table 4, lead utilities should be designated for the Maine and Vermont Yankees, New Haven Harbor, and Canal 2.

Unit	Suggested Lead Utility for Performance Standards
Pilgrim	BECo
Canal	Commonwealth
Yankee Rowe	MECo
Connecticut Yankee	WMECo
Wyman 4	MECo
Potter 2	BECo
Coleson Cove	MECo

Table 4: Suggested Lead Utilities for Performance Standards.

Second, and perhaps more importantly, BECo. continues to change the rated capacity of some units without adequate explanation. This tactic renders the capacity factors and equivalent availabilities of the affected units nearly meaningless. Capacity factor is simply the ratio of average output to rated capacity, so changing the rating will modify the reported capacity factor, without any change in the amount of power produced. Since EAF is an estimate of potential capacity factor, it responds to the rating in the same way as CF does. The ratepayer does not care about the rating, or about any measure of performance, but only whether the unit is efficiently producing as much power as it should be, to provide the lowest feasible rates.

Consider a hypothetical 1000 MW unit which is temporarily limited to 800 MW by an equipment malfunction, and actually produces an average of 600 MW. Rated at its usual 1000 MW capacity, the unit operated at 60% capacity factor. But the stroke of a pen can change the nominal rating to 800 MW and the capacity factor to 75% (600/800).

BECo's reratings have not been this dramatic, but neither have they been insignificant. For example, the New Boston units were rated at 380 MW for performance standard purposes in 1979 and 1980, derated to 355MW in 1981, and to 350 MW in 1982. The CF's reported in any particular year would have been different if one of the other capacity factor ratings had been used: the 69.8% CF reported for Unit 2 in 1981 (based on 355 MW) would have been 65.2% at the 380 MW rating and 70.8% at the 350 MW rating. If BECo had reported the unit's capacity as 248MW, the 1981 CF for unit 2 would have been reported as 100%, with no change in power production. Similarly, part of the "improvements" in performance at Mystic 4 and 5, following their overhauls, apparently results from their deratings from 146MW to 135MW.

Curiously, BECo continues to report much higher capacity ratings for other purposes. Table 5 shows the capacity figures used by BECo. in this filing and other filings. In addition to the clear trends of derating Mystic 4 and 5, and New Boston, BECo. also seems to treat Mystic 7 as a larger unit for almost all other purposes than it does in setting plant performance standards.

If the Commission allows BECo. to continue derating units without providing an explanation as complete and compelling as would be required for an equivalent and indefinite string of substandard performance, historical data on capacity factor and equivalent availability factor will become totally meaningless, BECo will be able to achieve prescribed goals by derating units rather than improving performance, and a major purpose of the fuel clause reform and of these hearings will have been defeated.

UNIT	Current Filing	EFSC Forecast [a]	FERC Cost-of-Service [b]	Fuel Adjustment Filing [c]
Pilgrim	670.0	670.0	670.0	670.0
New Boston 1, 2	350.0	380.0	380.0	380.0
Mystic 4	135.0	136.3	146.0	136.2
Mystic 5	135.0	135.0	137.9	137.9
Mystic 6	149.0	143.8	141.2	143.8
Mystic 7	565.0	592.0	585.0	592.0

Table 5: BECo-Operated Units, Claimed Capabilities.

Notes:
a. From BECo Long-Range Forecast, 3/1/83, Table E-12.
b. BECo FERC Form #1, year ended 12/31/82.
c. DPU 1009-k, Exh. BE-4.

Third, as I noted last year, the average of monthly heat rates will tend to be higher than the average annual heat rate. In general, the months with the lowest capacity factors will show the highest heat rates, since the unit will be operating at less efficient levels. Thus, the simple average of monthly heat rates will generally be larger (and hence more lenient) than the output-weighted annual heat rate. Thus, BECo's heat rate standards are even lower, relative to experience, then are the other standards.

Fourth, BECo's performance targets do not recognize some of the factors which are difficult to predict, but may affect heat rate performance significantly. These include the amount of gas available to Mystic 7, and the extent to which all the oil units are dispatched (which depends on the availability of nuclear, coal, and efficient oil units throughout NEPOOL). Both of these factors should be incorporated into the standard, as I suggested last year.

IV. COMPARISON ANALYSES

Q: Is BECo's comparison methodology appropriate?

A: No, for a number of reasons. Looking first at BECo's comparison groups for Pilgrim, we see that they include some highly irrelevant units and ignore some relevant data. The all-nuclear group includes a high-temperature gas-cooled reactor, very young reactors, very small demonstration reactors, and a large number of pressurized water reactors. Since capacity factors have generally been found to vary with technology, size, and (over the first few years) age, this aggregation is clearly inappropriate. The BWR group is closer to the mark, but includes the tiny Big Rock Point and La Crosse units; the first, second, and third years of Hatch 2 operation; and the third and fourth years of Brunswick 1 and Browns Ferry 3 operation. Maturation appears to end in year 5; see Easterling (1981) and GTF (1977). BECo also ignores the considerable amount of data from years prior to 1980, and does not examine the effect of size on commercial-size BWR units (ranging from 514MW to over 1,000MW). Generally, however, BECo includes too much irrelevant or doubtful data in the Pilgrim comparisons.

For the oil-fired units, BECo generally errs in the opposite direction, by excluding too much data. Again, all pre-1980 data is excluded, which is even harder to understand than in the nuclear comparison. While it is possible that nuclear capacity factors have changed over the last few years due to changes in regulatory standards and procedures, it is hard to identify any possible comparable change for oil plants. In addition, BECo starts with 134 comparison units, with better average reliability than BECo's units, and narrows the comparison groups for each BECo plant to 6-8 units, generally with lower reliability than theBECo units, and all with lower reliability than the original comparison group. BECo does not explain its selection criteria very clearly, but some problems are evident.

- o Only units burning 1% sulfur oil are included. No reason is given.
- o Units are rejected from the comparison groups for a variety of reasons, some of which have no obvious effect on performance (e.g., turbine manufacturer).
- o BECo made no attempts to correct for such factors as age, size, cycling, or design characteristics to make the comparison groups longer and/or more comparable to the BECo units.
- o BECo excludes units which outperformed its units despite unfavorable circumstances. For example, the Mystic 7 comparison drops the Anclote units and Arther Kill 3 because they cycle and because Anclote uses cooling towers; despite these disadvantages, these three units averaged 78.8% EAF and 10015 BTU/kwh, both better than Mystic 7.
- o BECo uses the arbitrarily derated capacity figures for New Boston, thus exaggerating this plants' EAF compared to other units.

Q: How can these problems be corrected?

A: First, BECo must be consistent in its use of data (such as MW ratings) and in its application of comparability criteria. Second, the analysis should start with the entire universe of relevant data, eliminating units and years only as required by data availability and by demonstrable incompatibilities. Third, in order to allow for any really thoughtful comparisons, BECo will also have to do some statistical analysis, to determine whether various factors affect performance, and if so, how much. Fourth, a group of units should be omitted from the comparison only when the analysis indicates that they behave in a pattern which is substantially different than the behavior of units more like the BECo unit of interest. For example, it is probably inappropriate to combine Westinghouse and GE turbines if one group improves with age and the other group deteriorates with age. Fifth, the remaining differences in the comparison groups can be corrected for either by statistical means, or for some simple variables (e.g., cooling water temperature) by engineering calculations. Finally, BECo must clearly document its data, decisions, and analyses.

BECo's comparisons are very limited, arbitrary, ad hoc, inconsistent and poorly documented. Hence, these analyses can not support the reasonableness of BECo's standards.

Q: Is BECo's application of the comparisons appropriate?

A: No. In several circumstances, BECo finds that its units have performed below the applicable comparison group. BECo then proposes that the standards be set <u>even lower</u> than the average of its historical performance. If the comparisons are valid, BECo should be using them in setting standards. If they are not valid, BECo should be improving them. I see no rationale for consistently setting standards below the level of a sub-standard (even marginally substandard) unit.

Q: Have you performed any comparison analyses?

A: Yes. I have used published analyses to suggest capacity factor standards for Pilgrim and Connecticut Yankee, used a BECo study to suggest a CF standard for Pt. Lepreau, and performed my own analysis for Pilgrim capacity factor. Due to the large amount of data and possible variables, I have not attempted to compare the oil plant performance to other utilities' oil plants.

Q: Please describe your use of published analyses.

A: A large group of plants can be incorporated into the standard-setting, by the use of more sophisticated statistical analyses. This approach has been taken in several regression analyses of coal and nuclear capacity factors (Komanoff, 1978; Perl, 1978, 1982; Easterling, 1979, 1981; Joskow and Rozanski, 1979). Regression techniques are advantageous for these screening purposes, in that they permit several descriptive variables to be incorporated simultaneously, which facilitates the merging of data from a greater variety of units.

The most recent such study which is useful for our purposes is Easterling (1981), which finds an expected MGN capacity factor for a mature BWR of 65.0%; for Pilgrim's 670MW rating this is equivalent to 65.8%. For Connecticut Yankee, the expected capacity factor would be 72.5% based on MGN, or 75.7% based on the 575MW NEPOOL rating.

Q: Do the regression studies you cited represent the most appropriate application of that technique to the purposes of this proceeding?

A: No. These studies only cover nuclear and coal plants, estimate only capacity factor, and neglect several explanatory variables which may be important in setting performance standards. Appendix B discusses further the design of regression studies of performance factors.

Q: Please describe your Pt. Lepreau comparisons.

A: BECo (1981), provides capacity factors for Canadian HWR's. For the first full year of commercial operation (which would be 1984 for Pt. Lepreau), six observations are provided, averaging 78%. However, the smaller Pickering units (515MW each) performed better in their first year (89.5% capacity factor) than did the 740MW Bruce units (72.3% capacity factor). Interpolating to Pt. Lepreau's 630MW rating gives a prediction of 80.7% for a first-year capacity factor. A similar size-dependence for performance is well established for U.S. light-water pressurized reactors; it is certainly plausible for Canadian heavy-water pressurized reactors.

Q: Please describe the regression analysis you performed for Pilgrim capacity factor.

A: I used data for all U.S. BWR's over 200MW through 1982, from the fifth full year of commercial operation onward. Excluding Pilgrim, this leaves a total of 20 units and 94 years of data. Maturation effects were eliminated by restricting data to the mature years.

The data used is reproduced in Appendix C. Regressions were performed for several equations, to determine the effect of size, refueling, and calendar year on capacity factor as measured by MDC. The results of these regressions are listed in Appendix D.

Three observations result from my analysis. First, refueling reduces BWR capacity factors by about 11 points in refueling years. Second, while there is a downward trend in capacity factors as a function of unit size, that trend does not appear to include the over-1000MW units. This non-linear relationship is difficult to model precisely, but does not appear to be very important for Pilgrim. The average size of the under-1000MW group is very close to that of Pilgrim, and the over-1000MW group would be expected to perform like a unit of close to Pilgrim's size. Third, capacity factors in 1980-82 averaged about 12 points below average.

For projecting Pilgrim performance, I would use Equation #3 in Appendix D, which indicates that the expected capacity factor with refueling would be 68.1% under pre-1980 conditions, and 55.6% under post-1980 conditions. If the post-1980 data reflects the impact of downtime for major plant revisions resulting from the TMI experience, it seems reasonable to expect capacity factors to rise back toward the pre-TMI norm, at least until the next major nuclear accident occurs. Hence, I would set a comparative standard for Pilgrim at the average of pre- and post-1980 experience, or 61.9%. Alternatively, the standard could incorporate actual experience through 1983 (which will be available by the end of the performance period), as average mature BWR capacity factor less 10.3 points for each unit-year in which refueling did not occur.

V. Absolute Standards

Q: What absolute standards do you consider appropriate for this proceeding?

A: There are three groups of units to which different kinds of absolute standards should apply: Pt. Lepreau, the other nuclear units, and the oil units. For Pt. Lepreau, BECo's preoperational expectations are explicit and clear, and were the basis of representations to the DPU regarding the desirability of the purchase. From BECo (1981), the base case capacity factor used in analyzing the project was 80%, which agrees well with the first-year comparison performed above, and is exactly the figure projected by New Brunswick Electric. Curiously, BECo claims to rely on this 80% projection, but actually uses a target of 71%, barely above the "pessimistic" 70% capacity factor used in the BECo (1981) sensitivity analysis.

Since the Pt. Lepreau purchase was justified on the basis of savings from oil displacement, a breakeven performance standard is also appropriate. That is, the costs passed on to customer in a year may reasonably be caused at the actual fuel savings in that year. The required capacity factors is thus a function of Pt. Lepreau's fixed and operating costs, as well as the cost of the avoided generation. If BECo does not collect all of its Pt. Lepreau costs in one year due to a breakeven cap, it seems fair to allow those costs to be recovered in later years when the unit exceeds its breakeven point.

For BECo's other nuclear units, neither the preoperational representations or breakeven analyses is particularly applicable. However, in light of BECo's willingness to rely on NEPOOL reliability projections in selling Pilgrim 2, it seems fair to use those projections (listed in Table 6) in setting performance goals. For Pilgrim, BECo has recently (BECo 1982) represented that a 17.3% FOR and 42 days of annual maintenance are typical: this is equivalent to a capaciaty factor of 73.2%. In recent fuel clause filings (e.g., BECo 1983), the FOR has been raised to 20%, which would still produce a 70.8% capacity factor.

For the oil units, I have used the same sources as for the nuclear units. However, the NEPOOL projections are of less relevance, since BECo has not used these figures to justify oil plant construction.

Q: Does BECo's design analysis for heat rates provide a justication for its heat rate standards?

UNIT	From NEPOOL Planning Studies EFOR [a]	Maintenance wks/yr [b]	EAF	From BECo Cost Data (BECo 1982) EFOR	Maintenance wks/yr	EAF
Pilgrim	9.1%	8.5	76.0%	17.3%	6.0	73.2%
Conn Yankee	9.2%	8.5	76.0%			
Mass Yankee	5.2%	8.5	79.3%			
New Boston 1, 2 [c]	9.0%	4.5	83.1%	15.4%	7.5	72.4%
Mystic 4, 5, 6 [d]	3.6%	3.5	89.9%	13.9%	7.7	73.4%
Mystic 7	7.5%	7.5	79.2%	6.9%	2.0	89.5%
Canal 1	7.5%	7.5	79.2%			
Wyman 4	9.1%	7.5	77.8%	9.1%	7.0	78.7%
Coleson Cove [e]	9.0%	4.5	83.1%			
Potter 2 [f]	11.3%	2.0	85.3%			

Table 6: NEPOOL and BECo Standards for EFOR and Maintenance

Notes:
a. From GTF (1977); oil units assumed to be drum-typ except as noted.
b. From NEPLAN (1979).
c. Once-through; BECo values averaged.
d. BECo values averaged.
e. Assumed to be once-through.
f. NEPOOL maintenance from NEPEX (1979).

A: I do not believe so. BECo simply lists a series of deviations from design heat rate, which more or less add up to current heat rates. Even if the figures listed in Exh. BE-14 are correct, they do not establish that the current heat rates represent efficient operation. BECo's analysis makes no attempt to demonstrate that the deterioration in performance is inevitable or prudent. Are the turbines (to take a wide-spread problem) less efficient than design due to poor operating and maintenance practices, or to an inevitable aging process, or to cost-effective deferral of maintenance, or to steam extraction for new pollution-control devices? Until BECo can answer these questions, the heat rate analyis explains very little.

VI. CONCLUSIONS

Q: Please summarize your recommendations for the standard-setting process for plant performance.

A: My major recommendations are:

Recommendation 1: Avoid the use of self-referent methodologies.

Recommendation 2: Require utilities to tell the same story for all purposes. Do not allow extravagant performance claims for construction planning and rate design, and very modest targets for actual performance. Do not allow utilities to change unit ratings without adequate explanation, or to use different ratings in different proceedings.

Recommendation 3: Use procedures which make sense and encourage utilities to perform well. Avoid methodologies which are subject to arbitrary manipulation (e.g., BECo's outage projections and selection of comparison units) or reward poor performance (e.g., BECo's moving self-referent standards).

Recommendation 4: Set standards at levels which represent adequate performance. Plants should not operate at below-average performance for long periods of time without triggering investigations. If there is a compelling reason to restrict the frequency of variances by setting the target a standard deviation (or any other ammount) below the mean value, the standard should at least be cumulative, so that the target gradually approaches the mean.

Recommendation 5: Set standards with a method which is intellectually consistent and which will remain applicable in the long run. Except on an explicitly interim basis, avoid the use of arbitrary methods which just happen to produce "about the right" standards this year. Such standards may provide perverse incentives in the future, or require frequent radical revisions.

Q: What are your recommendations for standards to be applied in this proceeding?

A: My recommendations are listed in Table 7. For the oil units and Yankee Rowe, these recommendations come straight from Table 6, since adequate comparisons and analyses of expectations have not been performed. For Pt. Lepreau, I list BECO's pre-operational representation, but I believe that a breakeven standard

UNIT	Comparative Approaches	Absolute Measures: Expected/ Promised	Absolute Measures: Other Filings [e]	Absolute Measures: Break-Even	Proposed Standards [f]
Pilgrim	[a] 61.9%		73.2%		67.5%
Conn Yankee	[b] 75.7%		76.0%		75.8%
Mass Yankee			79.3%		79.3%
Pt. Lepreau	[c] 80.7%	80.0%		[d]	80.4%
New Boston 1, 2			72.4%		72.4%
Mystic 4, 5, 6			73.4%		73.4%
Mystic 7			79.2%		79.2%
Canal 1			79.2%		79.2%
Wyman 4			77.8%		77.8%
Coleson Cove			83.1%		83.1%
Potter 2			85.3%		85.3%

Table 7: Recommended Standards for EAF (and Nuclear CF)

Notes:
a. Comparison from my regression analysis; see text.
b. Comparison from Easterling results.
c. Comparison uses size adjustment.
d. Breakeven value will vary with costs of Pt. Lepreau and of oil.
e. Lowest value for each plant from Table 6.

would also be appropriate. A simple breakeven standard would simply require a quarterly report from BECo on the costs and savings from the Pt. Lepreau purchase; if costs exceed savings, the difference should be deducted from current fuel expenses and deferred until savings exceed costs, at which time the shortfall could be corrected. For the other nuclear units, I use the average of the comparative analyses and of BECo's other filings.

Q: Does this conclude your testimony?

A: Yes.

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APPENDIX B:

Steam - Plant Performance:

Perspectives and Methods for Standard - Setting

Draft 1

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November 30, 1982

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II. Engineering Review of Power Plant Performance, or The Case of the Smoking Socket Wrench.

To date, regulatory commission investigations of outages and efficiency have generally centered on engineering analyses of utility decisions in construction, operation, or maintenance which demonstrably resulted in inadequate performance.[5] Typically, such investigations are triggered by a prolonged outage or some other obvious problem . Intervenors and regulatory staff then proceed to search for the "smoking socket wrench" which will link utility management to the operating difficulties: an object dropped into the boiler, a valve left open , a regulatory order ignored , an employee's warning neglected[6]. The utility generally argues either that the problem was beyond management's control, or that it was unforeseeable, or that it did not really extend (or create) the outage (or reduce plant output or efficiency), or that the problem would have arisen even sooner (or just a little later) if management had acted differently. The Commission must then decide whether the utility's actions and precautions were sufficient, whether there was some preventative or remedial action available which the utility failed to take, and whether the utility should have known facts it did not know. If the utility is found to have been at fault, the regulators must then determine exactly what effect the error had, what the dollar consequences were, and who should bear the cost of the consquences.

The engineering approach, while frequently useful, has several shortcomings. First it requires a detailed reconstruction of the events which led to poor performance. In some cases, this task is exceptionally simple: for example, the "smoking socket wrench" was in plain sight when a worker at Crystal River dropped a test weight into the reactor. In these circumstances, the facts are clear, and the adjudication centers on management's ability to prevent such events, and the costs attributable to the error. The causes of other problems, such as catastrophic turbine failure, or the premature failure of a tube wall, may be much harder to determine. The utility arguably may not have ordered exactly what it needed, received what it ordered, operated the unit as it had originally expected or as the vendor recommended, maintained the unit properly, or inspected it adequately. Even if deficiencies are acknowledged in all these areas, it may be impossible to link the instant problem to any particular management error over a decade or two of planning, construction, and operation. Thus, even in the case of major component failures, the causal connection to management may be virtually impossible to either establish or refute.

Second, engineering analyses are even more limited in their ability to detect numerous small cumulative problems than they are in explaining large obvious problems. For example, minor operator errors, or maintenance lapses, may result in small longterm reductions in output or efficiency which have just as large total costs as do many catastrophic failures. But such small problems will be difficult to detect, and even harder to relate to utility actions.

Third, while "smoking socket wrenches" are well suited to identifying at least some major utility errors, they are not generally capable of identifying superior utility performance. A few minutes of carelessness may halve the annual capacity factor of the typical baseload plant; increasing availability by a similar amount would probably require years of management excellence. It will generally be very difficult to determine through the engineering approach whether exceptional performance is due to good management or good luck. The engineering approach may thus be seen as causing an anti-utility bias, in that it will necessarily focus on mishaps or accidents.

Fourth, the preceeding considerations produce rather unfortunate incentives for utility behavior. It may be very difficult for the utility to receive any rewards for generally superior (but not dramatic) performance, and it will be very difficult for intervenors to establish utility responsibility for generally poor performance which is not associated with catastrophic failures. Thus, under engineering performance regulation, the utility will have very little incentive to improve the unglamorous but important details in plant operations and maintenance. Instead, only management will have an incentive to concentrate on avoiding the large, obvious errors which will result in penalties.

Fifth, retrospective engineering analyses place the regulatory commission in the position of second-guessing the utility in an area (plant operation) in which the utility has substantially greater expertise. Many regulators, even if convinced in hindsight that utility management did not make the correct decisions, will be reluctant to conclude that management should have been expected, without hindsight, to have identified the proper course of action, at the relevant times. Other regulators may hold utilities to impossibly high standards of prescience. In either case, the incentives for the utility to maintain good performance, for intervenors to investigate problems, and for utilities to explain their positions clearly and completely, are all reduced if the outcome of the case is dominated by the regulators' attitudes toward hindsight.

Sixth and finally, engineering investigations of plant can be prohibitively expensive. Every case requires a separate detailed record on a new set of engineering issues. Thus, it is generally necessary for intervenors and staff to retain experts in the particular technical area at issue, such as nuclear safety regulation, coal boiler maintenance, or turbine inspection. In many of these areas, very few experts are available to regulators and intervenors, and those few may have limited time to devote to any particular case. The utility may also be compelled to devote to these cases much skilled staff time and consultant resources which could be more productively used in other pursuits, in order to reproduce and defend the relevant chain of events and decisions. Given the complexity and uniqueness of each case, and the lack of staff engineering resources, regulators will often be reluctant to act decisively on the records produced.

These disadvantages of the *ad hoc*, "smoking socket wrench" approach to plant performance suggest that a more systematic objective basis for setting performance standards would be desirable. The next section considers several approaches to performance setting. Unlike episodic engineering reviews, these approaches will focus on overall performance.

III. Setting Plant Performance Standards: Considerations and Approach.

As previously noted, power plant performance standards are part of a general shift of fuel-cost regulation from positive to normative.

Performance standards might conceivably be based on any one of a range of concepts ranging from the purely positive to the purely normative. Starting with the positive end of the range, and proceeding to the normative end of the range, some of the possibilities include:

(1) "The plant should do as well as it will do." (This is equivalent of having no standards at all.)

(2) "The plant should do as well as the average (or the worst, or the best) that it has done in the past."

(3) "The plant should do as well as others like it have done."

(4) "The plant should do as well as similar ones, competently run, have done."

(5) "The plant should do as well as has been promised for it."

(6) "The plant should do as well as it could possibly do."

Except for some special purposes, where psychological reinforcement is thought to be more important than economic incentives (such as encouraging underachieving school children), performance standards should generally be based on the normative concepts from the second half of the preceding list. For example, it makes very little sense to hold a utility only to the level of its previous performance, without first determining whether that performance was very poor, very good, or somewhere in between.

This hierarchy of standard-setting concepts can be reorganized into three general ways in which standards could be set.

First, each unit's performance standard can be determined by a self-referent standard, based on the unit's past performance, such as standards of types #1 and #2 in the preceding list. Such standards are inherently stricter for those units with good performance histories than for those with poor past performance. This is hardly a fitting reward for those utilities which have historically taken the greatest care in plant operation. Unless there is some compelling reason for believing that the unit's history is representative of appropriate level of performance (neither extraordinary nor inadequate), self-referent standards are not likely to be useful in identifying efficient and cost-effective operations. Self-referent standards are also inherently inapplicable to new units. If applied on a rolling basis (e.g., if the standard in any year is determined by performance in the preceding three years), serious and perverse incentive problems may be created.[7] Therefore, this paper will not discuss self-referent standards further.

Second, standards can be based on comparative analyses, which aggregate the experience of many units. This approach includes standards of types #3 and #4. The comparisons may simply average data from a set of units which share some common characteristics, or they may involve more complex statistical analysis. Simple comparisons are generally performed on a set of very similar units, as it is difficult to justify direct comparisons between units which vary in any significant manner. The resulting data sets tend to be small, and the comparability of the units is almost always subject to some dispute. Various statistical techniques, such as multiple regression, may mitigate these limitations; they permit several descriptive variables to be incorporated simultaneously, which facilitates the merging of data from a greater variety of units.

Third, standards may be based on <u>absolute</u> measures of proper performance, as suggested in items #5 and #6 in the preceding list. Examples of sources for absolute standards include industry standards, power pool assumptions or recommendations, and reports of the unit's performance prepared by the utility for other purposes, such as in response to PURPA §133, for setting small power products rates, or in production costing models used in expansion planning. Other sources for absolute standards include the utility's preoperational expectations regarding the performance of its units, and the performance level necessary to justify the fixed costs of the unit.

The various kinds of standards are appropriate for different situations. Using pre-operational expectations to set performance standards is intrinsically appealing: if a utility builds a plant to operate in a particular manner, and the commission accepts that performance level as justifying construction, it seems reasonable to use that level as a base-line for assessing utility performance. This approach helps to tie together planning and operation, and gives the utility greater incentives to extract accurate projections and adequate performance from its suppliers.

Standards may most reasonably be based on prior projections for plants for which cost-effectiveness issues were extensively studied, and for which a reasonable amount of relevant experience with previous plants was available. Both of these conditions are met for most new large nuclear or coal units currently under construction or planned; neither condition will be met for many older plants, such as the earliest nuclear units.

Comparative standards can be established in a simple manner for any plant which is one of a group of similar units.

For a 600 mw boiling-water reactor (BWR), this set could be the other six BWR's between 500 mw and 700 mw. For a similar sized Westinghouse nuclear unit, the comparison set could be the other seven Westinghouse units between 400 mw and 650mw,[8] or it could be also include the other pressurized-water reactor in that size range, Fort Calhoun. In either case, the comparability of the units and their selection is debatable, especially as regards the inclusion of the smallest unit in each set. For the smallest nuclear units, no set of comparable units exists, at least in the United States, so this technique is not applicable for these plants.[9] Defining an unambiguous comparable set for a fossil unit may be just as difficult.

The more powerful statistical approaches avoid the problems of defining a totally comparable set; the next section explores this technique in greater detail.

IV. Design of Comprehensive Comparative Analyses

As discussed, there are severe limitations on the applicability of retrospective engineering reviews; and of self-referent, absolute, and simple comparative analyses for setting plant performance standards. This section sketches out a comprehensive regression analysis which could provide a sound statistical basis for fuel cost regulation. This approach would define acceptable, inadequate, and superlative performance based on the mean and variance of national experience with a broad range of similar[10] units, correcting for unit age, size, and other factors. Regulatory implementation of this technique would be easier on all parties than a series of engineering studies, and would permit more rapid adjudication of specific plant performance issues. This description is quite general in nature, and is intended to illustrate an appropriate approach to these subjects, rather than to describe a precise analysis plan in definitive detail. Indeed, the detailed analysis will vary with the needs of each utility and each jurisdiction, depending on the mix of plants and on the regulatory structure.

The economically most important plant performance characteristics are the equivalent availability factors of plants with relatively low fuel costs, and the heat rates of plants which use large dollar quantities of fuel. Equivalent availability factors are important for nuclear units, most coal-fired units, and in some systems, particularly efficient gas- and oil-fired units.[11] For truly baseload units, equivalent availability should be the same as capacity factors; for other units it is a measure of potential capacity factor, corrected for load following.[12] Heat rates are not generally important for nuclear power plants, because their fuel if relatively inexpensive, but heat rates are very important for coal units and major oil/gas units.

Let us first consider the problems of modeling availability, in which considerable work has already been done. Plausible regression models have been developed[13] for nuclear capacity factors, which account for such factors as:

1. technology (PWR or BWR);
2. unit age;
3. unit size (in megawatts); and
4. unit vintage.

Each of these studies uses multiple linear regression to explain the differences in capacity factors between units. They have all been directed toward predicting the average cost of power from a planned or proposed nuclear unit, rather than determining the reasonableness of a unit's performance in any particular year. For that purpose, it would be desirable to incorporate several improvements.

First, the effect of refueling outages on nuclear unit capacity factor has never been incorporated in a statistical study. Since refueling and associated activities account for a large portion of the year-to-year variation in capacity factor, including refueling in the analysis should considerably increase the explanatory power of the regression. One approach to modelling refueling would be to give a fixed credit in calculating the capacity factor for any year in which a refueling took place. An alternative would be to include a variable for the number of refuelings which occurred in the year. Refueling outages often overlap calendar years, so one year may have more or less than one full refueling.

Second, all past studies have found significant maturation effects, but have treated plant age in a highly simplified manner. The variable measuring age in a calendar year has invariably been treated as an integer.[14] For example, most analyses have treated the first full calendar year of a plant's life as year 1, even though some units (which started up in the previous February) were already eleven months old at the start of the year, while others were only a few days old at the start of the first calendar year.[15] This treatment of age would create modelling problems even if commercial operation dates were uniformly distributed through the year: as Table 1 illustrates, investor-owned utilities tend to declare new nuclear units in commercial service in December, presumably for tax and rate-making purposes. In future studies of plant performance, it would be desirable to use a more accurate measure of age, such as the actual time from first commercial operation to the middle of the calendar year. This improvement may also increase the revelance of experience in the first partial year of operation, which totals about 30 reactor-years for the large units currently on line.

Third, explanatory variables in previous analyses have measured time in terms of a plant's age and vintage (i.e., its commercial operation dat), but usually not in terms of the calendar year. Especially in modelling post-TMI performance, it is important to recognize that the current date on the calendar (e.g., 1979) may have as much influence on capacity factors as do the plant's age and vintage. Various dummy variable structures should be tested, such as dummies for individual calendar years, for all post-TMI experience, or for each unit's worst post-TMI year.

Fourth, analyses of nuclear performance for capacity planning purposes generally use measures of capacity which are known during the planning process, such as generator nameplate capacity or design electrical rating (DER). For the purposes of evaluating the operation of the plant, a measure of current acheivable output, such as maximum dependable capacity (MDC) may be more appropriate.[16] MDC is based on actual operating conditions, rather than conditions projected during the planning process. The statistical determinants of nuclear capacity factors should ideally be studied using both DER capacity and MDC capacity, at least until it can be determined that one of these measures produces superior results.

Fifth, BWR's and PWR's clearly have different performance histories, and most studies treat them as two different data sets, on which completely separate regressions are run. However, some explanatory variables (e.g., size, age, calendar year, refueling) may affect the two plant types in the same way. If this is the case, better estimates of average plant performance and the variability in performance may be obtained by pooling the data for some purposes.[17]

Sixth, there may be cyclical behavior (that is, serial correlation) in nuclear capacity factors, such that several better-than-average years at a plant are generally followed by a worse-than-average year or vice versa. This phenomenon could result, for example, from cycles of maintenance and safety-upgrading. It would be premature to label the capacity factor in a particular unit-year as being extra-ordinarily high or low without determining whether the deviation can be explained by such a cyclical phenomenon.

A comprehensive study of nuclear capacity factors would produce estimates of industry-wide experience for a plant of a given type, age and size, with a given refueling history, for a particular year, as well as prediction intervals, measuring the variability of industry experience around that average. From those results, both annual and cumulative performance targets could be calculated, as will be discussed in the next section.

Some of the previous statistical studies of nuclear capacity factor have also estimated coal capacity factors, recognizing unit size, age, vintage, and similar explanatory variables.[18] The use of capacity factor as the measure of availability does not distinguish between mechanical problems and load following; some of the studies attempt to correct for losses due to load following, as by including utility load factor among the explanatory variables, but equivalent availability factor would be a more useful measure of individual unit performance. Explanatory variables which deserve special attention for coal-plant availability include manufacturer, construc-

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tion and maintenance costs, and a set of technical variables, which may include load following ability, the extent of actual load following, O & M expenditures, fuel quality (heat content, sulfur content, and ash content), boiler technology, and pollution control equipment, and cooling water source(tower, pond, ocean, etc.)

It does not appear that the statistical approaches used in modelling nuclear and coal-plant capacity factors have been extended to modelling gas or oil plant availability or to modelling heat rates for any type of plant. These latter problems seem to be well suited to analysis by multiple regression and other statistical techniques; the insights gained in past analyses can be helpful in selecting the variables and functional forms for the entirely new analyses.

An analysis of equivalent availability for gas and oil fired steam plants would be very similar to that for coal plants, and it may even be possible to merge the two data bases for some purposes. One advantage of studying all fossil plants together would be the ability to predict the reliability effects of fuel-shifting.[20]

The products of the plant availability analyses would ideally include annual and cumulative performance targets, with allowance for the explanatory variables which are found to be relevant, and a methodology for determining actual plant equivalent availability factors for comparison with the performance standard.

Industry-wide heat rate performance standards can be determined statistically in much the same manner as reliability standards.

It is not clear whether separate analyses would be required for coal and gas/oil plants, or whether the two data sets may be combined. As previously noted, nuclear heat rates are of limited economic significance. Again, such standard factors as size, age, vintage, fuel quality, pollution control technology (if any), and manufacturer, should be investigated. In addition, the temperature of the cooling water source may be critically important, since this parameter determines the maximum theoretical efficiency of fuel conversion. The actual coolant temperature for each plant is probably not available, but a number of proxies (cooling tower, latitude, average air temperature, average water temperature at the closest observatory, river cooling, ocean cooling) should be relatively easy to assemble. Heat rates may also be affected by aspects of plant operation, such as load following, capacity factor, or time since last major maintenance.

Each of the analyses described in this section will produce a formula describing typical industry-wide relationships between a measure of plant performance and a number of explanatory variables, such as unit size, age, and design. The analyses will also result in measures of the residual uncertainty in the underlying relationships, and of the usual variation of annual performance from the mean. The next section will discuss how these results can be converted into performance standards, and how the results of comparative and absolute analyses may be utilized in ratemaking.

V. The Use of Plant Performance Standards in Ratemaking

The appropriate application of performance standards will vary, depending on:

a. the derivation of the standard.

b. whether the standard is a point estimate or a range, and

c. whether there is a fuel adjustment mechanism, and if so, whether it is prospective or retrospective, short-term or long-term.

Standards can not be set for all plants with the same type of analysis, as indicated in Table 2 for absolute standards. Due to the combined effects of inflation and depreciation, almost any older unit will produce sufficient fuel savings to cover its current carrying charges, so the "breakeven" approach is only meaningful for very new or future units. The preoperational representations approach makes little sense for many old units, which have been modified substantially from the original form. A twenty-year-old coal plant, for example, may have undergone several changes to accommodate different fuel types and fuel qualities, and to meet new pollution standards. It may be difficult or impossible to trace the efficiency effects each such change. Also, serious attempts to project plant availability seem to be fairly recent developments, so only heat rate standards could even potentially be set for older plants from preoperational representations.

The current assumptions approach is only useful if such assumptions exist in the relevant form in which the utility can be assumed to be candid about its expectations, such as in reports to power pools for dispatch purposes. In general, this source of standards can be used only once, since it would not be possible to determine whether future reports were modified (consciously or otherwise) to produce less stringent standards; this would reduce the value of the reports for their original purpose, and for standard-setting.[21] Current assumptions may be a valuable source of interim standards while more comprehensive analyses are performed.

Comparative analyses are useful only to the extent that comparable units exist. The definition of "comparable" is much more restrictive for the simple small-group analyses, so those methods are more limited than are the statistical analyses. But even the most sophisticaled statistical analyses will not produce useful results for very small or otherwise unusual units.

The absolute standards are normally all point estimates, with no indication of normal variation between units or between years. If taken at face value, the standards might suggest that utilities should assume all costs of performance below these standards, and retain all benefits above the standards. This interpretation might create periodic cash-flow problems for the utilities, especially those whose power supply is dominated by a few large units. It would probably be seen as a serious liability by utilities (especially if their plants were performing consistently below standard) and by consumer advocates (if the plants generally exceeded standards.) Fortunately, there are other ways to implement the absolute standards, besides this direct ratemaking method.[22]

First, the standards may be used only to trigger investigations, rather than to determine financial consequences. The utility may be afforded an opportunity to explain why its units failed to meet standards; the resultant division of costs between ratepayers and shareholders may be adjusted to reflect the degree to which the problem was foreseeable and subject to management control, whether there were offsetting improvements in other performance and cost parameters, and so on.

Second, the standards may be used for prospective fuel cost estimation. For those utilities which forecast fuel costs, subject to later reconciliation, the lag in receiving or refunding the difference between the standard-based projections and the actual costs should be a significant incentive for efficiency. The time lag would be unlikely to create unmanageable cash flow problems, and would implicitly share the benefits of improved performance between the customers and the company. The magnitude of this sharing depends on the frequency of reconciliation, the effective lag, and prevailing interest rates.

Third, the incentives can be applied as variations in the rate of capital recovery. This concept is particularly useful for new units under a breakeven standard: if the unit operates well, it is written off quickly, but if it operates poorly, capital recovery may not even cover return, let alone depreciation. In the latter case, the book cost of the plant will rise, as the additional return is added to the initial investment. When better performance and rising costs of alternatives make the new unit cost-effective, the investment can be paid off and the shareholders made whole. This approach is very similar to treating new units as small power producers, perhaps with some limits on the risks both to investors and to customers.[23]

Fourth, either independently or in connection with the previous options, the costs can be explicitly shared between ratepayers and shareholders. Ten, or twenty, or fifty percent of the savings or additional costs due to variations of actual performance from the standar can be retained by the company, and the rest can be passed on to ratepayers.

The comparative approaches have the advantage of providing measures of uncertainty in the underlying relationships (confidence intervals) and of normal variability (prediction intervals). Over time, the prediction interval shrinks: one bad year may be just luck, but three bad years in a row may indicate a fundamental problem. Therefore, the statistical approaches allow the development both of single-period standards (one year, or one quarter) and of cumulative standards (from commercial operation, or the beginning of the performance program). The cumulative standards will be much tighter, and will identify superior or inferior performance more reliably.

The comparative approaches also allow the extent of the incentive to vary with the extent of the deviation from industry norms. Performance close to the norm (say, between the 40th and 60th percentiles) may receive no incentives, those further from the norm may retain a small part of the excess cost or savings, and the increments furthest from typical performance (say, under the 5th percentile or over the 95th) may retain all the additional costs or benefits. Alternatively, incentives may be applied only when the performance is different from the mean to a statistically significant degree. This latter option would avoid penalizing (or rewarding) a utility for a year of conspicuously poor (or good) performance, after a long period of above-average (or below-average) performance. Only distinct trends or very extreme years would trigger the incentives under this approach.

All of the techniques discussed in connection with the absolute standards, may be applied to comparative standards, at various levels of the historical distribution. For example, prospective fuel costs may be estimated by the mean of historical experience, investigations may be triggered by performance more than 25 percentile points from the mean, and automatic incentives may be applied to performance more than 45 points from the mean.

VI. Conclusion

This paper has considered several approaches to the establishment and implementation of comprehensive plant performance standards.

Various absolute and comparative approaches can produce fair and unbiased results, so that some units (and some utilities) will exceed the standards, and others will fall below standard. The comparative techniques allow greater flexibility in the design of standards; when such techniques are applicable, they generally appear to be superior to the absolute approaches.

MONTH	# OF UNITS	
JANUARY	0	
FEBRUARY	2	**
MARCH	7	*******
APRIL	1	*
MAY	3	***
JUNE	4	****
JULY	5	*****
AUGUST	2	**
SEPTEMBER	4	****
OCTOBER	3	***
NOVEMBER	4	****
DECEMBER	19	*******************
AVERAGE	4.5	****

TABLE 1: DISTRIBUTION OF IN-SERVICE DATES FOR IOU-OWNED NUCLEAR PLANTS, 1970-1982

AGE CATEGORY (YEARS)	STANDARD-SETTING APPROACHES: BREAKEVEN ANALYSIS	ORIGINAL EXPECTATIONS	CURRENT ASSUMPTIONS
OLD (OVER 10)		LOW	HIGH
NEW (2 TO 10)		MEDIUM	HIGH
VERY NEW (UNDER 2)	MEDIUM	HIGH	HIGH
UNDER CONSTRUCTION	HIGH	HIGH	HIGH

TABLE 2: APPLICABILITY OF VARIOUS ABSOLUTE STANDARD-SETTING APPROACHES TO PLANTS OF DIFFERENT VINTAGES

Notes

1. Examples of such investments include conversion of oil-fired units to coal, and construction of additional nuclear and coal units in areas with large reserve margins.

2. See, for example, Innovative Regulatory Approaches to Power Plant Productivity and Cost Allocation Issues, by Lynn Danielson, California Energy Commission, September 1981; more recently, state commissions have investigated the fuel contracts of PG&E, So Cal Ed, and Commonwealth Edison.

3. This was true in Massachusetts, for example, under the fuel clause statute in effect from 1974 to 1981. See M.G.L. c. 164, §94G, before August 6, 1981.

4. For example, the new Massachusetts fuel claus statute (M.G.L. c. 164, §94G, effective August 6, 1981, added by c. 375 of the Acts of 1981) requires the DPU to address such questions as whether the utility has made "all reasonable or prudent efforts. . . to achieve the lowest possible overall costs." This recent transformation of fuel clause regulation into a normative process brings fuel clause regulations into line with base rate regulation which has been normative for many years.

5. Note that the remainder of the discussion relates only to plant performance, and not to fuel or power purchases, interchange arrangements, or other factors which affect fuel expenses.

6. A number of such incidents are listed in Danielson, op. cit. In addition, the Massachusetts D.P.U. has investigated outages of Boston Edison's Pilgrim nuclear unit, related to slow and erroneous responses to NRC orders and to engineering problems, see MDPU 1009-F and 1009-G.

7. The Ohio incentive rate standards described in "A Cost Effective Measure Applied to Incentive Rates in Ohio," by Raymond Harr in Award Papers in Public Utility Economics and Regulation, Institute for Public Utilities, 1982, have this unfortunate characteristic, as noted by the discussants in that volume. Concerns about inappropriate incentives were also apparently involved in the Ohio PUC's decision to abandon the standards.

8. There are large gaps in the size distribution of nuclear units, between 660 and 789 MW for BWR's, and between 575 and 693 MW for PWR's.

9. This category of the very small nuclear plants includes Big Rock Point (72 MW), La Crosse (50 MW), and Yankee Rowe (175 MW), as well as the smallest of the over-400 MW units, such as San Onofre 1 (436 MW). Similarly, Ft. St. Vrain in the only high-temperature gas-cooled reactor in the United States, so no comparable set exists. The same kind of problem would exist for new or unusual technologies (e.g. fluidized bed, combustion, geothermal, and wood-burning plants.)

10. In this sense, "similar" is a much weaker term than the "comparable" units in the simple comparisons. A much larger group of units can be included in statistical analyses than in the simple comparisons. Larger data sets increase the statistical precision of the analysis, but may include less comparable data; the result may be a better estimate of a less useful parameter. Fortunately, it is often possible to determine whether an addition to the data set, such as older, larger, or foreign plants, has different statistical characteristics than the original data.

11. The principle criteria for inclusion in this list are that the plant be economical to operate at a relatively high capacity factor, and the replacement power source be significantly more expensive.

12. See Figure 2-1 in Nuclear and Large Fossil Unit Operating Experience, EPRI NP-1191, September 1979.

13. The earliest such studies appear to have been those by Charles Komanoff, first published by the Council on Economic Priorities in Power Plant Performance (November 1976) and the Update May (1977), and then by Komanoff Energy Associates in Update 2 (June 1978). Similar analyses have been performed by Robert G. Easterling of Sandia Laboratories for the NRC in Statistical Analysis of Power Plant Capacity Factors, NUREG/CR-0382, February 1979 and in an update, Through 1979, NUREG/CR-1881, April 1981. NERA's analysis of capacity factors was included in Lewis Perl's presentation to the N.Y. Society of Security Analysts on "Estimated Costs of Coal and Nuclear Generation," in December 1978.

Other studies along the same lines have been less successful. "The Effects of Learning by Doing on Nuclear Plant Operating Reliability," by Paul Joskow and George Rozanski, in the Review of Economics and Statistics, (May, 1979), pp. 161-168, uses a functional form which creates artificial relationships; see Fact or Artifact," by Paul Chernick and Herbert Weisberg, Analysis and Inference, Inc., December 29, 1981.

An analysis by George Gantz of the New Hampshire PUC staff [Staff Testimony, Docket DE 81-312 , September 1982] followed the general approach of Komanoff and Easterling, but had some data problems. The Impact of Early Retirement of Nuclear Power Plants: The Case of Maine Yankee, by Paul Raskin and Richard Rosen, Energy Systems Research Group (ESRG), August 1982, includes a very interesting and complex capacity factor analysis, which treats salt-water cooling as an explanatory variable and models age effects in great detail. Unfortunately, the data for the ESRG study is dependent on utility descriptions of outage causes, which may not be consistent over time.

14. Joskow and Rozanski measure unit experience in terms of output, rather than age.

15. A few studies have taken the alternative approach of treating the first calendar year, whether full or partial as year 1. Gantz includes all such partial years without special treatment, while ESRG weights the partial year experience less than full year experience.

16. Gantz uses MDC capacity factors in a planning analysis, where that measure of capacity is patently irrelevant.

17. At somewhat greater effort, experience with PWR's and BWR's outside the United States can be incorporated in the analysis. Joskow and Rozanski use an international cross-section combining PWR's and BWR's for a single year. All other studies use time-series of U.S. units (sometimes with particular units or years deleted). Easterling and Komanoff perform separate regressions for PWR's and BWR's, Perl studies only PWR's, while Gantz and ESRG combine reactor types in a single regression.

18. Specifically, Easterling, Perl, and Komanoff.

19. Intervenors have claimed that utilities have spent more on O & M for particular units then have been justified by their performance. Similarly, utilities have asserted that improvements in performance are only possible with increased expenditures, and that recent declining performance has been due to inadequate cash flow for maintenance. Including O & M expenditures as an explanatory variable would permit the testing of these hypotheses.

20. Northeastern utilities have been converting plants from oil to coal and (at least temporarily) to gas, while southwestern utilities have been converting from gas to oil.

21. The validity of standards based on subsequent reports will be greater for those values of intrinsic importance to the utility (such as heat rates used for economic dispatch) than for those with little practical effect (such as PURPA §133 or

§210 filings).

22. Note that statutory requirements and time constraints may require that penalties and bonuses be handled differently. In some states, the fuel adjustment may exclude imprudent fuel costs, but may not include a share of fuel savings. Similarly, the time limits on fuel adjustment cases may prevent adjudiction of all incentive issues. In such situations, special proceedings or base rate cases can be used to conclude the issues.

23. See Michael B. Meyer "Partial Deregulation of Electric Utilities", Public Utilities Fortnightly, forthcoming.

APPENDIX C: Data for Pilgrim Capacity Factor Regression

Unit	Year	MDC	Original DER	CF @ MDC	CF @ DERorig	Refuelings
Browns Ferry 1	79	1065	1065	80.3	80.3	0.358447
Browns Ferry 1	80	1065	1065	64.8	64.8	1
Browns Ferry 1	81	1065	1065	47.2	47.2	1
Browns Ferry 1	82	1065	1065	53.6	53.6	0
Browns Ferry 2	80	1065	1065	60.1	60.1	1
Browns Ferry 2	81	1065	1065	80.1	80.1	0
Browns Ferry 2	82	1065	1065	53.1	53.1	0
Browns Ferry 3	82	1065	1065	64.2	64.2	0.590909
Brunswick 1	82	790	821	50.4	48.5	0.15
Brunswick 2	80	790	821	26.9	25.9	1
Brunswick 2	81	790	821	47.5	45.7	0
Brunswick 2	82	790	821	42.5	40.9	1
Cooper	79	764	778	74.6	73.3	1
Cooper	80	764	778	56.4	55.4	1
Cooper	81	764	778	57.5	56.5	1
Cooper	82	764	778	64.3	63.1	1
Dresden 2	77	772	809	52.2	49.9	1
Dresden 2	78	772	809	84.3	80.5	0
Dresden 2	79	772	809	73.0	69.7	1
Dresden 2	80	772	809	67.6	64.5	0
Dresden 2	81	772	809	50.4	48.1	1
Dresden 2	82	772	809	58.5	55.8	0
Dresden 3	76	773	809	58.3	55.7	1
Dresden 3	77	773	809	76.6	73.2	0
Dresden 3	78	773	809	56.6	54.1	1
Dresden 3	79	773	809	51.4	49.1	0
Dresden 3	80	773	809	63.8	60.9	1
Dresden 3	81	773	809	76.4	73.0	0
Dresden 3	82	773	809	58.1	55.6	1
Duane Arnold	80	515	538	61.8	59.2	1
Duane Arnold	81	515	538	49.2	47.1	1
Duane Arnold	82	515	538	53.0	50.7	0
Fitzpatrick	80	810	821	60.9	60.1	1
Fitzpatrick	81	810	821	67.4	66.5	0.480620
Fitzpatrick	82	810	821	58.5	57.7	0.590909
Hatch 1	80	764	786	72.2	70.2	0
Hatch 1	81	764	786	41.7	40.5	1
Hatch 1	82	764	786	55.2	53.7	0.955056
Millstone 1	76	647	690	66.1	62.0	1
Millstone 1	77	654	690	84.2	79.8	0
Millstone 1	78	654	690	81.2	77.0	1
Millstone 1	79	654	690	73.7	69.8	1
Millstone 1	80	654	690	59.0	56.0	0.451776
Millstone 1	81	654	690	44.0	41.7	1
Millstone 1	82	654	690	63.0	59.7	1
Monticello	76	536	545	84.7	83.3	0
Monticello	77	536	545	76.1	74.8	1
Monticello	78	536	545	82.2	80.8	1
Monticello	79	536	545	93.7	92.2	0
Monticello	80	536	545	73.3	72.1	1
Monticello	81	536	545	69.3	68.2	1
Monticello	82	525	545	73.2	70.5	1
Nine Mi Pt	74	610	610	61.7	61.7	1

Unit	Year	MDC	Original DER	CF @ MDC	CF @ DERorig	Refuelings
Nine Mi Pt	75	610	610	56.9	56.9	1
Nine Mi Pt	76	610	610	76.8	76.8	0
Nine Mi Pt	77	610	610	55.1	55.1	1
Nine Mi Pt	78	610	610	83.6	83.6	0
Nine Mi Pt	79	610	610	56.2	56.2	1
Nine Mi Pt	80	610	610	83.3	83.3	0
Nine Mi Pt	81	610	610	60.2	60.2	1
Nine Mi Pt	82	610	610	58.7	58.7	0
Oyster Creek	74	620	650	70.9	67.6	1
Oyster Creek	75	620	650	64.6	61.6	1.064194
Oyster Creek	76	620	650	70.9	67.6	0.935805
Oyster Creek	77	620	650	59.8	57.0	1
Oyster Creek	78	620	650	67.1	64.0	1
Oyster Creek	79	620	650	84.0	80.1	0
Oyster Creek	80	620	650	36.0	34.3	1
Oyster Creek	81	620	650	48.4	46.2	0
Oyster Creek	82	620	650	62.3	59.4	0
Peach Bottom 2	79	1051	1065	93.1	91.9	0
Peach Bottom 2	80	1051	1065	47.0	46.4	1
Peach Bottom 2	81	1051	1065	72.0	71.1	0
Peach Bottom 2	82	1051	1065	63.1	62.3	1
Peach Bottom 3	79	1035	1065	67.3	65.4	1
Peach Bottom 3	80	1035	1065	79.5	77.3	0
Peach Bottom 3	81	1035	1065	34.6	33.6	1
Peach Bottom 3	82	1035	1065	66.3	64.4	0
Quad Cities 1	78	769	809	70.1	66.6	0
Quad Cities 1	79	769	809	71.0	67.5	1
Quad Cities 1	80	769	809	51.0	48.5	1
Quad Cities 1	81	769	809	85.1	80.9	0
Quad Cities 1	82	769	809	61.2	58.1	1
Quad Cities 2	78	769	809	65.7	62.4	1
Quad Cities 2	79	769	809	59.1	56.2	0.333108
Quad Cities 2	80	769	809	53.6	50.9	0.666891
Quad Cities 2	81	769	809	55.9	53.2	1
Quad Cities 2	82	769	809	60.8	57.8	0
Vermont Yankee	77	504	514	80.2	78.6	1
Vermont Yankee	78	504	514	73.4	72.0	1
Vermont Yankee	79	504	514	78.1	76.6	1
Vermont Yankee	80	504	514	67.3	66.0	1
Vermont Yankee	81	504	514	80.9	79.3	1
Vermont Yankee	82	504	514	71.6	70.2	0
			Average	63.9	62.1	
			Std. Dev.	13.3	13.2	
			Number	94		

APPENDIX D: Pilgrim Capacity Factor Regression Results

Equation #1:

variable	reg.coef.	std.error coef.	computed t	beta coef.
MDC	-0.01852	0.00743	-2.49258	-0.24188
REFUEL	-10.37253	2.75323	-3.76740	-0.36558

intercept	84.71628		
multiple correlation	0.40537	(adjusted r =	0.38205)
std. error of estimate	12.16062		

analysis of variance for the regression

source of variation	d.f.	sum of sq.	mean sq.	f value
attributable to regression	2	2646.193	1323.096	8.947
deviation from regression	91	13457.141	147.881	
total	93	16103.336		

Equation #2:

variable	reg.coef.	std.error coef.	computed t	beta coef.
MDC	-0.01008	0.00686	-1.46903	-0.13161
REFUEL	-10.80943	2.46182	-4.39083	-0.38098
1980+?	-11.58509	2.36634	-4.89577	-0.43437

intercept	85.65463		
multiple correlation	0.58316	(adjusted r =	0.56398)
std. error of estimate	10.86636		

analysis of variance for the regression

source of variation	d.f.	sum of sq.	mean sq.	f value
attributable to regression	3	5476.344	1825.448	15.460
deviation from regression	90	10626.992	118.078	
total	93	16103.336		

Equation #3

variable	reg.coef.	std.error coef.	computed t	beta coef.
REFUEL	-10.29197	2.45194	-4.19748	-0.36274
1980+?	-12.45903	2.30487	-5.40553	-0.46714

intercept	78.39940		
multiple correlation	0.56943	(adjusted r =	0.55624)
std. error of estimate	10.93528		

analysis of variance for the regression

source of variation	d.f.	sum of sq.	mean sq.	f value
attributable to regression	2	5221.523	2610.762	21.833
deviation from regression	91	10881.812	119.580	
total	93	16103.336		

Equation #4:

variable	reg.coef.	std.error coef.	computed t	beta coef.
MDC	-0.03847	0.01160	-3.31693	-0.50244
REFUEL	-10.75985	2.36123	-4.55689	-0.37923
>1000MW	15.41391	5.18528	2.97263	0.44259
1980+?	-11.37702	2.27068	-5.01041	-0.42657

intercept	103.86159		
multiple correlation	0.63220	(adjusted r =	0.61049)
std. error of estimate	10.42208		

analysis of variance for the regression

source of variation	d.f.	sum of sq.	mean sq.	f value
attributable to regression	4	6436.168	1609.042	14.814
deviation from regression	89	9667.168	108.620	
total	93	16103.336		

*session costs: $1.05/$0.00
*current balances: $214.42/$0.00
*sign-off at 15:28:09 thu jul 14, 1983
*good-bye