AG-1
52

BEFORE THE

NEW MEXICO PUBLIC SERVICE COMMISSION

PUBLIC SERVICE OF NEW MEXICO

CASE No. 2004

Testimony of

Paul Chernick

on Behalf of the

New Mexico Attorney General

May 7, 1986

ANALYSIS AND INFERENCE, INC. RESEARCH AND CONSULTING

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Table of Contents

1 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 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 extended 1977-78 maintenance outages and associated derating of the Pilgrim 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 Nuclear Regulatory Commission, analyses of gas and electric rate designs, nuclear power cost estimation, design of conservation programs, and several other topics.

Q: Have you testified previously as an expert witness?

A: Yes. I have testified more than forty times before such agencies as the Massachusetts Department of Public Utilities, the Massachusetts Energy Facilities Siting Council, the Massachusetts Division of Insurance, the Atomic Safety and Licensing Board of the Nuclear Regulatory Commission, and before the utility commissions of Texas, Michigan, Illinois, New Hampshire, Connecticut, the District of Columbia, Pennsylvania, Maine, and Vermont. My resume lists my previous testimony.

Q: Have you testified previously before this Commission?

A: Yes. I testified on the economics of the Eastern Interconnection Project of Public Service of New Mexico in Case 1974, and on El Paso Electric's nuclear decommissioning fund in Case 1833, Phase II.

Q: Have you testified previously regarding performance targets for utility power plants?

A: Yes. I testified in Massachusetts Department of Public Utilities (MDPU) docket numbers 1048 and 1509, the first two reviews of Boston Edison's proposed power plant performance standards, under the new fuel clause statute, M.G.L. c. 164, section 94G (effective August 6, 1981). That statute eliminated the essentially automatic recovery of fuel costs, and required that the fuel adjustment charge be based on "the efficient and cost-effective operation of individual generating units".

I also testified before the Michigan Public Service Commission in the 1984 Power Supply Cost Recovery proceedings of Detroit Edison (Case No. U-7775) and Consumers Power (Case No. U-7785), on performance targets for those companies' nuclear power plants.

In addition to power plant performance cases, I have also testified on nuclear capacity factors in a number of planning and ratemaking proceedings, including Massachusetts DPU 20055, 20248, 84-25, 84-49/84-50, 84-145, 84-152, and 85-270; NHPUC DE 81-312; Illinois Commerce Commission 82-0026; Connecticut PUCA 83-03-01; NMPSC 1794; MEFSC 83-24; Maine PUC 84-113 Phase I, 84-113 Phase II, and 84-120; and Pennsylvania PUC R-842651 and R-850152; among others. This testimony is also listed in my resume.

Q: Have you authored any publications on power plant performance standards?

A: Yes. My paper "Power Plant Performance Standards: Some Elementary Principles," published in **Public Utilities Fortnightly**, is attached as Appendix B to this testimony.

2 INTRODUCTION

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

A: My testimony discusses the performance standards to be imposed on the share of Palo Verde Nuclear Generating Station (PVNGS) owned by Public Service of New Mexico (PNM). PVNGS consists of three pressurized water reactors (PWRs), each of 1270 MW net design electrical rating.

Q: Why is it appropriate to set standards for power plant performance, rather than simply allowing PNM to recover its actual fuel costs, regardless of how well, or how poorly, PVNGS performs?

A: This Commission has a legitimate concern with the reasonableness of PNM's rates. If PVNGS does not perform as well as it should, and PNM recovers both the costs of PVNGS and the cost of power to replace PVNGS output when it is not operating, rates will be unnecessarily high.

It may also be important to insure that PNM's past projections for PVNGS performance ~~is~~ are consistent with the performance for which consumers will be asked to pay. In particular, PNM's cost recovery for PVNGS is determined by the inventory stipulation. It is my understanding that the settlement which established the inventory procedure was premised in part on the projected costs and benefits of

PVNGS, including the number of kWh's each unit would generate annually, and the rate at which deferred return on the units increases their cost. If PVNGS does not perform as well as was assumed at the time of the inventory stipulation, consumers will end up paying more for PVNGS than had been anticipated.

Q: What is the fundamental goal of the standard-setting process?

A: In setting power plant performance standards, the objective is to develop <u>normative</u> or <u>prescriptive</u> goals, specifying how the plant <u>should</u> behave. This is a very different concept from <u>positive</u> or <u>descriptive</u> projections, which predict how the plant <u>will</u> behave. These two types of analyses have very different purposes and may yield very different results. For example, if a utility breaks a plant in 1986, an accurate positive analysis might project a 1987 capacity factor of zero. It may be appropriate to base 1987 power supply cost recovery on the costs which should have been incurred reasonably and prudently if the plant had not been broken. Thus, the normative standard may be different from both the actual performance, and from the best estimate of future performance.

Q: What measure of performance is most important for PVNGS?

A: In economic terms, the important performance parameter for PVNGS, or any other nuclear plant, is the amount of power the plant produces. The high cost of nuclear capacity is justified, if at all, by its low fuel costs and by the ability to spread the initial investment over many kilowatt-hours each year. Since nuclear fuel is relatively inexpensive, the economics of a nuclear plant depend more on the ability to produce many kWh, than on the ability to produce those kWh efficiently.[1] Hence, the capacity factor (CF) may be the most significant measure of PVNGS performance.

Q: Is capacity factor the only important measure of nuclear plant performance?

A: No. There are times when a plant does not produce all the energy of which it is capable, for reasons unrelated to its technical capabilities. The potential capacity factor, if not for economic and other systems constraints, is called the equivalent availability factor (EAF). The major difference between the capacity factor and the EAF for most units is a practice called "load following" or "cycling," in which the units' output increases at times of high demand and falls during periods of low demands. Utilities rarely have all their available units operating at full capacity, simply

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1. This description is slightly less true for PNM than for most other utilities, including the other owners of PVNGS. The fuel costs of Four Corners are not very different than those of PVNGS, at least in the next few years. San Juan fuel is more expensive, but is still only about one cent/kWh more than PVNGS fuel. Since PNM has already backed out most of its gas use, the fuel savings from PVNGS operation will be rather limited in the near term. Still, the net cost of PVNGS will be largely determined by the number of kWh it produces, for PNM's own use or for off-system sales.

because the amount of power necessary to meet peak loads in the middle of a weekday is not needed for other hours, particularly at night and on weekends. However, except in the Pacific Northwest, with its large hydroelectric capacity, nuclear plants are rarely if ever involved in load following. With their low fuel costs, nuclear plants are generally among the first units dispatched to meet load, and virtually all other plants will be turned down before the nuclear units' output is affected.

Other factors do produce differences between CF and EAF for most nuclear units. Transmission line failures can force units off line, even though there is nothing wrong with the generating plant. Power output is sometime reduced to delay the refueling of a nuclear plant, in order to avoid having several nuclear units (or other baseload plants) out of service simultaneously, to allow a unit to remain in service through the peak season, or to permit the utility's crews to complete refueling of another nuclear unit before starting on this unit.

Q: Which of these factors is a better indicator of the performance of a nuclear plant?

A: It is difficult to define one measure as more important than the other. The capacity factor reflects the plant's actual energy production, the real bottom line. CF is also an objective measure of performance, determined by the metered output of the unit, and by its rated capacity. On the other hand, there are times when increased capacity factor would be impossible for reasons independent of the plant's performance (e.g., there is nowhere for the power to go), or would be uneconomical. The EAF does not penalize the plant for these reductions in output, and is therefore a better measure of the plant's performance.

Unfortunately, EAF is not an objective measure. EAF is a subjective measure, reported by the operating utility and representing only the utility's opinion of what the unit might have done, if not for factors which the utility may wish to consider to be "economic". Furthermore, the calculation of EAF assumes that the unit would have run <u>perfectly</u> if not for the "economic" limitation.

Considering all of the preceding factors, it is probably most useful to state nuclear power plant performance targets in terms of EAF, but to use the metered CF as a reality check. Differences between EAF and CF of more than 0.1% points should be thoroughly explained, including identification of the hours during which power was voluntarily reduced, and a description of the reason for each reduction. Differences of more than 0.5% are quite uncommon: if the reported EAF performance is to be used for ratemaking, such large differences should generally trigger an investigation to ensure that the reported EAF reasonably represents the plant's capability.

Q: How is the remainder of this testimony organized?

A: Section 3 describes the principles and concepts upon which power plant performance targets may be based. Section 4 discusses the PVNGS capacity factor projections utilized by PNM, and PNM's testimony on the propriety of performance standards for PVNGS. In Section 5, I suggest equivalent availability factor performance standards to be applied to PNM's share of PVNGS.

3 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. Self-referent standards may be set at various levels of stringency, such as:

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

Any of these standards may be calculated from any time period (e.g., last year, or the plant's entire life) and for a variety of intervals (monthly data, annual data).

Q: Do these self-referent methods generally produce fair and even-handed standards?

A: Not usually. Self-referent 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-effective operations.

Q: What is the next category in your list of standard-setting approaches?

A: In the second group of options, standards are based on <u>comparative</u> analyses, which aggregate the experience of other 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</u> <u>run</u> unit.
- The unit will perform better than half (or any other percentage) of the comparable units.

Q: How may comparative targets be derived?

A: The comparisons may simply average data from a set of units which share some common characteristics, or they may involve more complex statistical analyses, such as regression. 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 always subject to some dispute. Various statistical techniques may mitigate these limitations. In multiple regressions, for example, several descriptive variables may be incorporated simultaneously, facilitating the merging of data from a greater variety of units. Statistical tests can also be useful in determining whether particular units belong in a comparison group.

Q: You have stated that the purpose of analyzing power plant performance is to establish normative standards. Is this consistent with the use of actual operating data in these first two types of approaches?

A: Yes, normative standards can be derived from actual operating data. Positive models describe the way things are (or have been), leading to such conclusions as "Once they reach maturity, 1200-MW PWR's have an average capacity factor of 60%." This sort of statement is not a performance standard; it only becomes a standard when a prescription is added, such as "Therefore, PVNGS 1 should have a 55% mature capacity factor." The way things are <u>may</u> be the basis for determining the way things should be, but this relationship is not automatic.

Q: What is the third group of standard-setting approaches?

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

- The unit will perform as was promised, or expected.

- The unit will perform as well as the utility has assumed for other purposes, such as rate design, setting rates to be paid to small power producer, and capacity planning.

- The unit will perform well enough to justify its fixed costs.

None of these various absolute standards depend on actual performance data, either for the subject plant or for other plants. 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 over-optimistic projections cause problems for the utility, should be the same as those used in proceedings where over-optimistic 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.

Q: Is one particular approach to standard-setting preferable in all applications?

A: No. The various kinds of standards are appropriate for different situations. As noted above, self-referent standards raise major equity issues. 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. Self-referent standards are also inherently inapplicable to new units. There are special circumstances in which self-referent standards are useful, particularly when no other basis for standard-setting exists; these are the exceptions, rather than the rule.

Comparative standards are appealing wherever a reasonable comparison group exists. They are not applicable for experimental units and other unique designs.[2] Comparative analyses establish business-as-usual standards, which simply ask utilities to keep up with general industry performance levels.

Absolute standard-setting approaches rely on other concepts of fairness, which may be applicable even where business is far from usual. For example, using pre-operational

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2. The concept of uniqueness must be applied carefully. In one sense, no steam power plant is unique, since all such plants are alike in having a boiler, a turbine, and a heat sink. In another sense, every unit is unique, except for those few sister units which are exact carbon copies. Generally speaking, if a group of similar units can be defined, a meaningful comparative analysis can be conducted, and statistical tests can determine whether differences between plants are important.

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 volume discounts to large energy users 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.

The application of this approach is limited by performance factors and units for which expectations and representations are either unavailable or otherwise of limited usefulness. For many fossil units constructed prior to the establishment of regulatory review, no reliability measures were ever projected. For other technologies, early performance expectations were widely held, based on virtually no data, and seriously incorrect; this certainly was true of projections for nuclear capacity factors made in the 1960's and early 1970's. In such cases, it seems unfair to hold an individual utility responsible for a universal, and perhaps understandable, error.

As an alternative to the projection standard, 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. This standard can be derived for all units, regardless of the existence of a comparison group, of prior data on the unit's own performance, or of pre-operational projections.

4 PNM'S APPROACH

Q: What are PNM's projections of the performance of its nuclear units?

A: Table 1 lists the equivalent availability factors projected by PNM for each PVNGS unit, as of 10/1/85. Except for changes in the in-service dates, and minor revisions in the intervals between refuelings, these EAF projections appear to be the same as those PNM has used for several years. The projections in Table 1 have been used in many applications, such as for rate design, in evaluation of the Eastern Interconnection Project, and during the negotiations which produced the inventory stipulation.

Q: Are these projections likely to be achieved?

A: No. Table 2 displays the capacity factors of all the PWRs of over 1000 MW which were in operation through the end of 1982. The average capacity factors (which in most cases are very similar to the EAFs) have been running between 55% and 60%.

Table 3 provides the results for PVNGS of Analysis and Inference's most recent regression analyses of PWR capacity factors, which are described in more detail in Appendix C. The same table lists the PVNGS capacity factor projections of Energy Systems Research Group, the consultant on power plant performance standards for the Attorney General and PNM.

Q: For how long has there been evidence that PNM's projections of PVNGS capacity factor have been overstated?

A: This has been evident for several years. Table 4 lists the capacity factors for all PWR's of more than 800 MW, through 1985, and the averages through 1975, 1977, 1979, and 1981. The data clearly shows that PNM's projections are inconsistent with the experience of the industry even in the late 1970's.

Statistical analyses also indicated many years ago that capacity factors of large PWRs were much lower than PNM's projections for PVNGS. Komanoff (1976) projected from available experience that 1150 MW PWRs would have average capacity factors in their first ten years of 47.6%. Updates (Komanoff 1977 and 1978) revised the projections of levelized capacity factors to 55% and 59%. An analysis performed at Sandia National Laboratory for the Department of Energy (Easterling 1978) concluded that average capacity factors for 1100 MW PWRs in years 2-10 of operation would be about 57%. Applying Easterling's results to a unit with a 1270 MW DER (and assuming that the maximum generator nameplate, or MGN, rating Easterling uses would be 4% higher than the DER rating) would project a mature capacity factor of 55.5%.

Q: What is PNM's position regarding performance standards for PVNGS?

A: PNM opposes such standards. As explained in the testimony of Mr. Begley, PNM's principal argument for not imposing standards is the assertion that poor PVNGS performance would have much greater effects on shareholders than on ratepayers, due to the operation of the inventory ratemaking arrangement.

Q: Is it true that the inventory process would cause shareholders to bear a much larger burden than the ratepayers, if PVNGS performance is below PNM's projections?

A: Not really. Table 5 displays PNM's estimates of the present value burdens on ratepayers and shareholders, for various levels of PVNGS availability. Mr. Begley computes the percentage increases in the burdens as EAF falls from 74% to lower levels,[3] and concludes that the shareholders are affected much more by lower performance than are the ratepayers. That analysis is flawed in three respects.

First, Mr. Begley's criterion is fundamentally irrelevant. The question he asks is "By what percentage does each group's burden increase when EAF declines?" The percentage change depends on the initial value: the lower the shareholder burden is assumed to be at 74% mature EAF, the higher the

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3. PNM does not clearly describe the lower performance levels used in its analyses. PNM's current projections of annual immature availabilities are not clearly stated in either Mr. Begley's testimony or Mr. Fisher's testimony, although I assume that they are identical to the 10/1/85 projections. Mr. Begley's testimony suggests that the 65%, 55%, and 45% availabilities used in his change cases are comparable to the 74% mature EAF in the base case, but does not explicitly say so.

percentage effect of any increase. For example, if the base case shareholder cost were $1 million, a $1 million increase would be a 100% increase, but if the initial shareholder cost were $4 million, the same increase would be only 25% of the base value. Thus, the percentage increases in Mr. Begley's testimony are of almost no practical significance.

Second, the base values are entirely inconsistent, as Mr. Begley defines them. The shareholder burden is limited to the costs which would have been recovered under full ratebase treatment, but which are not recovered under the inventory process. The ratepayer burden is defined much more broadly, to include both the additional AFUDC costs due to inventory, and the entirety of system production costs.[4] Since the ratepayer burden includes costs which are not affected by inventory, the percentage increases due to low PVNGS capacity factors appears much smaller than if the base case included only inventory effects. This point is illustrated in Table 5: the ratios of the increases in ratepayer burdens to the base case inventory-related burden of increased AFUDC are much larger than the ratio of the increases to the entire cost of PNM's production system. Conversely, if the measure of shareholder welfare also included non-inventory effects -- for example, if it were defined as total return on equity --

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4. "System production costs" appears to include capital recovery and operating costs for the entire retail generation system, including costs which have little or nothing to do with PVNGS.

the base value would be higher and the percentage increases from a reduction in PVNGS performance would be lower.

Third, contrary to Mr. Begley's conclusions, the ratepayers bear the bulk of the burden due to low PVNGS availability. Table 5 also shows the percentage of the present value cost increases which are borne by shareholders: depending on the EAF, shareholders would be responsible for only 11% to 17% of the increased cost. It is not surprising that the shareholders wind up with only a small fraction of the present value burden, since in most years they would assume only a small fraction of the excess production costs due to lower performance, even while the plant is still in inventory. Table 6 compares my rough estimate of the costs of lower performance, based on an average 3 cent/kWh value of power from PVNGS for 1986-1995,[5] to the total shareholder losses estimated by PNM. While this comparison is obviously only an approximation, it is clear that the shareholders pay only a very small portion of the excess costs due to low availability, even in those years in which the inventory methodology places them at risk. The stockholders bear no performance risk once the capacity leaves inventory.

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5. This estimate, which includes both the cost of replacement power and the sales price of off-system sales, is probably too low for the 1990's. The higher the value of PVNGS power, the lower the fraction of the cost which is assumed by the shareholders.

Q: Do you agree with PNM's position that there is no empirical evidence that performance standards improve plant performance?

A: I am not aware of any study which has attempted to measure such an effect. There are reasons to believe that the effect would be difficult to detect, even if it were important. First, performance standards have tended to be imposed where plants are not performing well, so the presence of standards may well correlate with poor performance. Second, most performance programs are fairly recent, so little data is available concerning their long-term effects, once management and maintenance has been adjusted to the new conditions. Third, there is very high annual variability in nuclear power plant performance, so even real and immediate improvements will be hard to sort out from the background noise.

Of course, improved performance is not the only reason for implementing power plant performance standards, and such improvement may not be the primary objective of a standard-setting program. Equity concerns, such as fairness and proper allocation of materialized risk, are at least equally important.

Q: Is Mr. Begley correct in stating that "the Inventory Stipulation protects current ratepayers by deferring those incremental costs arising from any operational inefficiencies of PVNGS. Future ratepayers are protected by the cap on AFUDC" (page 9)?

A: Only partially. Current ratepayers are protected by the deferral of costs. Future ratepayers, however, pay for both the deferred costs (up to the AFUDC cap) and the additional cost of any poor PVNGS performance once the capacity is out of inventory. The inventory rules provide some limited protection of future ratepayers from poor performance while the plant is in inventory, but no protection once it is out of inventory.

5 RECOMMENDATIONS

Q: What type of performance standard would you recommend be applied to PNM's share of PVNGS?

A: I recommend that the Commission institute an absolute performance standard based on PNM's representations regarding the EAFs of the PVNGS units. Table 7 lists these representations in terms of availability between refuelings, the period between refuelings, and the length of the refueling outages, from Case No. 1916. Table 1 provides PNM's projections for calendar year EAFs, for the commercial operation dates assumed as of 10/1/85. Variation in commercial operation dates and startup periods (which affects the time from commercial operation to the first refueling) may cause changes in the annual EAFs, even given PNM's basic assumptions.

To moderate the effects of poor performance on earnings, I would suggest that the shareholders assume only half of the EAF risk, and that cost recovery be calculated as if PVNGS had operated at the average of its actual EAF and PNM's projection. This could be achieved by calculating power supply cost recovery and inventory effects as the average of actual costs and the costs which would have resulted had

PVNGS operated at the standard.[6] I suspect that it will be easier to calculate cost recovery as if PVNGS availability were equal to the average of actual EAF and the performance target. Either approach will require the use of a production costing model to determine cost recovery, but the inventory arrangement will require the use of such a model anyway, to compute sales from inventoried capacity to the retail jurisdiction, and to allocate revenues from off-system sales to inventoried and jurisdictional capacity.

Q: Should an EAF performance standard of 68.4% be imposed for PVNGS 1 immediately?

A: Yes. While the inventory process causes the shareholders to bear a small portion of the cost of poor performance at PVNGS, that portion is minuscule compared to the costs borne by the ratepayers. Unfortunately, PNM has not presented its results in a form which allows for easy comparison of the shareholder burden to the total losses in each year due to poor performance.[7] Therefore, I would recommend that the performance standard be imposed during the inventory period, as well as after the capacity emerges from inventory.

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6. The average may be a weighted average, if the Commission wishes to set the shareholder portion of the risk at a value other than 50%. At this point, I see no reason to deviate from the 50% risk allocation.

7. The ratepayers costs due to increased AFUDC accrual are reported in the year they are paid, rather than in the year the AFUDC accrues.

Q: For what period of time would you suggest that PNM be held to these standards?

A: I would suggest that the standard be applied for at least until the last portion of the plant is taken out of inventory. PNM should have known for at least the last eight years that it was using highly aggressive projections of availability. It seems fair to apply the representations standard several years to come, especially in light of the role of that representation in the inventory stipulation. Continuation of this standard, or another performance standard,[8] may be appropriate after the end of the initial performance standard program, but that issue need not be addressed for several years. If the inventory arrangement is radically revised, or if declining load growth results in PVNGS remaining in inventory for much longer than is currently projected, the performance standard should be re-examined.

Q: Is it necessary to have a "dead band" around the standard, so that small deviations have no effect?

A: No. Small deviations would produce small rewards or penalties, which will not matter much. A dead band would only make sense where the deviation is so small that the effort of running the production costing model is not

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8. In particular, a comparative standard is likely to be appropriate for PVNGS, once the prior representations standard is abandoned.

justified. As I noted above, the production costing runs will be necessary in any case.

Indeed, there are disadvantages to dead bands, which argue against their use except where they are required for administrative convenience. Depending on the distribution of outcomes around the target, applying a dead band on an annual basis may result in a net reward for poor performance, or a penalty for good performance. For example, if a plant often operates at an EAF 5 points above its target, but occasionally has a very bad year and operates 15 points below target, a 10 point dead band would result in penalties and no bonuses. In addition, dead bands may encourage utilities to manipulate maintenance outages, to keep one performance period within the dead band (even if very close to the bottom), while pushing another above the top of the dead band. In these situations, overall performance of a plant may be decreased, while the utility receives a performance incentive reward.

Q: Would the standard you have proposed have any other benefits?

A: Yes. This precedent would tend to encourage more accurate performance projections by PNM and other New Mexico utilities for new plants. So long as utilities can justify cost recovery for their new plants by projecting (among other things) optimistic future operating performance, there is a positive disincentive for PNM to offer realistic projections to this Commission. If the Company's cost recovery is tied to the performance of the plant, this strategy no longer works. Promising stellar performance to get a plant into rate base is much less effective, if the utility bears some of the cost of not achieving that performance.

Q: Does this conclude your testimony?

A: Yes.

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TABLES TO ACCOMPANY

THE TESTIMONY OF

PAUL CHERNICK

TABLE 1: PALO VERDE EQUIVALENT AVAILABILITIES USED IN PNM'S OCTOBER 1, 1985 FILING (PERCENT)

Year	Palo Verde #1	Palo Verde #2	Palo Verde #3
1986	68	68	
1987	60	68	68
1988	69	67	68
1989	74	70	66
1990	74	74	73
1991	74	74	74
1992	74	74	74
1993	74	74	74
1994	74	74	74
1995	74	74	74
1996	71	74	74
1997	74	71	74
1998	74	74	71
1999	74	74	74
2000	74	74	74
2001	74	74	74
2002	74	74	74
2003	74	74	74
2004	74	74	74

Source: Testimony of Eugene W. Fisher, Exhibit EWF-2.

Note: Equivalent Availability (%) = (1.0 - Maintenance Outage Rate) * (1.0 - Effective Forced Outage Rate) * 100%.

TABLE 2: HISTORICAL CAPACITY FACTORS (DER), UNITS SIMILAR TO PVNGS

UNIT	DER NET [1]	first full year	CAPACITY FACTOR BY CALENDAR YEAR [2] 1	2	3	4	5	6	7	8	9	10	11	12
ZION 1	1050	74	37.8%	53.4%	51.6%	54.7%	73.6%	60.2%	70.6%	67.3%	51.0%	43.7%	61.7%	52.3%
ZION 2	1050	75	52.5%	50.3%	68.2%	73.2%	51.8%	57.2%	57.2%	56.1%	67.2%	64.9%	55.6%	
COOK 1	1090	76	71.1%	50.1%	65.8%	59.3%	67.5%	71.0%	56.1%	55.4%	78.9%	22.2%		
TROJAN	1130	77	65.6%	16.8%	53.2%	61.2%	64.9%	48.5%	41.2%	47.7%	69.8%			
SALEM 1	1090	78	47.4%	21.4%	59.4%	64.8%	42.9%	56.3%	22.2%	94.3%				
COOK 2	1100	79	61.8%	69.3%	66.3%	72.6%	72.8%	55.5%	59.0%					
SEQUOYAH 1	1148	82	48.8%	73.0%	60.5%	40.4%								
SALEM 2	1115	82	81.3%	7.5%	32.7%	51.4%								
MCGUIRE 1	1180	82	41.6%	44.8%	61.9%	65.6%								
SEQUOYAH 2	1148	83	66.5%	63.5%	55.8%									
AVERAGES:														
ALL UNITS [3]	1106		57.4%	51.5%	57.5%	60.3%	62.2%	58.1%	51.0%	64.2%	66.7%	43.6%	58.7%	52.3%
FIRST SIX [3]	1085		56.0%	55.8%	60.7%	64.3%	62.2%	58.1%	51.0%	64.2%	66.7%	43.6%	58.7%	52.3%

ADJUSTMENT FOR DEVIATIONS AT SALEM 1 AND TROJAN

		1	2	3	4	5	6	7	8	9	10	11	12
ALL UNITS:													
Salem/Trojan deviation [4]	64.8%												
unit-years [5]	70												
deviation/unit-year	0.9%												
ADJUSTED AVERAGE (all units) [5]		56.5%	50.6%	56.6%	59.4%	61.3%	57.2%	50.1%	63.2%	65.8%	42.7%	57.7%	51.4%
all years		56.5%											
>5 years		56.2%											
FIRST SIX UNITS:													
Salem/Trojan deviation [6]	73.3%												
unit-years [5]	55												
deviation/unit-year	1.3%												
ADJUSTED AVERAGE (first six) [7]		54.7%	54.4%	59.4%	63.0%	60.9%	56.8%	49.7%	62.8%	65.4%	42.2%	57.3%	51.0%
all years		57.4%											
>5 years		55.8%											

NOTES TO TABLE 2:

1. Original reported value.
2. Computed from NRC-reported net output and original DER; Grey Book, January of each year to 1986.
3. Values for year 2 for Trojan and Salem 1 are excluded from averages.
4. 2*51.5% - 16.8% - 21.4%.
5. Excludes Salem 1 and Trojan second years.
6. 2*55.8% - 16.8% - 21.4%.
7. Simple averages minus Salem/Trojan deviation per unit/year.

TABLE 3: PWR CAPACITY FACTOR PROJECTIONS FOR PALO VERDE NUCLEAR GENERATING STATION UNIT 1, FROM REGRESSION RESULTS

	Analysis and Inference					
	With Aging [6]		With CE Effect [7]			
YEAR	Pre-1979 Conds.	Avg. 1979-83 Conds.	Pre-1979 Conds.	Avg. 1979-83 Conds.	Average of four cases	ESRG
	[1]	[2]	[3]	[4]	[5]	[8]
1986	62.94%	55.78%	66.69%	59.66%	61.26%	
1987	55.24%	48.08%	59.45%	52.42%	53.79%	
1988	57.55%	50.39%	61.75%	54.72%	56.11%	
1989	59.86%	52.71%	64.06%	57.03%	58.42%	
1990	62.18%	55.02%	66.37%	59.34%	60.73%	
1991-1997	63.34%	56.18%	67.52%	60.49%	61.88%	61.90%
1998-2025	52.45%	45.29%	67.52%	60.49%	56.44%	

Notes:

Calculated for a 1270 MW unit with a General Electric turbine, and a COD of 1/1/86.

[1],[3] Assumes pre-1979 conditions exist in the projection years; therefore YR79_83 variable is set equal to 0.

[2],[4] Adjusts the projected capacity factor by the coefficient of the YR79_83 variable.

[5] Average of columns [1] through [4].

[6] Uses data from 1973-1985 for all units of more than 300 MW. Includes decrease in capacity factor after 12 years of operation.

[7] Excludes data for Palisades and San Onofre 1. Includes credit for aging effect.

[8] ESRG (1986), Volume II, page I-26. Projections for 1991-95 are averaged and reported on 1991-97 line.

TABLE 4: ANNUAL PWR CAPACITY FACTORS, 1968-85 (%) UNITS 800 MW +

Plant	DER	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
-----	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Palisades	821	24.5%	33.5%	1.1%	33.8%	39.5%	70.7%	36.5%	47.7%	33.0%	48.2%	46.5%	52.4%	11.3%	73.7%
Surry 1	823		48.0%	46.0%	54.3%	60.8%	69.7%	65.2%	31.3%	34.2%	33.0%	76.1%	56.7%	46.2%	77.9%
Maine Yankee	825			51.6%	65.1%	85.4%	74.3%	77.4%	65.6%	63.5%	75.3%	65.4%	67.0%	74.2%	77.4%
Surry 2	823			36.5%	70.1%	46.2%	61.8%	74.5%	8.5%	31.0%	71.4%	76.2%	56.7%	72.3%	56.5%
Oconee 1	886			51.5%	68.1%	51.3%	50.8%	65.1%	64.4%	65.7%	38.6%	66.4%	66.2%	79.5%	91.0%
Indian Point 2	873			43.5%	63.9%	29.6%	68.1%	57.1%	62.8%	55.6%	39.9%	58.1%	0.8%	37.8%	87.2%
Zion 1	1050			37.8%	53.4%	51.6%	54.7%	73.6%	60.2%	70.6%	67.3%	51.0%	43.7%	61.9%	52.3%
Oconee 2	886				64.0%	54.3%	49.3%	61.7%	76.9%	49.8%	66.9%	44.3%	66.2%	94.0%	65.2%
TMI 1	819				77.2%	60.3%	76.1%	79.1%							
Zion 2	1050				52.5%	50.3%	68.2%	73.2%	51.8%	57.2%	57.2%	56.1%	67.2%	65.1%	55.6%
Oconee 3	986				58.3%	54.9%	60.7%	70.2%	37.7%	60.2%	72.6%	24.5%	82.2%	62.0%	56.2%
Arkansas 1	850				65.5%	52.1%	68.5%	70.5%	44.6%	50.7%	65.8%	50.0%	43.2%	61.8%	69.7%
Rancho Seco	913					27.5%	73.5%	62.4%	71.4%	55.1%	32.9%	42.1%	35.6%	47.1%	24.2%
Calvert Cliffs 1	845					84.9%	66.0%	63.2%	56.7%	61.1%	82.5%	72.4%	75.2%	84.1%	58.9%
Cook 1	1090					71.1%	50.1%	65.8%	59.3%	67.5%	71.0%	56.1%	55.4%	79.1%	22.2%
Millstone 2	828					62.4%	59.9%	62.0%	60.2%	67.1%	84.0%	69.1%	33.8%	91.1%	48.2%
Trojan	1130						65.6%	16.8%	53.2%	61.2%	64.9%	48.5%	41.2%	47.8%	69.8%
Indian Point 3	873						72.2%	71.4%	62.7%	40.0%	39.7%	18.8%	0.8%	79.0%	61.8%
Beaver Valley 1	852						39.8%	33.2%	23.8%	4.0%	62.5%	36.0%	62.7%	63.6%	79.1%
St. Lucie 1	802						76.1%	71.2%	69.5%	73.8%	70.4%	96.6%	15.2%	60.2%	83.5%
Crystal River 3	825							35.9%	52.1%	46.3%	56.5%	68.0%	52.2%	89.6%	39.4%
Calvert Cliffs 2	845							70.6%	74.2%	86.4%	73.2%	67.6%	82.6%	72.1%	75.8%
Salem 1	1090							47.4%	21.4%	59.4%	64.8%	42.9%	56.3%	22.3%	94.3%
Davis-Besse 1	906							32.9%	39.4%	26.3%	55.0%	40.5%	61.5%	54.1%	24.5%
Farley 1	829							81.5%	24.0%	63.2%	36.0%	71.8%	82.4%	74.2%	80.8%
Cook 2	1100								61.8%	69.3%	66.3%	72.6%	72.8%	55.7%	59.0%
North Anna 1	907								52.7%	70.7%	58.4%	30.2%	66.8%	47.6%	73.0%
Arkansas 2	912										54.1%	47.7%	55.4%	77.7%	58.8%
North Anna 2	907										71.1%	50.9%	73.0%	59.4%	85.8%
Farley 2	829										72.9%	50.9%			

AVERAGES THROUGH:	1975	1977	1979	1981
	====	====	====	====
Cumulative	50.0%	56.2%	56.1%	56.9%
Immature Years (1-4)	50.0%	56.0%	56.0%	56.3%
Mature Years (5+)		60.0%	56.2%	57.2%

TABLE 5: PNM ESTIMATE OF PRESENT VALUE EFFECTS AT VARIOUS AVAILABILITIES ($ MILLION)

	Base Case			
1. Equivalent Availability	74%	65%	55%	45%
2. Ratepayers Outcomes:				
a. AFUDC Revenue Requirements	$311.32	$338.34	$361.10	$374.76
Change From Base Case		$27.02	$49.78	$63.44
b. System Production Costs	$2,617.7	$2,670.7	$2,733.5	$2,816.3
Change From Base Case		$52.90	$115.72	$198.53
c. Total Ratepayer Costs	$2,929.1	$3,009.0	$3,094.6	$3,191.0
Change From Base Case		$79.93	$165.50	$261.97
Change as % of Base Case Total		2.73%	5.65%	8.94%
Change as % of Base Case AFUDC		25.67%	53.16%	84.15%
3. Shareholder Costs	$37.64	$47.30	$65.74	$92.84
Change From Base Case		$9.67	$28.10	$55.20
Change as % of Base Case		25.68%	74.66%	146.67%
4. Total Cost Increase		$89.59	$193.60	$317.18
Change as % of Base Case		3.02%	6.53%	10.69%
5. Shareholder Cost Increase as % of Total Cost Increase		10.79%	14.51%	17.41%

Source: Exhibit DAB-1, pages 12-14.

Notes: [1] All present values at 11.811%.

Table 6: SHAREHOLDER COST AS PERCENTAGE OF TOTAL COSTS DUE TO POOR PERFORMANCE

CHANGES IN COSTS FROM BASE CASE ($ MILLION)

Year	Units in Service	|--to 65% (9% decrease)--|			|--to 55% (19% decrease)-|			|-to 45% (29% decrease)-|		
		Total Cost	Share-holder Cost	Share-holder Cost as % of Total	Total Cost	Share-holder Cost	Share-holder Cost as % of Total	Total Cost	Share-holder Cost	Share-holder Cost as % of Total
----	--[1]--	--[2]--	--[3]--	--[4]--	--[2]--	--[3]--	--[4]--	--[2]--	--[3]--	--[4]--
1986	1.3	$4.0	$0.7	16.4%	$8.4	$1.4	16.8%	$12.9	$2.2	17.1%
1987	2.3	$7.1	$1.2	16.4%	$14.9	$2.5	17.0%	$22.8	$4.4	19.3%
1988	3	$9.2	$1.4	14.8%	$19.5	$4.2	21.7%	$29.7	$8.6	28.9%
1989	3	$9.2	$1.1	12.5%	$19.5	$2.9	14.9%	$29.7	$6.2	20.9%
1990	3	$9.2	$2.8	30.5%	$19.5	$6.3	32.2%	$29.7	$9.8	32.9%
1991	3	$9.2	$2.7	29.7%	$19.5	$6.7	34.6%	$29.7	$10.7	35.9%
1992	3	$9.2	$2.1	23.2%	$19.5	$6.5	33.4%	$29.7	$10.8	36.5%
1993	3	$9.2	$1.2	13.4%	$19.5	$5.5	28.0%	$29.7	$10.3	34.5%
1994	3	$9.2	$1.3	13.9%	$19.5	$4.9	25.4%	$29.7	$11.7	39.3%
1995	3	$9.2	$1.2	12.8%	$19.5	$3.0	15.4%	$29.7	$11.9	39.9%

Notes: [1] Assumes that Unit 2 enters service in 10/86, Unit 3 in 10/86.

[2] [1] x 8760 hours x 130 MW x availability decrease x 3 cents/kwh.

[3] From Exhibit DAB-1, pages 12-14.

TABLE 7: PNM EAF PROJECTIONS AS INTERVALS, EAF BETWEEN REFUELINGS, AND LENGTH OF REFUELINGS

	UNIT 1	UNIT 2	UNIT 3
1. EAF from COD to first refueling	68.4%	68.4%	68.4%
2. Months from COD to end of first refueling	12	16	16
3. Weeks for first refueling outage	7	7	7
4. EAF from end of first refueling to end of second refueling	78.5%	78.5%	78.5%
5. Months from end of first refueling to end of second refueling	12	12	12
6. Weeks for second refueling outage	7	7	7
7. Mature EAF between refueling	85.4%	85.4%	85.4%
8. Mature months between refueling	12	12	12

Source: Exhibit JRH-2, Case # 1916.

Appendix A

Resume of Paul L. Chernick

Appendix B

Power Plant Performance Standards: Some Introductory Principles

Power Plant Performance Standards: Some Introductory Principles

By PAUL L. CHERNICK

This article describes some approaches to the determination of how well electric power generating plants perform, demonstrating their applications and citing their respective advantages. The techniques described may be used to determine whether a plant's efficiency is adequate and whether units with the lowest running costs are being sufficiently utilized.

Interest in assessing the prudence of electric utility fuel costs has increased over the last several years, as a result of rising fuel costs and large utility construction programs intended to displace expensive fuel sources, primarily with coal and nuclear fuel.[1] Several regulatory agencies have attempted to pass some of the costs (or benefits) of inadequate (or superior) performance on to the utilities, by modifying the amount or the timing of reimbursement for fuel costs, operation and maintenance expenses, rate base, or return on equity.

This article explores some approaches to determining how well power plants should perform, and discusses the advantages and applications of each. These techniques may be applied to determine both whether the efficiency (heat rate) of plants which burn large dollar amounts of fuel is adequate, and whether the units with the lowest running costs were available and utilized sufficiently.

Some Basic Approaches

In setting power plant performance standards, the fundamental objective is to develop, *normative* or *prescriptive* goals, specifying how the plants *should* behave. This is a very different concept from *positive* or *descriptive* projections, which predict how the plants *will* behave. These two types of analyses have very different purposes and may yield very different results. For example, if a utility's plant breaks down in 1983, an accurate positive analysis might project a 1984 capacity factor of zero. Regulators may well determine that 1984 fuel costs should only reflect the costs which would have been incurred if the plant had been available. Thus, the normative standard may be different from both the actual performance and from the best estimate of future performance.

There are three basic types of alternative approaches which can be taken to establishing standards for power plant performance. First, each unit's performance standard can be determined by a *self-referent* standard, based on the unit's past performance. Self-referent standards may be set at various levels of stringency, such as:

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

Any of these standards may be calculated from any time period – e.g., last year, or the plant's entire life – and for a variety of intervals (monthly data, annual data).

These self-referent methods are easy to estimate and apply, but they do not usually produce fair and even-handed standards. Self-referent 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

[1]See *Innovative Regulatory Approaches to Power Plant Productivity and Cost Allocation Issues*, by L. Danielson, California Energy Commission, September, 1981, for a review of regulatory actions to that time.

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extraordinary nor inadequate), so self-referent standards are not likely to be useful in identifying efficient and cost-efficient operations.

In the second group of options, standards are based on *comparative* analyses, which aggregate the experience of other 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 *competently run* 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 analyses, such as regression. 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 always subject to some dispute. Various statistical techniques may mitigate these limitations. In multiple regressions, for example, several descriptive variables may be incorporated simultaneously, facilitating the merging of data from a greater variety of units. Statistical tests can also be useful in determining whether particular units belong in a comparison group.

Even though both self-referent and comparative analyses use actual operating data, they are not just descriptions of that data. Positive models describe the way things are (or have been), leading to such conclusions as "In their second year of operation, 800-megawatt pressurized water reactors have an average capacity factor of 55 per cent." This sort of statement is not a performance standard; it only becomes a standard when a prescription is added, such as "Therefore, this particular reactor should have a 55 per cent capacity factor in its second year." The way things are may be the basis for determining the way things should be, but this relationship is not automatic.

In the third group of approaches, standards are to be based on *absolute* measures of proper performances, such as:

- The unit will perform as was promised, or expected.
- 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.
- The unit will perform well enough to justify its fixed costs.

None of these various absolute standards depends on actual performance data, either for the subject plant or for other plants. The first example suggests that, when the utility (and hence, the ratepayers) buys 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.

Selecting a Standard Setting Approach

No one particular approach to standard setting is preferable in all applications. The various kinds of standards are appropriate for different situations. As noted above, self-referent standards raise major equity issues. 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. Self-referent standards are also inherently inapplicable to new units. There are special circumstances in which self-referent standards are useful, particularly when no other basis for standard setting exists. Examples of these situations would include the small nuclear reactors completed in the early 1960s, the few geothermal plants currently operating, and such new technologies as wood burning units and fluidized bed plants. These are the exceptions, rather than the rule.

Comparative standards are appealing wherever a reasonable comparison group exists. They are not applicable for experimental units and other unique designs.[2] Comparative analyses establish business-as-usual standards, general industry performance levels as the basis for determining whether a utility may deserve a bonus or penalty.

Absolute standard setting approaches rely on other concepts of fairness, which may be applicable even where business is far from usual. For example, using preoperational 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 be encouraged to present consistent projections in different proceedings, whether they are requesting permission to build the plants of their choice; estimating marginal generation costs to determine whether declining blocks are justified, whether conservation programs are cost effective, and whether higher rates for small power producers are necessary; or determining the level of fuel cost recovery.

The application of the prior expectations approach is limited to those performance factors and units for which reasonably serious expectations and representations are available. For many fossil units constructed

[2]The concept of uniqueness must be applied carefully. In one sense, no steam power plant is unique, since all such plants are alike in having a boiler, a turbine, and a heat sink. In another sense, every unit is unique, except for those few sister units which are *exact* carbon copies. Generally speaking, if a group of similar units can be defined, a meaningful comparative analysis can be conducted, and statistical tests can determine whether differences between plants are important.

prior to the establishment of regulatory review, no reliability measures were ever projected. For other technologies, early performance expectations were widely held, based on virtually no data, and seriously incorrect; this certainly was true of projections for nuclear capacity factors made in the 1960s and early 1970s. In such cases, it seems unfair to hold an individual utility responsible for a universal, and perhaps understandable, error.

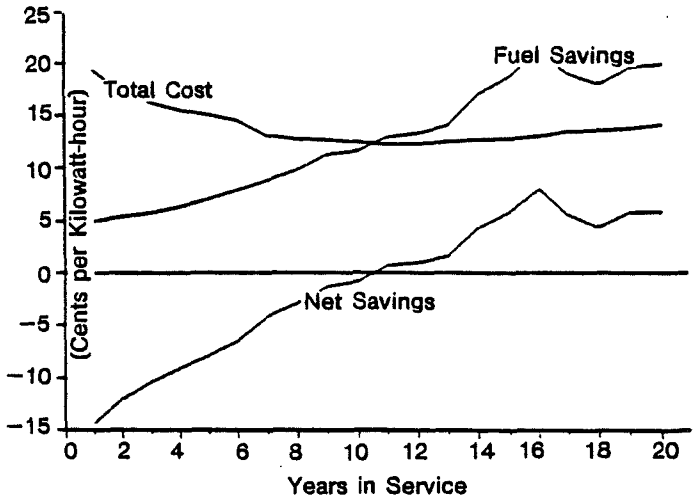
As an alternative to the projection standard, the cost-effectiveness standard may be particularly appealing: This standard asks only that the ratepayers be better off with the plant than without it, but this may be all that can be expected from new (and especially from exotic) generating units. This standard can be derived for all units, regardless of the existence of a comparison group, of prior data on the unit's own performance, or of preoperational projections.

A break-even standard may also be particularly appropriate in the case of the many relatively expensive nuclear plants[3] nearing completion. Those plants are being built with the knowledge that they will be far more expensive per kilowatt than other capacity sources, but with the expectation that they will pay off the additional capital costs through long hours of output at very low fuel cost. In many cases, it has long been clear that the plant would not be necessary in the near future for reliability purposes, yet construction was continued to realize the anticipated fuel savings. Since these plants are being built to save money, it seems reasonable to expect them to do so, or at least to investigate the reasons for their failure to break even, if that occurs.

The break-even standard would also help to solve a serious timing problem. Traditional rate-making treatment for expensive new base-load plants tends to impose a disproportionately large share of the costs on customers in the first few years of a generating plant's life, even though (under current conditions) most of the benefits are expected much later, often in the second half of the unit's life. Costs tend to fall over the first decade or so, due to depreciation of the rate base contribution. The benefits of major base-load plants are generally relatively small in the early years, while the price of the alternative fuels is low and the need for the added capacity does not exist. This pattern of costs and benefits is illustrated in the accompanying figure.[4]

As a result of this pattern of cost and benefits, customers in the early years (frequently a decade or more) wind up worse off than they would have been if the plant had never been built. This may be true even if the plant is justified by its later savings, to a substantially different mix of customers. Unfortunately, regulators must decide whether to allow full recovery for the cost of the plant before much of its benefits are experienced. At best, this situation amounts to a sizeable tax on today's customers to provide lower-cost power to tomorrow's customers. At worst, it may pe-

New Nuclear Plants — Typical Cost Benefit Pattern



nalize utilities for units that will eventually pay off, and fail to recognize that other units never do.

If the ratepayer benefits of the plant are constrained to be at least as large as the costs, the large ratepayer losses in the early years do not occur.[5] As a result, there is no subsidy (or less subsidy) by the ratepayers of the 1980s to the ratepayers of the next century. The people who receive the major benefits of the plant (avoiding the large costs of escalating fuel prices) also pay the major proportion of the costs.

A final advantage of break-even standards is that they would tend to encourage accurate cost forecasting and evenhanded planning on the part of utilities engaged in major construction projects. Traditionally, utilities have had very asymmetrical incentives regarding decisions to complete or cancel construction projects. Completed plants, whether economical, or needed, are generally placed in rate base more or less when they enter service.[6] Canceled plants are generally considered to be at least partially imprudent (or at least partially the responsibility of the stockholders), and their costs are rarely recovered in full from the ratepayers. Therefore, a utility which can actually complete and operate a new plant is largely home free, even if the net cost of the project is greater than the cost of cancellation. The result is that utilities frequently continue with construction projects long after an impartial analysis would indicate that they should be abandoned.

With a break-even cost recovery standard, this asymmetry is eliminated. Cost recovery will be far from automatic in any case, and (even if the plant is completed) will not rely on projections of future benefits. A completed plant which costs a billion dollars more than it is worth would pose the same problems for the utility as a plant which is canceled after a billion dollars have been spent on it. Therefore, the bias towards completion should be largely neutralized, and decisions regarding cancellation, deferral, or completion should be made on the basis of total future costs

[3]This reasoning also applies to some coal-fired units.

[4]The data are from Northeast Utilities, for Millstone 3, and are illustrative of the general problem.

[5]Alternatively, the nonfuel costs passed on to ratepayers may be constrained to be less than or equal to the savings received.

[6]More recently, some units have been phased into rate base over the period of a few years, resulting in limited costs being borne by the shareholders.

and benefits, without regard to whether customers or shareholders are likely to bear the costs.

In determining the kind and level of standard which is appropriate in a particular situation, it is important to consider the intended use of a performance standard. If the standards only set the level of a prospective fuel clause, or create an obligation for the utility to explain and justify any deviations from expected performance, they may be set in a relatively demanding fashion. Indeed, this would be true for any standards which basically flag performance requiring some scrutiny or explanation.[7] While a higher standard might be appropriate for this screening purpose, a lower one might be justified if there were automatic financial consequences when the utility failed to meet the standard.

Good Standards Require Thoughtful Design

Once a general approach to standard setting is chosen, several additional methodological issues will remain. I will only touch on a few of them here.

One problem in setting comparative standards for capacity factors and similar reliability measures is the selection of a consistent definition of plant capacity in the reference group. Some care must be taken to ensure that the capacity factors for other units in the comparison group[8] are all computed on the basis of the same measure of capacity, whether that is *design net,* or *dependable gross,* or some other comparable measure. If a comparative standard is to be based on a regression analysis, some of the variables which ideally ought to be examined include unit size, unit age, cooling system, design (e.g., once-through versus drum-type boilers), fuel type and quality (especially for coal-fired plants), pollution controls, maintenance schedules,[9] manufacturer of boiler and turbine, and regulatory environment.

The regulatory variable would include the reductions in nuclear capacity factors following the accident at Three Mile Island, and possibly future reductions in coal-plant reliability and efficiency due to acid rain legislation. My analyses of nuclear capacity factors indicate that the TMI effect is as important as age or size in determining performance, and that nuclear utilities would be unfairly penalized if their units were expected to perform as well in the early 1980s as they did in the mid-1970s.

For several of these variables, especially the age and size effects, the mathematical form which best approximates the effect on performance is of interest, and can be studied in considerable detail. The generally comparable data set may be improved for the specific purpose of determining average *prudent* performance by deleting the few specific unit-years which can be identified as reflecting acknowledged imprudent behavior on the part of the operators.[10]

A comparative standard can be applied in at least two ways: on an annual basis and on a cumulative basis. The annual standard simply takes the group projection for the size, current age, and other characteristics of the unit. In other words, it requires that: A unit of these characteristics shall perform this year at the average level of similar units. The cumulative approach derives the current year's standard which will bring the plant's cumulative performance to the group prediction.[11] Thus, the cumulative standard is indifferent to this year's performance, except to specify that: A unit of these characteristics shall *through this year* perform at the average level of similar units. The period used in the cumulative calculation may be the entire life of the plant, the mature portion of its life – e.g., from the fifth year of operation – or perhaps some other interval, such as the last five years.

For a unit which has performed well in the past, the cumulative standard is more lenient than the current standard; for a unit which has performed poorly, the cumulative standard is more stringent. In general, I believe that the cumulative standard is more equitable. A unit which performed exceedingly well in the past seems entitled to an off year or two, while one which has performed in an unsatisfactory manner has some catching up to do. On a more causal basis, the cumulative standard may be justified by the observation that many operating problems require some time out of service for their correction. A unit which has performed especially well may have deferred some maintenance or upgrading to achieve high reliability in the past, and may reasonably require more downtime now than a unit which has already been out of service for major modifications and maintenance.

If a cumulative performance standard is employed it may not be physically possible for particular units with poor performance histories to catch up in the first year of the standards,[12] while exceptional units might be guaranteed to exceed the standard. For the underachieving units, it may be necessary to set the targets at some lower, feasible level. Examples (for capacity factor) might be 100 per cent, or the highest annual capacity factor in the comparative data set, or some more likely value, such as 80 per cent. The lower the annual target, the longer a time is required to catch up to the average. Similar considerations are involved in setting standards for very successful units.

It is to be expected that many plants will fail the break-even standard for several of their early years, even if they eventually are quite valuable. So long as this is the case, I would recommend that the utility be allowed to accrue interest on the difference between its actual power supply costs and the fuel charges allowed under the break-even target. If the plant eventually pays off, the actual costs will be less than those under the (gradually decreasing) break-even standard, and the utility can collect its deferred fuel costs. In the ordinary case, in which the plant is economically justified, the deferred costs would gradually be recov-

[7]Or conversely, performance eligible for some reward.

[8]In general, the utility's own units should not be in the comparison group.

[9]This is particularly important for nuclear refuelings, and accounts for much of the otherwise unexplained variation in nuclear capacity factors.

[10]For example, cases in which regulators have already ruled that the performance was low due to imprudence.

[11]If the utility's cost recovery is determined by the target, rather than by actual performance, then the target should be used in subsequent computations.

[12]A capacity factor of 210 per cent might be required, or a heat rate of 3,000 Btus per kilowatt-hour.

ered, and the break-even standard would finally become obsolete. At that point, a comparative standard could be substituted.

If the utility should determine at some point that the benefits of a plant are unlikely to catch up with its costs, it can ask its regulators for explicit treatment of the difference, just as it would for any other large investment which must be written off. In this situation, it would be crucial that the utility be absolutely candid regarding the costs and benefits of the plant, in order accurately to assess the size of the net loss. The regulator would then have to determine what portion of the total cost of the plant should be recovered over its life. This fraction may range from 100 per cent of the costs down to the portion of costs justified by the savings, or perhaps some lower figure.[13] Once that fraction is determined, a multiplier can be calculated, so that applying the break-even standard with the multiplier over the anticipated life of the plant will recover those costs which the commission has approved. The multiplier may be applied to the fuel savings factor, to the cost of the displaced fossil fuel, to capacity cost savings, or to total savings. The choice of the application of the multiplier should depend on the regulators' perceptions of why the plant will not pay,[14] why its completion was justified,[15] and what costs the plant represents the best insurance against.[16]

[13]The extent of the savings seems to me to be the lower limit for cost recovery, so long as the utilitys errors are confined to decisions to continue construction after that became imprudent. If the regulator finds that the plant should have been completed, but that competent management would have brought it into service for a much lower cost, then cost recovery may reasonably be limited to the cost of completing the plant prudently.

[14]For example, if the principal problem is that capacity factor projections were too high, the multiplier might be applied to all fuel savings.

[15]If decisions to continue construction were reasonable because of concern that resurgent demand would otherwise require enormous efforts to catch up in installed capacity, the multiplier might be applied to the avoided capacity costs.

[16]For example, a nuclear unit would provide some insurance against future coal price increases (from acid rain legislation, perhaps), in which case perhaps the excess costs are most appropriately recovered from a surcharge on avoided coal prices.

Training Programs Offered by Major Engineering and Construction Firm

Bechtel Power Corporation last year logged more than 130,000 hours of power plant operator and maintenance personnel training at Bechtel projects. This year, for the first time, it is offering its extensive training resources to all electric utilities. Bechtel currently offers more than 1,300 operations and maintenance training courses.

Bechtel's training programs in many instances meet accreditation subject matter requirements established by the Institute of Nuclear Power Operations for training of maintenance and technical personnel at nuclear power plant facilities. Utilities will have the opportunity to adapt existing training courses rather than undertake the expensive and time consuming task of developing their own programs.

"It has become increasingly apparent that high quality training is the key to successful operation of modern power systems," says Lou Peoples, manager of planning and plant operations at Bechtel.

The company has instituted successful training programs at a wide variety of facilities around the world. Among the successful Bechtel programs, one in Spain graduated more than 2,000 technical, professional, and field nonmanual employees from training programs at five nuclear facilities. As part of the design and construction of a large petrochemical complex in Puerto Rico, Bechtel graduated more than 6,000 trainees in various craft specialties. In Papua, New Guinea, Bechtel prepared all courses and carried out on-the-job training for the plant operating and maintenance staff of a three-unit, oil-fired steam generating unit.

Bechtel has carried out many successful training programs at power plants in the U. S. Included in Bechtel's training program are courses in technical support and management, cost-effectiveness, quality control, radwaste handling, security, and start-up. More information about the 1,300 Bechtel courses can be obtained from Lou Peoples, Bechtel Power Corporation, P. O. Box 3965, San Francisco, California 94119.

Appendix C

Capacity Factor Regression Analyses

APPENDIX C

Regression Analysis of PWR Capacity Factors

May 1986

By Anne Edwards and Paul Chernick

Table of Contents

1 Introduction

This analysis builds on previous work, which was based on data through 1983. Since then, the database regarding capacity factors of PWR nuclear power plants has grown a great deal with the addition of data through 1984 and again with data through 1985. With the increased number of observations, a better representation of nuclear power plant experience, we can be more confident about the results which are generated by our analyses. The analysis which is described here includes plots, correlations, and regressions, and results in an equation for predicting capacity factors into the future.

2 Data and Sources

The variables in Table 1 were originally entered into or calculated within the capacity factor database. The database has a separate observation for each unit of each plant, because there are no economies of scale in capacity factors.

TABLE 1: Variables used in Regression Analysis of PWR Capacity Factors

Variable	Description	Source
NAME	Separate name for each unit	[1]
ID	Identification number for each unit; index based on chronological order of commercial operation date	
MW	Design Electrical Rating (DER)	[1]
YEAR	Datapoint year	[1]
COD	Month and year of commercial operation date	[1]
GWH	Annual Net Electric Energy output (MWH), divided by 1000.	[1]
CF	CF = Capacity Factor = MWH/DER/8760	Calculated
AGE	Years from commercial operation to middle of current year	Calculated
CE	Dummy variable indicating NSSS is Combustion Engineering	[2]
BW	Dummy variable indicating NSSS is Babcock and Wilcox	[2]
W40	Dummy variable indicating unit contains Westinghouse turbine generator with 40" blade	[2,3]
W44	Dummy variable indicating unit contains Westinghouse turbine generator with 44" blade	[2,3]
REFUEL	Number of full refuelings which occurred during the year. Usually 0 or 1, but may be partial or slightly greater than one if the unit was out over the new year.	[1]

Table 1 Sources:

[1] NRC "Green Books," Nuclear Power Plant Operating Experience, NUREG/CR-3430, for data 1973-1982. NRC "Gray Books," Licensed Operating Reactors, Status Summary Report, NUREG-0020, up to September 1985.
[2] Electrical World, "Annual Generation Construction Surveys," annual.
[3] Electric Power Research Institute, Nuclear Unit Operating Experience: 1980 Through 1982 Update, (EPRI NP-3480), April 1984, Appendix C. Westinghouse turbines entering service after 1978 assumed to have 44" blade.

Other variables were created during the course of our analyses, but they are defined in the text which follows. To complete the list of all variables used in this analysis, the new variables are: AFT78, YR79_83, OUT, AGE5, and AGE_12.

3 Preliminary Analyses

Before running regressions, it may be helpful to see what the data looks like in its simplest form. Plots of the raw data, and correlations between the variables, are helpful in determining the variables which have a strong effect on capacity factors. This is easily done by plotting capacity factors on other variables, one at a time. If there is a clear trend in any one plot, then that variable may explain some part of the variability. Attachment 1 contains all of the plots run for this analysis.

The first three plots display all capacity factor data plotted first on AGE, then on MW, then on YEAR. When compared with AGE, capacity factors do appear to increase in the first few years. The existence of very low capacity factors in later years suggests not only that capacity factors level off after five years, but also that they appear to decrease as age increases past ten or twelve years. It is not clear from the plot whether the low capacity factors in later years will be explained by variables other than age.

At first sight, there appears to be a strong negative trend when capacity factor is compared to MW. However, the distribution of datapoints on size leads one to visually separate the units into groups. There is a gap around 600-700 MW, to the left of which the capacity factors are higher. Once the small plants are distinguished from the larger plants, the size trend does not appear to be smooth at all, but rather there appears to be a sharp drop which occurs at the 600-700 MW gap.

When compared with YEAR, capacity factors do decrease on average, and the majority of seriously low capacity factors occur after 1978. The plot of CF on YEAR suggests that the regulatory reaction to the TMI accident in 1979 had a profound effect on the performance of nuclear power plants. To test this, we created a variable called AFT78, (AFT78 = 1 if 1979 or later, and 0 otherwise), and looked at plots of all data where AFT78=1, and then where AFT78=0, separately.[1] These plots are included in Attachment 1, with the plots of earlier data first.

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1. Note that the dataset was once divided at the <u>end</u> of 1979, but the division at the <u>beginning</u> of 1979 has more significance.

The age effect, when we compare the plots from the two time periods, is more strongly positive before 1979 than after. The size effect (MW) is strongly negative before 1979, but in the later years the negative trend is more vague and could be considered to be positive. Because the difference in time periods does influence the relationship between other variables, we decided to include the AFT78 variable in our regressions.

The effect of refuelings appears to be negative in both time periods. The plots of CF on REFUEL show extremely low capacity factors in years with no refuelings. Further research indicated that many of those low capacity factors were caused by extended outages for reasons other than refueling. We created another variable called OUTAGE to indicate each plant-year during which the NRC reports a single-purpose, non-refueling outage lasting more than three months. The value of OUTAGE, like REFUEL, is usually and in this case always equal to 0 or 1. Table 2 below is a list of observations for which OUTAGE = 1.

All further analyses used OUT in place of REFUEL, where OUT = REFUEL + OUTAGE.

TABLE 2: Major Outages Other Than Refuelings

Plant name	Year	Portion of outage within year
Surry 2	1974	1.00
Zion 1	1974	1.00
Rancho Seco	1976	1.00
Beaver Valley 1	1978	1.00
Crystal River 3	1978	1.00
Surry 1	1979	1.00
Surry 1	1980	1.00
San Onofre 1	1981	1.00
Surry 1	1981	1.00
San Onofre 1	1982	1.00
San Onofre 1	1983	1.00
San Onofre 1	1984	1.00
Salem 2	1984	1.00

Source: NRC "Green Books," Nuclear Power Plant Operating Experience, NUREG/CR-3430, for data 1973-1982. NRC "Gray Books," Licensed Operating Reactors, Status Summary Report, NUREG-0020, up to September 1985.

For comparison, plots of CF on REFUEL and CF on OUT are included in Attachment 1, for both time periods. Note that when each plot of CF on REFUEL is compared with the plot of CF on OUT for the same time period, the low capacity factors at REFUEL=0 have shifted to OUT=1. As would be expected, major outages do on average cause lower annual capacity factors.

Another helpful step in determining which variables to include in the regressions is a correlation matrix. Each correlation in the matrix demonstrates the relationship between two variables in the dataset (see page 1 of Attachment 2). When two variables are highly correlated, due to factors other than the effect we are trying to measure, the correlation can confound the results of a regression which includes both variables. For example, YEAR and AGE are highly correlated because age increases with time directly. We must expect that the effects of these two variables will be difficult to distinguish in the regression equations. The calculated effect of one could hide the true effect of the other. Likewise, problems may arise from using the Westinghouse turbine variables in a regression with MW, because of the fact that Westinghouse 44" turbines were generally installed in later, larger plants, while Westinghouse 40" turbines were installed in the smallest units.

The second page of Attachment 2 is the correlation matrix which includes most of the variables which were ultimately used in our analyses. This was a helpful reference tool when specifying the regression equations.

4 Regressions

Our first regressions duplicate those which appeared in an early A&I PWR capacity factor analysis, using data through 1982 (Tables 3.16 and 3.17, Testimony of Paul Chernick, State of New Hampshire before the Public Utilities Commission, Docket #84-200). These are simple regressions, but they indicate the bottom line effects of age and size on capacity factors. With the added data for 1983 through 1985, the size trend has not changed much at all, and the age effect has decreased. (See also Attachment 3, pp. 1-2)

4.1 Outage Effects

The outage indicator, as we have already seen, is an extremely important explanatory variable. OUT is included for all but the simplest regressions in this analysis, and remains significant throughout.

4.2 Age Effects

First in the simple regressions, and then in all regressions that followed, we included AGE5, which is the minimum value of AGE and 5. This version of the age variable represents the fact that the typical unit's performance improves over the first five years of its life (more or less), and then levels off. Other analyses have also indicated that there is a maturation level at the age of 5 (see Easterling, Statistical Analysis of Power Plant Capacity Factors through 1979, NUREG/CR-1881). We tested other ages as level-off points, but reconfirmed that the upward trend continues most notably until age 5, and loses significance when the level-off age is later. (See Attachment 3, pp. 3-4)

4.3 Turbine Effects

The next variables added to the regression were the Westinghouse turbine indicators, W40 and W44. These seemed to improve the equations (see Attachment 3, pp. 4-6), but two things indicated that the coefficients were not representing their true effects. First of all, the Westinghouse 44" turbine appeared to have a negative effect, while the 40" turbine had an even stronger positive effect. Other sources on past experience indicate that the opposite is true: 44" turbines have actually performed better than 40" turbines, and neither should have a positive effect on capacity factors (see Attachment 4).[2]

It is likely that the turbine variables are picking up the size effect in the regression. When MW is introduced into the equation which contains turbine variables, it is not significant. However, when MW is in the equation without turbine variables, as we have seen, it is very significant (Attachment 3, pp. 6-7). The size effect is better established than the turbine effect, and demonstrates the expected sign, so we chose to omit the Westinghouse variable from the estimation equation at this point.

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2. All of the units in our database have either Westinghouse or General Electric turbines, with the two exceptions of Cook 2 which has a Brown-Boveri turbine, and San Onofre 2 which has a GEC turbine (General Electric Company, U.K.).

4.4 Year Effects

The transformation of the age variable to AGE5 leaves it less correlated with time, which allows us greater flexibility in introducing time-related variables into the equation. As we learned from our preliminary analyses, the YEAR variable is highly correlated with other variables in its raw form. With data through 1984 in our earlier regresssions, the variable AFT78 explained a large part of the variability in the data. With the addition of 1985 data, AFT78 explains less of the variability, suggesting that nuclear power plant performance has improved over the last couple of years.

To determine a more detailed time pattern of PWR performance in the post-TMI period, we created a dummy variable for each year, 1979 and after. The separate year dummies are not highly correlated with age variables (see page 2 of Attachment 2), presumably because in any one year there is a large variety of ages among the plants. For that reason, we could add them to our regressions without the fear of confounding the results we had already discovered.

The results on the separate year variables including 1985, begin on page 14 of Attachment 3, and indicate the definite improvement in performance in 1984 and 1985. Some years, namely 1981, 1984, and 1985, do not have a significant effect, so the overall equation loses some significance when the separate year dummies are used (see Attachment 3, pp. 14, 15, and intermittently thereafter).

For our latest analysis we introduced one more variable (YR79_83) to distinguish the post-TMI years from pre-1979 and post-1983 time periods, The significant results of equations including this variable (Attachment 3, pages 15+), indicate that the years 1979-83 were distinctly worse than other years. Whether this is a cyclical change or a one-time event has yet to be determined.

4.5 Size Effects

Previous analyses of PWR capacity factors have consistently indicated strong negative correlations between size and capacity factor. Consistent with common practice, we have previously represented size with the continuous variable MW, assuming that the size effect is roughly linear over the range of interest (400-1200 MW). However, inspection of the plots in Attachment 2, and the regressions in Attachment 3, page 8, indicates that increased size beyond 600 MW has little, if any, effect on capacity factors. The trend which had been detected in the size effect may be better modeled as a downward shift at MW=600.[3] The new variable MW600, a dummy variable to indicate plants larger

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3. No units have original DER's between 575 MW and 707 MW.

than 600 MW, was created and added to our regressions. (See Attachment 3, pp. 11+)

4.6 More Age Effects

Once we had a good regression (Attachment 3, page 8, bottom), we plotted the residuals on size (MW) and age (AGE) to see if there was remaining variability which could be attributed to either of those variables (Attachment 3, pp. 9 and 10). Indeed, we discovered that although we had adequately modelled the trend in the maturation years with AGE5, there also exists a downward trend in the later years of a unit's life. At first we defined a variable which, in effect, was the opposite of AGE5. AGE_12 equaled the maximum value of AGE and 12. This variable was a significant addition to the regression, but indicated a very rapid downward trend. A more appropriate definition, given the small amount of datapoints for plants greater than 12 years old, was to make AGE_12 a dummy variable (AGE_12 = 1 if AGE is greater than or equal to 12, and 0 otherwise). The coefficient then indicates the inefficiency of a plant 12 or more years old (Attachment 4, pp. 11+).

For the sake of completeness, we also tried AGE_10 and AGE_11 dummy variables in the equation. AGE_12 was the most significant break-off point (Attachment 3, pp. 11-12).

4.7 More Turbine Effects

The last variable to be added, or rather added again, was W44. The correlation between W44 and MW600 is still high (see page 2 of Attachment 2), which is one reason for the lower F-statistic when W44 is added. However, it is an additional variable which explains some variability, so the adjusted R^2 increases, and the coefficient is significant (Attachment 3, pages 13 and 17).

5 Results

The results from our "best" regression on the full database (Attachment 3, page 17) are recorded as Equation 1 in Attachment 5, and projections from that equation are calculated in Table 3.

Three things should be noted when considering these results. First, all results reported here are based on data from 1973 to 1985. We have data for the majority of the variables back to 1968, but we have no source of refueling data before 1973. Therefore, because REFUEL and OUT are missing for all observations before 1973, those observations are excluded when a regression is run. In order to be able to include those observations, we tried to assign average values for the years 1973-1978, to the earlier years. When the regressions were run on this hypothetical data, however, none of the effects were particular strengthened. In any case, there are only 16 of those "missing" observations, and they represent the experience of only the earliest and smallest plants (only Robinson 2 and Palisades, which both entered commercial operation in 1972, are larger than 600 MW).

Second, the second unit of the Farley nuclear plant was inadvertantly left out of the database. It has only been operating since 1981, and would not be expected to change the results.

Finally, the DER of Sequoyah 1 is incorrectly entered in this analysis as 1128 MW. The DER is actually 1148, which means that the capacity factors for Sequoyah 1 are calculated to be slightly lower than the true capacity factors.

6. Regressions on Reduced Dataset

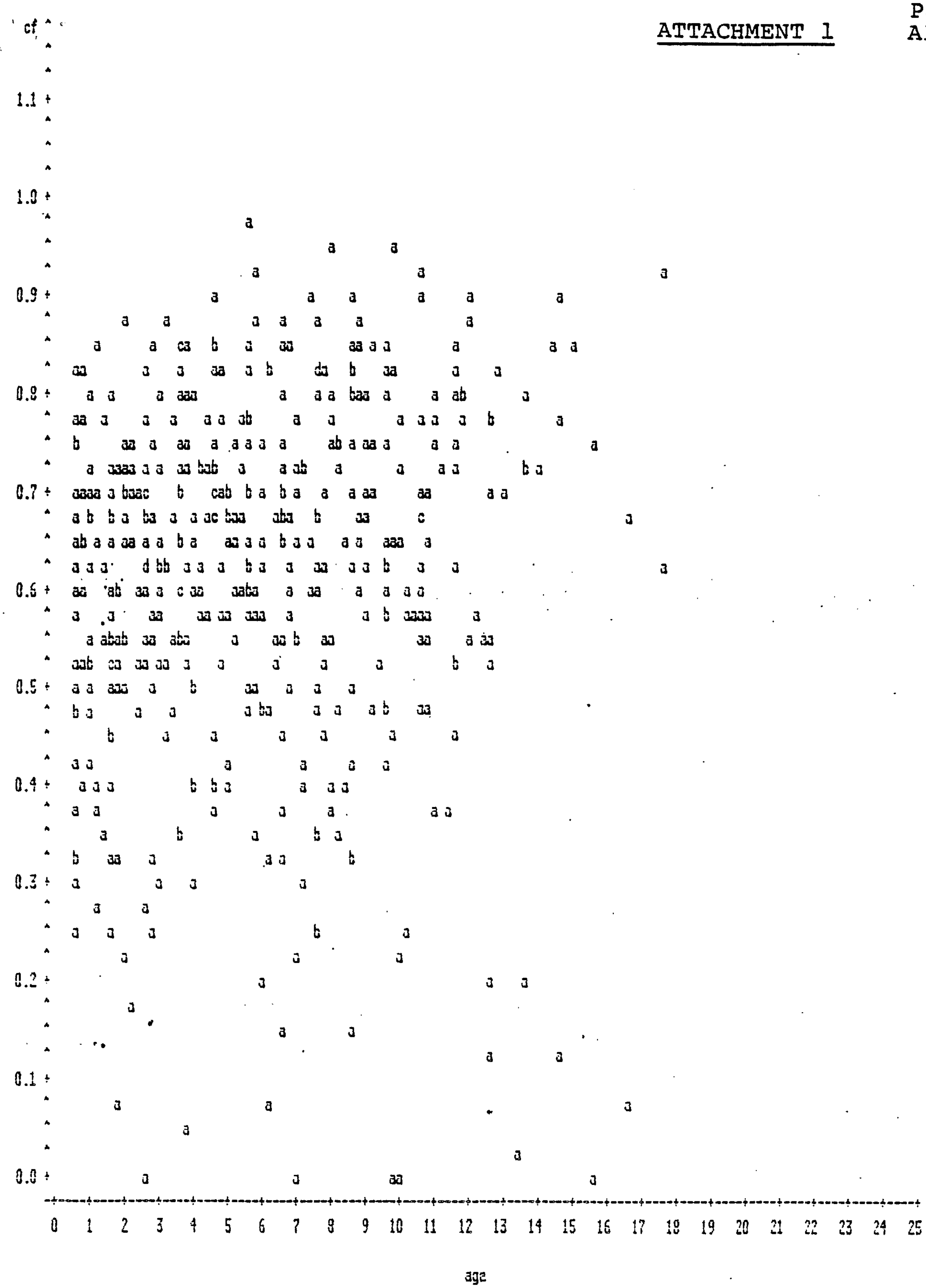
32 observations were deleted from the database in order to test a couple of hypotheses of particular interest to Palo Verde. First, San Onofre 1 was deleted, because it is a unit which has performed extremely poorly since its twelfth year in operation. Second, Palisades was deleted, because it is the only Combustion Engineering plant which has had particularly low capacity factors.

After running various regressions on this dataset, beginning with Equation 1, the preferred composition of the equation changed. Once San Onofre is removed, the AGE_12 variable loses its significance (Attachment 3, page 18), and is taken out. When Palisades is removed, the dummy variable CE is added to the equation and found to be significant (Attachment 3, page 19). Combustion Engineering units have generally had good experience, with the exception of Palisades, which is unusual in several respects. Palo Verde is a Combustion Engineering plant, so a positive coefficient on the CE variable increases the capacity factors projected for Palo Verde.

Finally, during the course of these changes, the W44 variable loses significance and is removed. The best results from this reduced dataset (Attachment 3, page 23) are reported as Equation 2 in Attachment 5, and projections from that equation are calculated in Table 3.

plot of cf*age   legend: a = 1 obs, b = 2 obs, etc.

ATTACHMENT 1   Page 1
All data



plot of cf*year   legend: a = 1 obs, b = 2 obs, etc.

cf

year

All data

sas 16:37 thursday, april 3, 1986 3

plot of cf*mw legend: a = 1 obs, b = 2 obs, etc.

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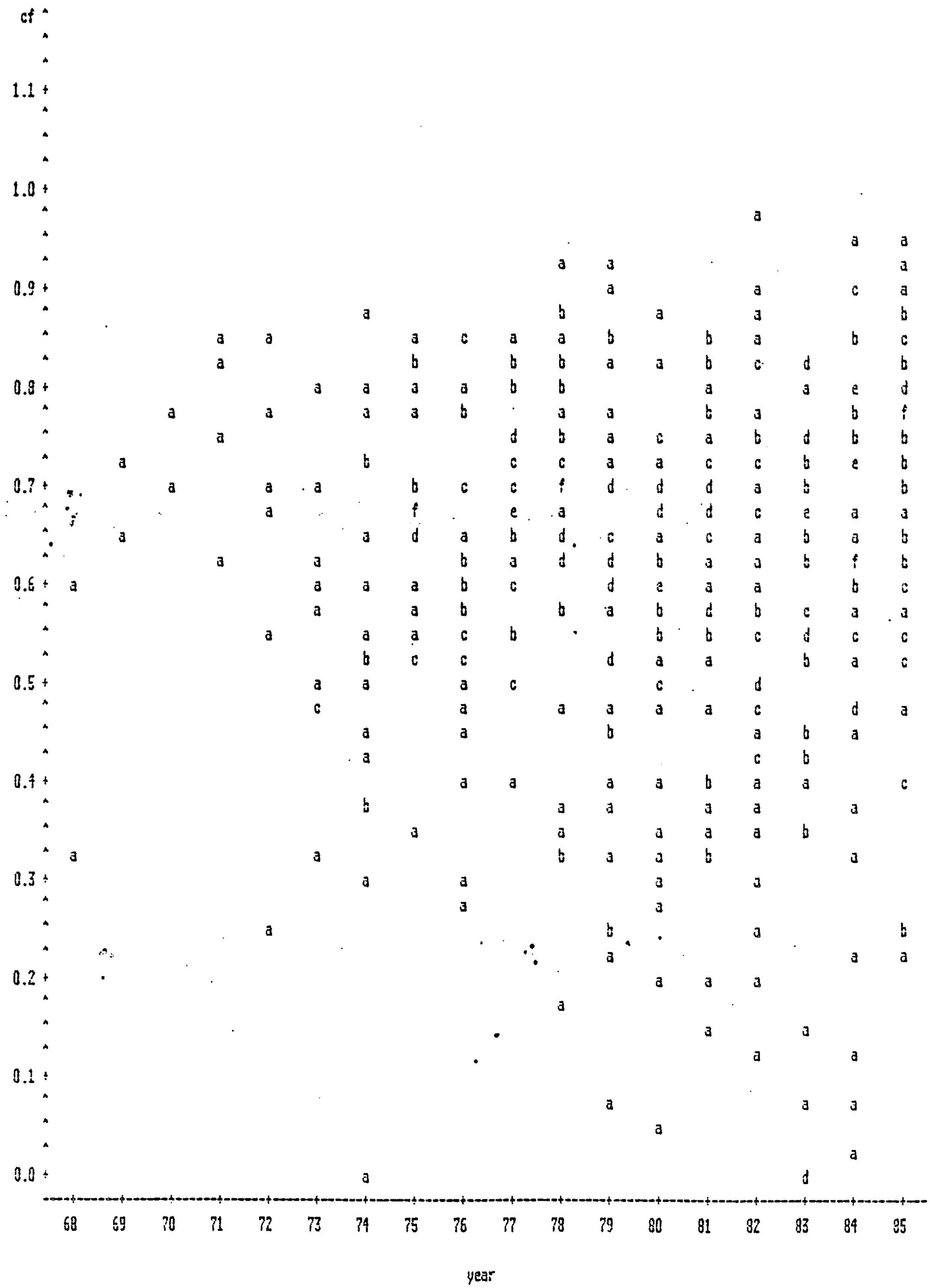
All data

plot of cf*year legend: a = 1 obs, b = 2 obs, etc.



plot of cf*mw legend: a = 1 obs, b = 2 obs, etc.

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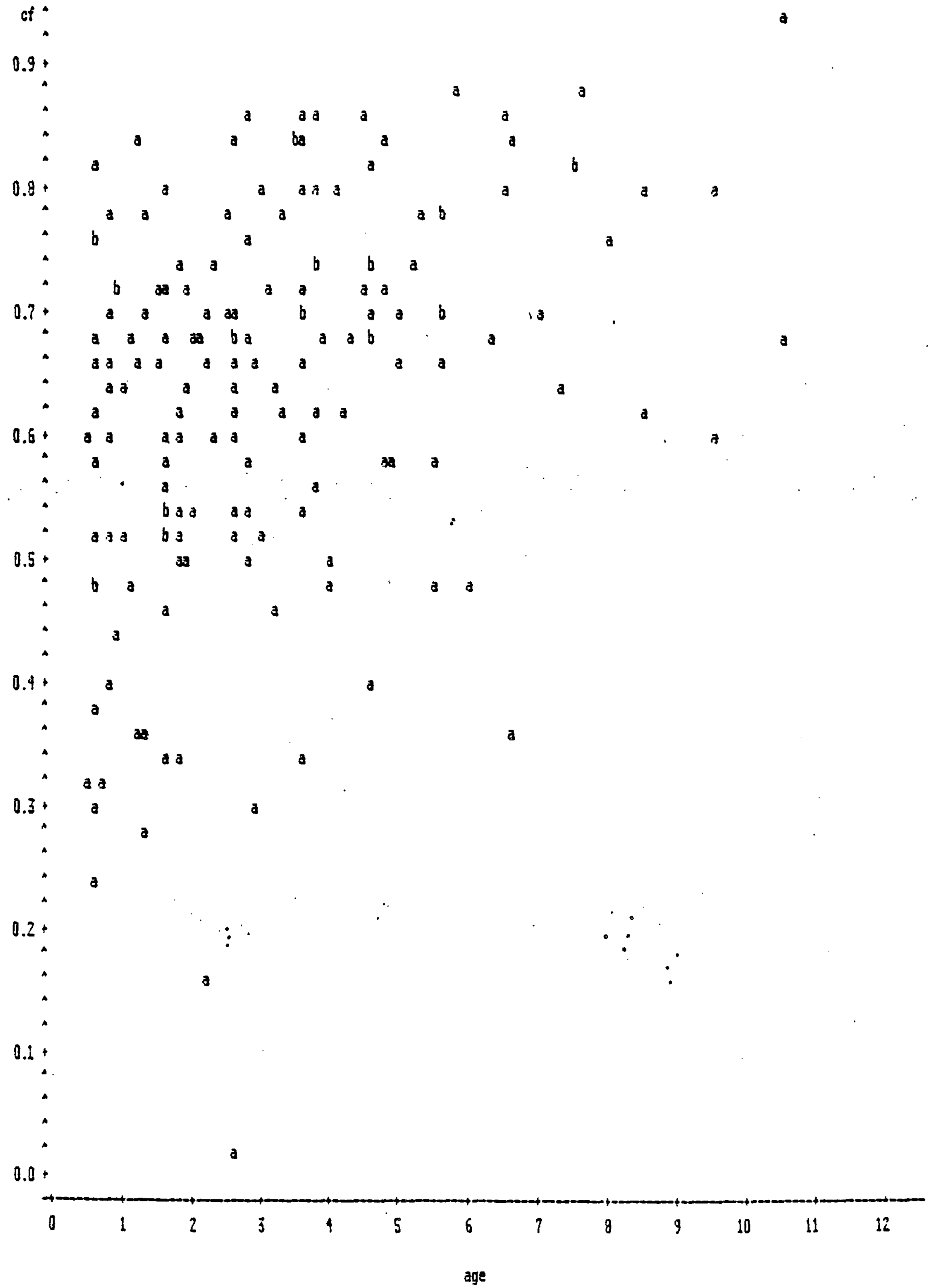
Pre-1979

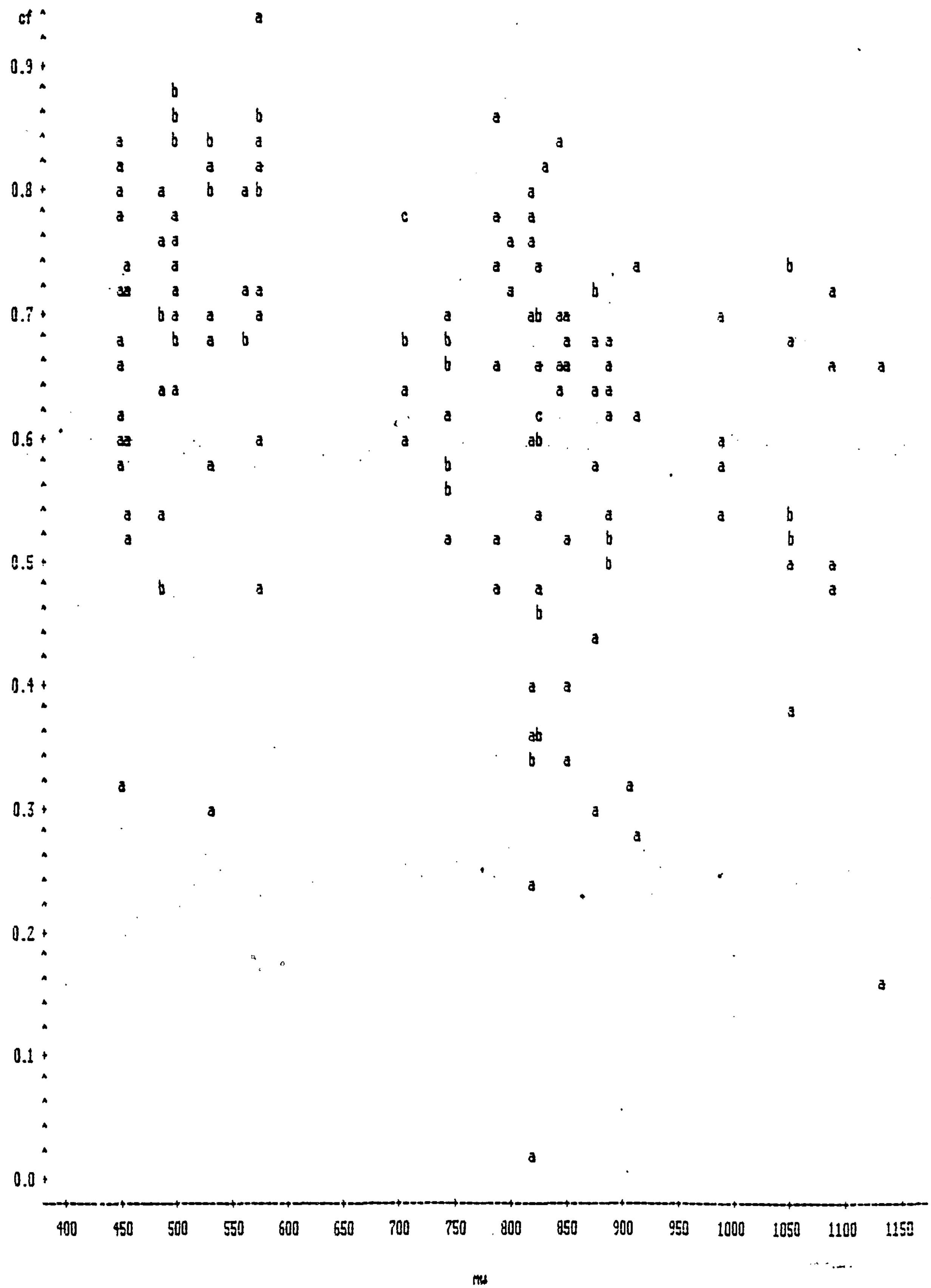
plot of cf*age legend: a = 1 obs, b = 2 obs, etc.



Pre-1979

note: 16 obs had missing values

plot of cf*mu legend: a = 1 obs, b = 2 obs, etc.



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10 11 12

age

Pre-1979

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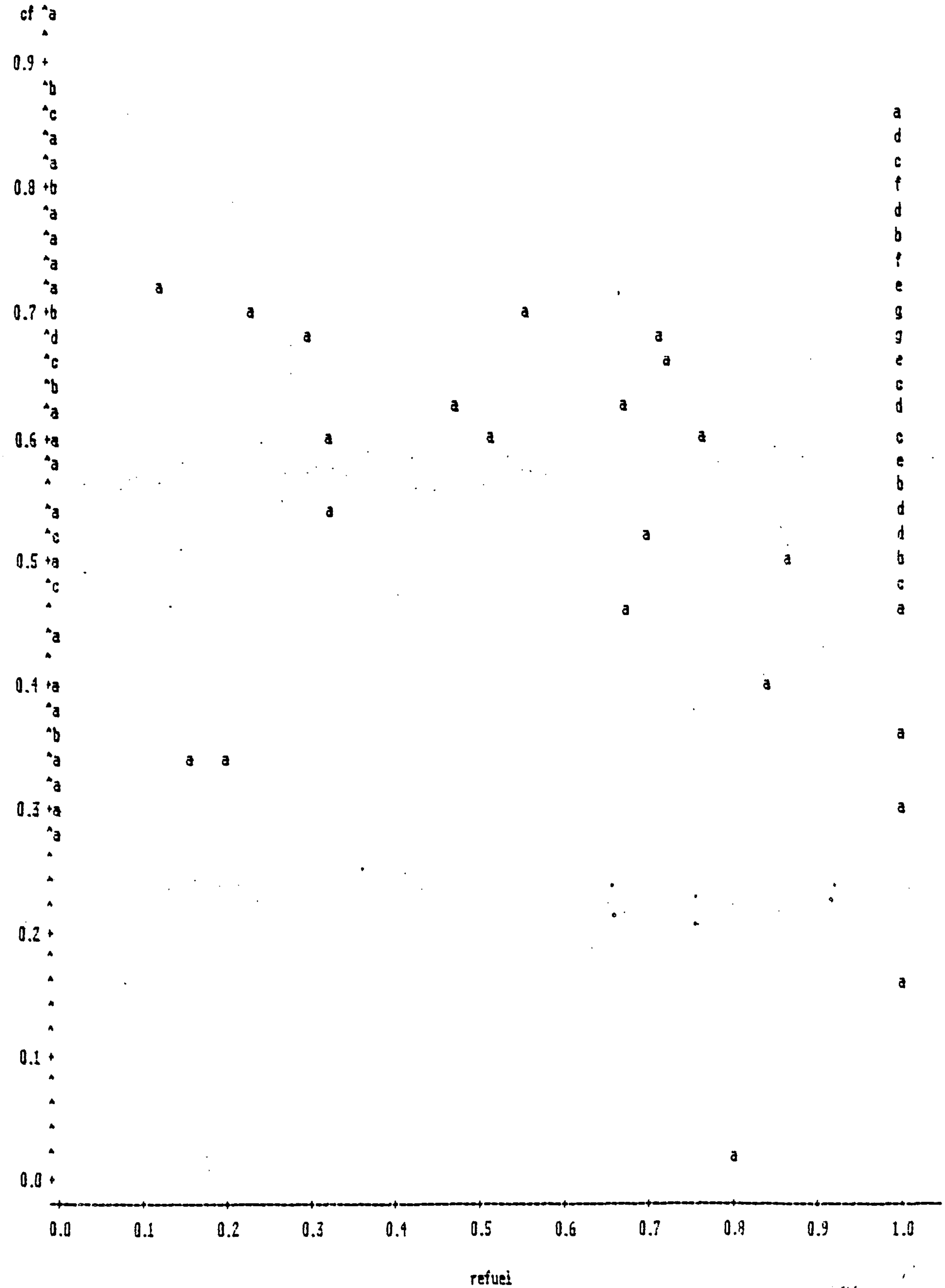

note: 16 obs had missing values

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Pre-1979

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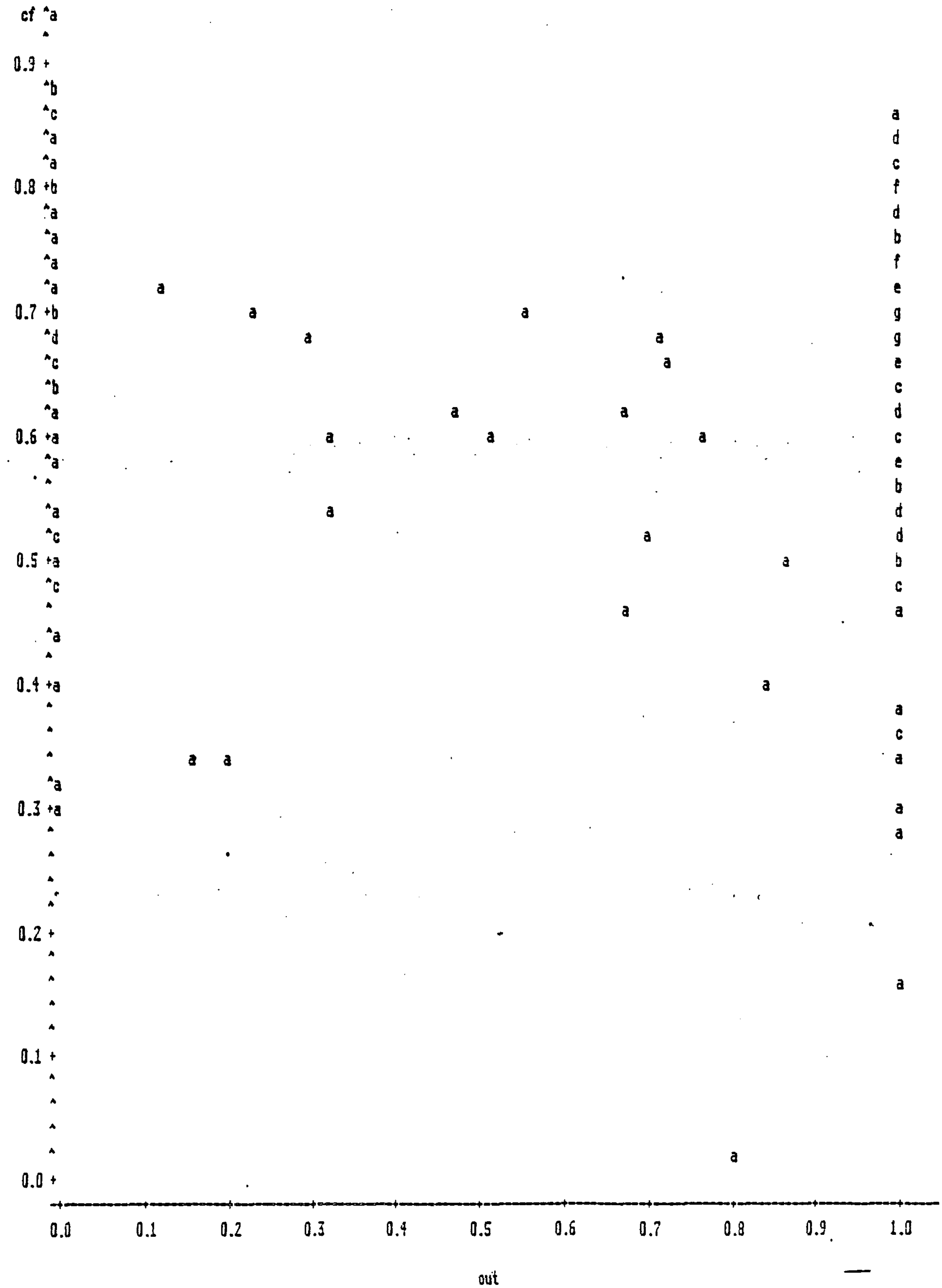
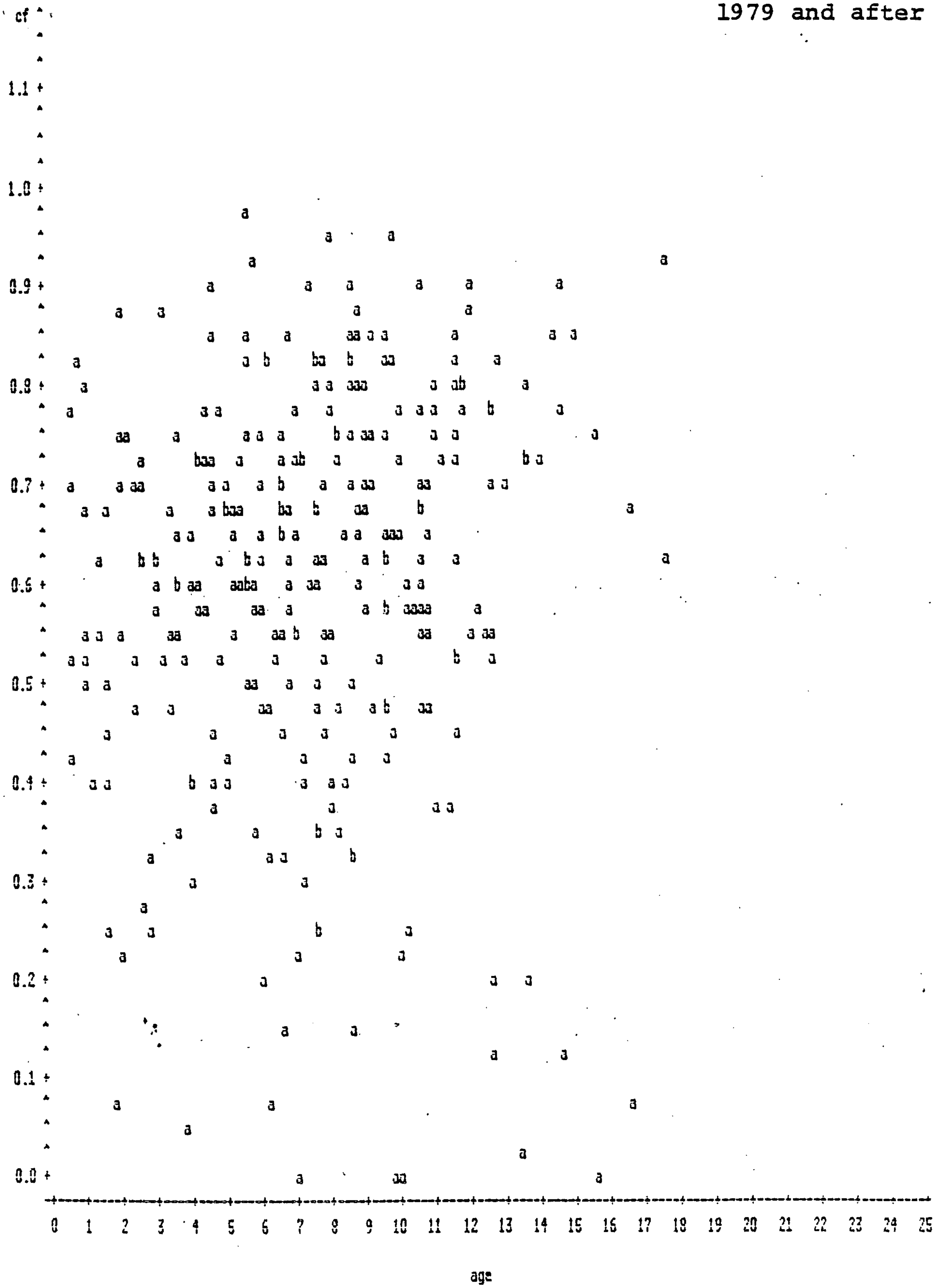


note: 16 obs had missing values

plot of cf*age   legend: a = 1 obs, b = 2 obs, etc.

1979 and after



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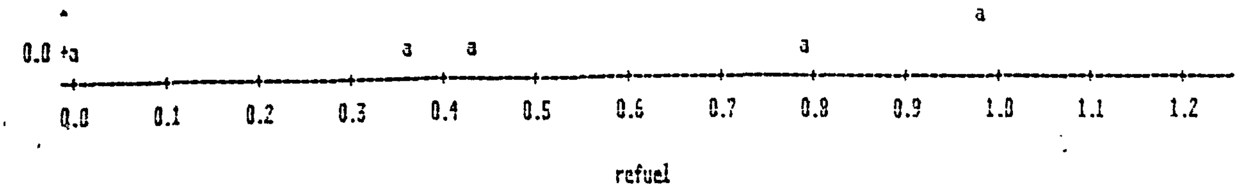
cf



1979 and after

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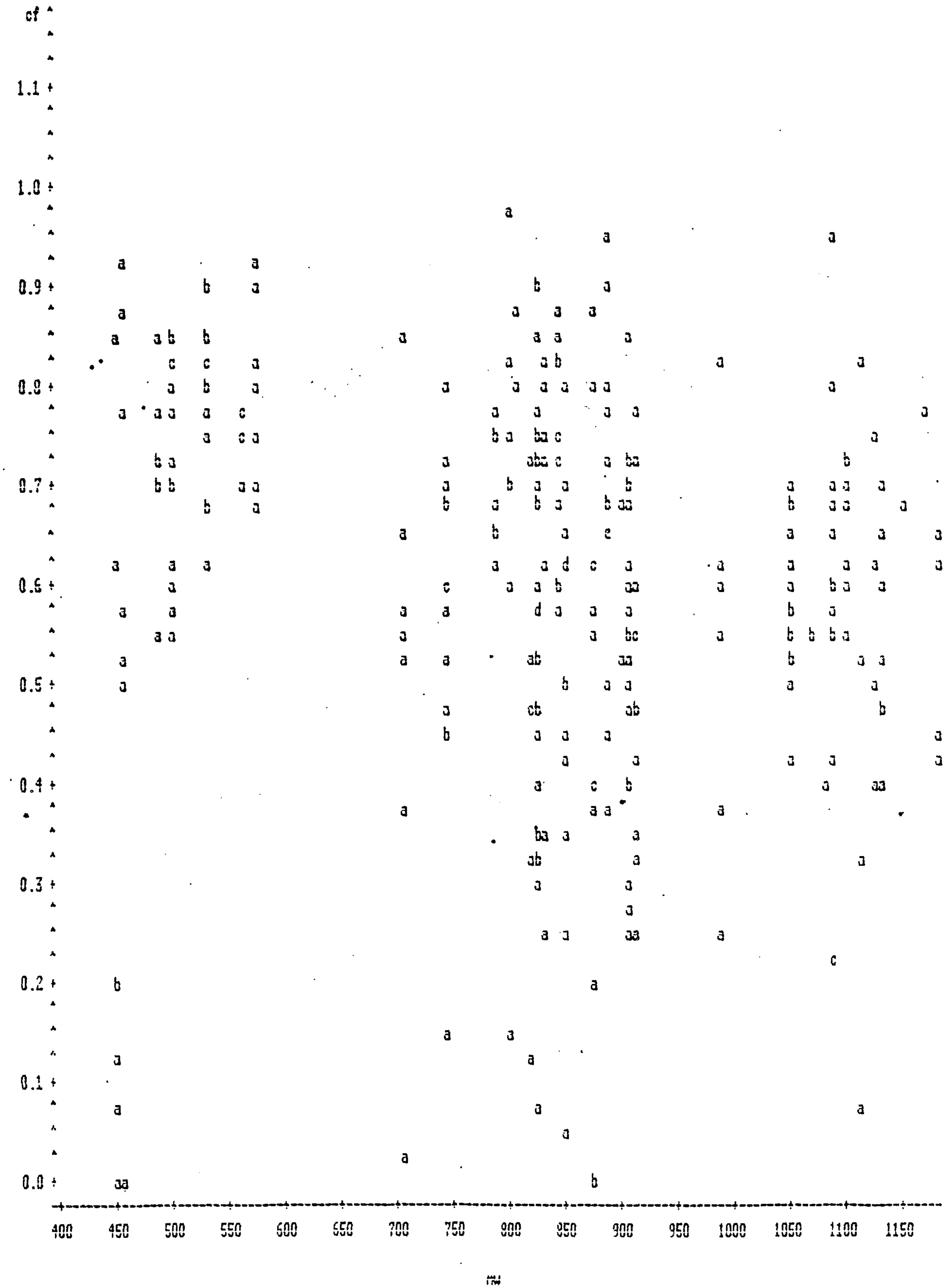
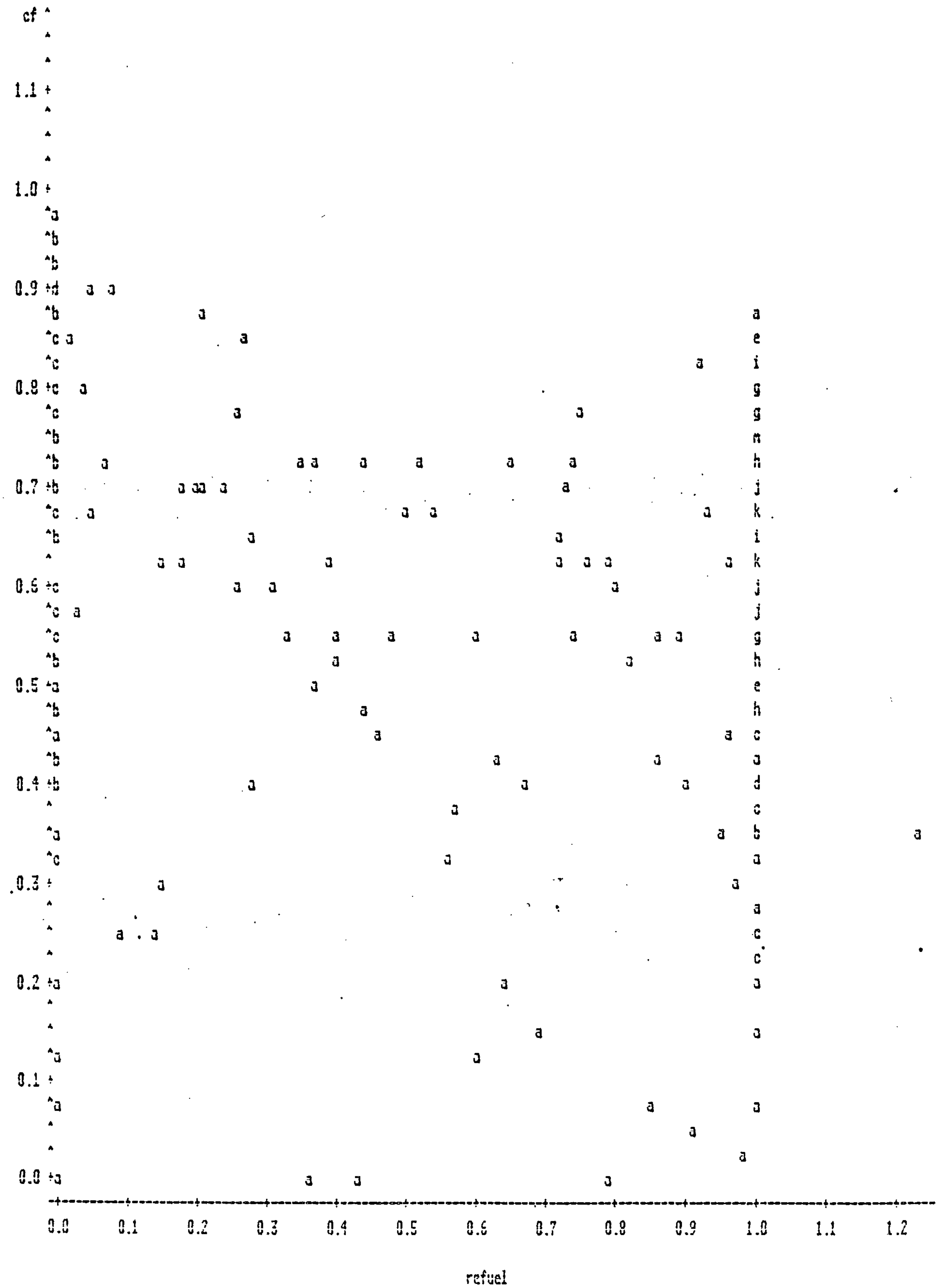


age

1979 and after

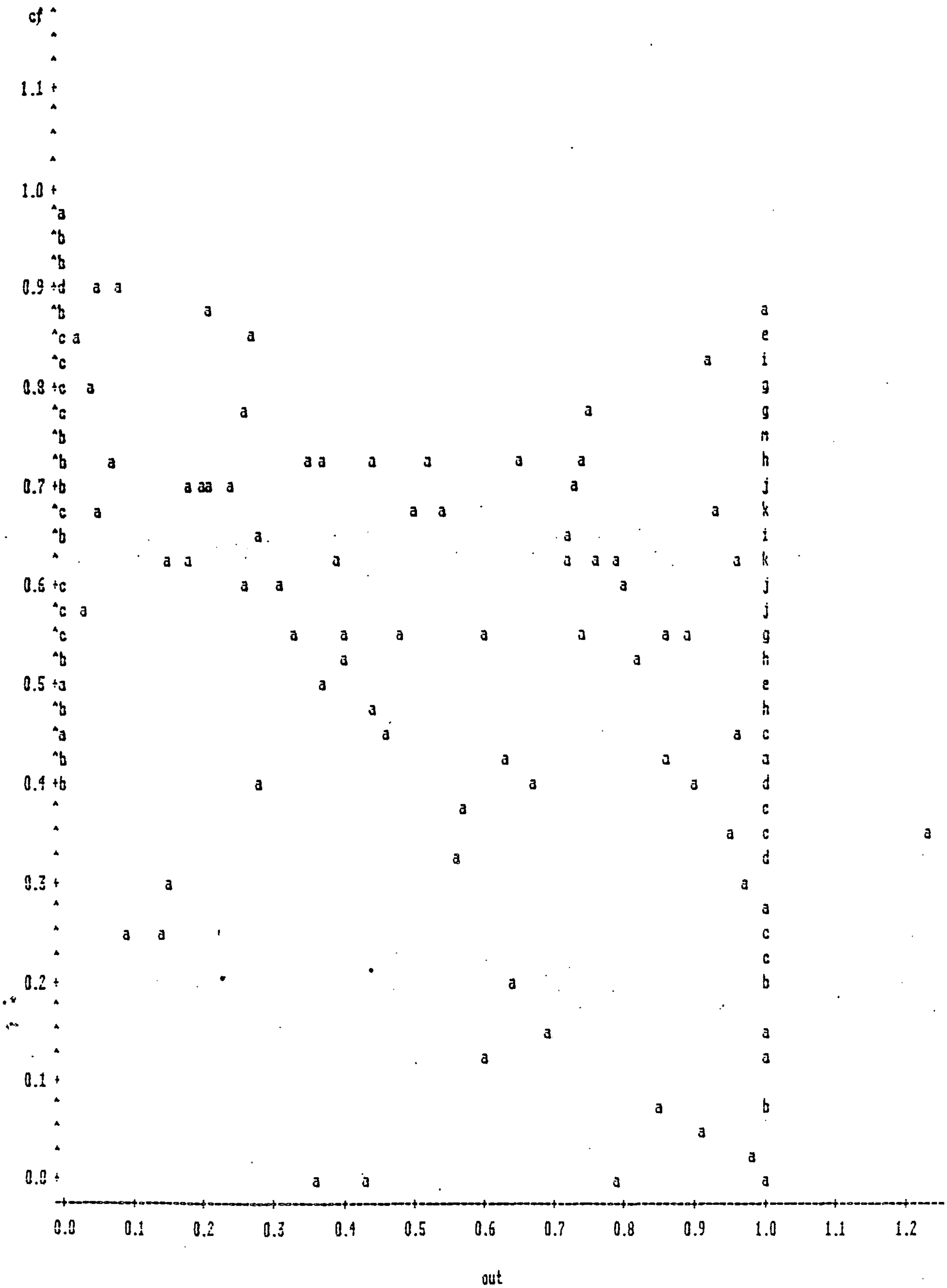
plot of cf*refuel legend: a = 1 obs, b = 2 obs, etc.



aft79=1

1979 and after

plot of cf*out legend: a = 1 obs, b = 2 obs, etc.



note: the procedure plot used 0.09 seconds and 554k and printed pages 4 to 5.
note: sas used 1466k memory.

note: sas institute inc.
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474 proc corr; var cf age mw u40 u44 bw ce year out;

'sas 11:40 friday, april 4, 1986 1

variable	n	mean	std dev	sum	minimum	maximum
cf	461	0.6108	0.1967	281.6	-0.0030	0.966
age	461	5.9261	3.7594	2731.9	0.5000	17.500
mw	461	790.0304	201.3740	364204.0	450.0000	1180.000
u40	460	0.2239	0.4173	103.0	0.0000	1.000
u44	460	0.5370	0.4992	247.0	0.0000	1.000
bw	461	0.1627	0.3695	75.0	0.0000	1.000
ce	461	0.1966	0.3900	86.0	0.0000	1.000
year	461	79.8265	3.7856	36800.0	68.0000	85.000
out	445	0.6919	0.4241	307.9	0.0000	1.234

pearson correlation coefficients / prob > ^r^ under h0:rho=0 / number of observations

	cf	age	mw	u40	u44	bw	ce	year	out
cf	1.00000	0.06400	-0.25890	0.25998	-0.20454	-0.09754	0.02737	-0.01716	-0.15539
	0.0000	0.1701	0.0001	0.0001	0.0001	0.0363	0.5579	0.7133	0.0010
	461	461	461	460	460	461	461	461	445
age	0.06400	1.00000	-0.28426	0.15453	-0.02966	-0.06377	-0.05742	0.62153	0.09078
	0.1701	0.0000	0.0001	0.0009	0.5257	0.1717	0.2185	0.0001	0.0557
	461	461	461	460	460	461	461	461	445
mw	-0.25890	-0.28426	1.00000	-0.69687	0.32178	0.21842	-0.01657	0.29734	-0.11502
	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.7227	0.0001	0.0152
	461	461	461	460	460	461	461	461	445
u40	0.25998	0.15453	-0.69687	1.00000	-0.57842	-0.23707	-0.15057	-0.15360	0.15233
	0.0001	0.0009	0.0001	0.0000	0.0001	0.0001	0.0012	0.0009	0.0013
	460	460	460	460	460	460	460	460	444
u44	-0.20454	-0.02966	0.32178	-0.57842	1.00000	-0.13303	-0.03554	0.04560	-0.11025
	0.0001	0.5257	0.0001	0.0001	0.0000	0.0043	0.4470	0.3291	0.0201
	460	460	460	460	460	460	460	460	444
bw	-0.09754	-0.06377	0.21842	-0.23707	-0.13303	1.00000	-0.21109	0.03422	-0.04090
	0.0363	0.1717	0.0001	0.0001	0.0043	0.0000	0.0001	0.4636	0.3894
	461	461	461	460	460	461	461	461	445
ce	0.02737	-0.05742	-0.01657	-0.15057	-0.03554	-0.21109	1.00000	0.06469	-0.01371
	0.5579	0.2185	0.7227	0.0012	0.4470	0.0001	0.0000	0.1656	0.7731
	461	461	461	460	460	461	461	461	445
year	-0.01716	0.62153	0.29734	-0.15360	0.04560	0.03422	0.06469	1.00000	0.05563
	0.7133	0.0001	0.0001	0.0009	0.3291	0.4636	0.1656	0.0000	0.2415
	461	461	461	460	460	461	461	461	445
out	-0.15539	0.09078	-0.11502	0.15233	-0.11025	-0.04090	-0.01371	0.05563	1.00000
	0.0010	0.0557	0.0152	0.0013	0.0201	0.3894	0.7731	0.2415	0.0000
	445	445	445	444	444	445	445	445	445

note: the procedure corr used 0.10 seconds and 554k and printed page 1.

475 proc reg; model cf=age mw;

476 * Simple Regression #1;

pearson correlation coefficients / prob > ^r^ under h0:rho=0 / number of observations

	cf	aft78	age5	age_12	out	nw600	u44	if79	if80	if81	if82	if83	if84
cf	1.00000	-0.09357	0.10844	-0.03896	-0.15539	-0.29027	-0.20454	-0.04813	-0.06496	-0.00870	-0.04724	-0.11658	0.01507
	0.0000	0.0447	0.0199	0.4039	0.0010	0.0001	0.0001	0.3024	0.1638	0.8521	0.3115	0.0122	0.7469
	461	461	461	461	445	461	460	461	461	461	461	461	461
aft78	-0.09357	1.00000	0.51617	0.19605	0.03590	0.17869	0.04607	0.22272	0.22272	0.22905	0.23834	0.24139	0.24740
	0.0447	0.0000	0.0001	0.0001	0.4500	0.0001	0.3242	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	461	461	461	461	445	461	460	461	461	461	461	461	461
age5	0.10844	0.51617	1.00000	0.19396	0.17420	-0.11458	-0.01922	0.02697	0.11167	0.13700	0.13134	0.15218	0.14187
	0.0199	0.0001	0.0000	0.0001	0.0002	0.0138	0.6810	0.5635	0.0165	0.0032	0.0047	0.0010	0.0023
	461	461	461	461	445	461	460	461	461	461	461	461	461
age_12	-0.03896	0.19605	0.19396	1.00000	0.00968	-0.23473	-0.01958	-0.07908	-0.01512	-0.01984	0.00610	0.06395	0.08822
	0.4039	0.0001	0.0001	0.0000	0.8387	0.0001	0.6754	0.0899	0.7461	0.6866	0.8961	0.1705	0.0584
	461	461	461	461	445	461	460	461	461	461	461	461	461
out	-0.15539	0.03590	0.17420	0.00968	1.00000	-0.14880	-0.11025	0.01120	0.01171	0.06508	-0.06011	0.05482	-0.00447
	0.0010	0.4500	0.0002	0.8387	0.0000	0.0016	0.0201	0.8138	0.8055	0.1705	0.2056	0.2485	0.9250
	445	445	445	445	445	445	444	445	445	445	445	445	445
nw600	-0.29027	0.17869	-0.11458	-0.23473	-0.14880	1.00000	0.48139	0.02313	0.02313	0.03200	0.04462	0.04867	0.05654
	0.0001	0.0001	0.0138	0.0001	0.0016	0.0000	0.0001	0.6204	0.6204	0.4931	0.3391	0.2971	0.2256
	461	461	461	461	445	461	460	461	461	461	461	461	461
u44	-0.20454	0.04607	-0.01922	-0.01958	-0.11025	0.48139	1.00000	-0.00640	-0.00640	0.00807	0.02862	0.02862	0.01889
	0.0001	0.3242	0.6810	0.6754	0.0201	0.0001	0.0000	0.8911	0.8911	0.8629	0.5404	0.5404	0.6861
	460	460	460	460	444	460	460	460	460	460	460	460	460
if79	-0.04813	0.22272	0.02697	-0.07908	0.01120	0.02313	-0.00640	1.00000	-0.08983	-0.09239	-0.09613	-0.09736	-0.09979
	0.3024	0.0001	0.5635	0.0899	0.8138	0.6204	0.8911	0.0000	0.0539	0.0474	0.0391	0.0366	0.0322
	461	461	461	461	445	461	460	461	461	461	461	461	461
if80	-0.06496	0.22272	0.11167	-0.01512	0.01171	0.02313	-0.00640	-0.08983	1.00000	-0.09239	-0.09613	-0.09736	-0.09979
	0.1638	0.0001	0.0165	0.7461	0.8055	0.6204	0.8911	0.0539	0.0000	0.0474	0.0391	0.0366	0.0322
	461	461	461	461	445	461	460	461	461	461	461	461	461
if81	-0.00870	0.22905	0.13700	-0.01984	0.06508	0.03200	0.00807	-0.09239	-0.09239	1.00000	-0.09886	-0.10013	-0.10262
	0.8521	0.0001	0.0032	0.6866	0.1705	0.4931	0.8629	0.0474	0.0474	0.0000	0.0338	0.0316	0.0276
	461	461	461	461	445	461	460	461	461	461	461	461	461
if82	-0.04724	0.23834	0.13134	0.00610	-0.06011	0.04462	0.02862	-0.09613	-0.09613	-0.09886	1.00000	-0.10418	-0.10678
	0.3115	0.0001	0.0047	0.8961	0.2056	0.3391	0.5404	0.0391	0.0391	0.0338	0.0000	0.0253	0.0218
	461	461	461	461	445	461	460	461	461	461	461	461	461
if83	-0.11658	0.24139	0.15218	0.06395	0.05482	0.04867	0.02862	-0.09736	-0.09736	-0.10013	-0.10418	1.00000	-0.10815
	0.0122	0.0001	0.0010	0.1705	0.2485	0.2971	0.5404	0.0366	0.0366	0.0316	0.0253	0.0000	0.0202
	461	461	461	461	445	461	460	461	461	461	461	461	461
if84	0.01507	0.24740	0.14187	0.08822	-0.00447	0.05654	0.01889	-0.09979	-0.09979	-0.10262	-0.10678	-0.10815	1.00000
	0.7469	0.0001	0.0023	0.0584	0.9250	0.2256	0.6861	0.0322	0.0322	0.0276	0.0218	0.0202	0.0000
	461	461	461	461	445	461	460	461	461	461	461	461	461

note: the procedure corr used 0.11 seconds and 554k and printed pages 1 to 2.

478 proc plot; plot cf*out;

ATTACHMENT 3

Regression Results for

PWR Capacity Factor Analysis

476 * Simple Regression #1;

Page 1

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	2	1.07630263	0.53815131	16.479	0.0001
error	458	14.95652681	0.03265617		
c total	460	16.03282944			

root mse	0.1807102	r-square	0.0671
dep mean	0.6108416	adj r-sq	0.0631
c.v.	29.5838		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.80571440	0.04150917	19.411	0.0001
age	1	-0.000518232	0.002337650	-0.222	0.8247
mw	1	-0.000242778	0.000043641	-5.563	0.0001

note: the procedure reg used 0.07 seconds and 768k and printed page 2.

477 proc reg; model cf=age5 mw;
478 * Simple Regression #2;

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	2	1.14529159	0.57264580	17.617	0.0001
error	458	14.88753785	0.03250554		
c total	460	16.03282944			

root mse	0.1802929	r-square	0.0714
dep mean	0.6108416	adj r-sq	0.0674
c.v.	29.51549		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.75986404	0.04379761	17.353	0.0001
age5	1	0.008328818	0.005651692	1.474	0.1413
mw	1	-0.000229664	0.000042332	-5.425	0.0001

note: the procedure reg used 0.07 seconds and 768k and printed page 3.

479 proc reg; model cf=age5 mw aft78;
480 * PWR Regression with dummy for 1979 and after;

source	df	sum of squares	mean square	f value	prob>f
model	3	1.27494310	0.42498103	13.160	0.0001
error	457	14.75788634	0.03229297		
c total	460	16.03282944			

root mse	0.1797024	r-square	0.0795
dep mean	0.6108416	adj r-sq	0.0735
c.v.	29.41883		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.73031891	0.04606788	15.853	0.0001
age5	1	0.01631341	0.006900159	2.364	0.0185
mw	1	-0.000195654	0.000045480	-4.302	0.0001
aft78	1	-0.04408491	0.02200165	-2.004	0.0457

note: the procedure reg used 0.07 seconds and 768k and printed page 4.

481 proc reg; model cf=age5 mw if79 if80 if81 if82 if83 if84;
482 * PWR Regression with year dummies;

sas 11:40 friday, april 4, 1986 5

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	8	1.71330866	0.21416358	6.760	0.0001
error	452	14.31952078	0.03168036		
c total	460	16.03282944			

root mse	0.1779898	r-square	0.1069
dep mean	0.6108416	adj r-sq	0.0911
c.v.	29.13845		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72615886	0.04444787	16.337	0.0001
age5	1	0.01840577	0.006266763	2.937	0.0035
mw	1	-0.000190063	0.000043325	-4.387	0.0001
if79	1	-0.06707421	0.03189641	-2.103	0.0360
if80	1	-0.08538531	0.03246500	-2.630	0.0088
if81	1	-0.05167367	0.03201469	-1.614	0.1072
if82	1	-0.06800086	0.03121875	-2.178	0.0299
if83	1	-0.10772701	0.03117024	-3.456	0.0006
if84	1	-0.03139023	0.03053382	-1.028	0.3046

note: the procedure reg used 0.08 seconds and 768k and printed page 5.

483 proc reg; model cf=age5 w40 w44 bw ce mw aft78 out;
484 * PWR Regression with the works!;

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	3	1.12558081	0.37519360	11.481	0.0001
error	441	14.41223774	0.03268081		
c total	444	15.53781855			

root mse	0.1807783	r-square	0.0724
dep mean	0.6089258	adj r-sq	0.0661
c.v.	29.68807		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.59769219	0.02669007	22.394	0.0001
aft78	1	-0.07732379	0.02092970	-3.694	0.0002
age5	1	0.03052096	0.006815964	4.478	0.0001
out	1	-0.08387789	0.02057770	-4.076	0.0001

note: the procedure reg used 0.08 seconds and 768k and printed page 1.

```
477        proc reg; model cf=aft78 age7 out;
```


dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	3	1.01091233	0.33697078	10.230	0.0001
error	441	14.52690622	0.03294083		
c total	444	15.53781855			

root mse	0.1814961	r-square	0.0651
dep mean	0.6089258	adj r-sq	0.0587
c.v.	29.80594		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.62408152	0.02395184	26.056	0.0001
aft78	1	-0.07883943	0.02174973	-3.625	0.0003
age7	1	0.01870108	0.004616220	4.051	0.0001
out	1	-0.07855791	0.02051140	-3.830	0.0001

note: the procedure reg used 0.07 seconds and 768k and printed page 2.

```
478        proc reg; model cf=aft78 age9 out;
479
```

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	3	0.97935115	0.32645038	9.889	0.0001
error	441	14.55846740	0.03301240		
c total	444	15.53781855			

root mse	0.1816931	r-square	0.0630
dep mean	0.6089258	adj r-sq	0.0567
c.v.	29.8383		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.63591884	0.02267773	28.042	0.0001
aft78	1	-0.07805142	0.02186046	-3.570	0.0004
age9	1	0.01411208	0.003593719	3.927	0.0001
out	1	-0.07635002	0.02047446	-3.729	0.0002

note: the procedure reg used 0.07 seconds and 768k and printed page 3.

480 proc reg; model cf=aft78 age5 out w40 w44;

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	5	2.31111879	0.46222376	15.310	0.0001
error	438	13.22354837	0.03019075		
c total	443	15.53466716			

root mse	0.1737549	r-square	0.1488
dep mean	0.6087995	adj r-sq	0.1391
c.v.	28.54057		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.62144093	0.02881707	21.565	0.0001
aft78	1	-0.06202135	0.02049648	-3.026	0.0026
age5	1	0.02565436	0.006734791	3.809	0.0002
out	1	-0.10114299	0.01997932	-5.062	0.0001
w40	1	0.09189799	0.02506311	3.666	0.0003
w44	1	-0.04182441	0.02006919	-2.084	0.0377

note: the procedure reg used 0.08 seconds and 768k and printed page 4.

481 proc reg; model cf=aft78 age5 out w;

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	4	1.16547916	0.29136954	8.902	0.0001
error	439	14.36918900	0.03273164		
c total	443	15.53466716			

root mse	0.1809189	r-square	0.0750
dep mean	0.6087995	adj r-sq	0.0666
c.v.	29.71731		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.60011620	0.02978793	20.146	0.0001
aft78	1	-0.08014071	0.02112066	-3.794	0.0002
age5	1	0.03182196	0.006934547	4.589	0.0001
out	1	-0.08520758	0.02062797	-4.131	0.0001
u	1	-0.006949971	0.02004799	-0.347	0.7290

note: the procedure reg used 0.08 seconds and 768k and printed page 5.

```
482        proc reg; model cf=if79 if80 if81 if82 if83 if84 age5 out u40 u44;
483
```


dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	10	2.74126765	0.27412677	9.278	0.0001
error	433	12.79339951	0.02954596		
c total	443	15.53466716			

root mse	0.1718894	r-square	0.1765
dep mean	0.6087995	adj r-sq	0.1574
c.v.	28.23415		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.61935375	0.02858755	21.665	0.0001
if79	1	-0.07132371	0.03078928	-2.317	0.0210
if80	1	-0.09278826	0.03127563	-2.967	0.0032
if81	1	-0.05138326	0.03083386	-1.666	0.0963
if82	1	-0.08617138	0.02997857	-2.874	0.0042
if83	1	-0.11867727	0.03018828	-3.931	0.0001
if84	1	-0.04320723	0.02921481	-1.479	0.1399
age5	1	0.02597936	0.006255447	4.153	0.0001
out	1	-0.09974451	0.01983461	-5.029	0.0001
u40	1	0.09392386	0.02461103	3.816	0.0002
u44	1	-0.03989498	0.01984363	-2.010	0.0450

note: the procedure reg used 0.09 seconds and 768k and printed page 5.

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	6	2.35339095	0.39223183	13.004	0.0001
error	437	13.18127621	0.03016310		
c total	443	15.53466716			

root mse	0.1736753	r-square	0.1515
dep mean	0.6087995	adj r-sq	0.1398
c.v.	28.5275		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > *t*
intercep	1	0.69221165	0.06635858	10.431	0.0001
aft78	1	-0.05378946	0.02163501	-2.486	0.0133
age5	1	0.02290068	0.007122255	3.215	0.0014
out	1	-0.10058102	0.01997582	-5.035	0.0001
u40	1	0.06733059	0.03252536	2.070	0.0390
u44	1	-0.04438687	0.02017644	-2.200	0.0283
mw	1	-0.000074086	0.000062591	-1.184	0.2371

note: the procedure reg used 0.07 seconds and 768k and printed page 7.

485 proc reg; model cf=aft78 age5 out mw;

sas 16:34 thursday, april 3, 1986 8

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	4	1.76045603	0.44011401	14.056	0.0001
error	440	13.77736252	0.03131219		
c total	444	15.53781855			

root mse	0.1769525	r-square	0.1133
dep mean	0.6089258	adj r-sq	0.1052
c.v.	29.05978		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > *t*
intercep	1	0.79328022	0.05068783	15.650	0.0001
aft78	1	-0.04305267	0.02185485	-1.970	0.0495
age5	1	0.01870021	0.007169611	2.608	0.0094
out	1	-0.08940160	0.02017953	-4.430	0.0001
mw	1	-0.000210033	0.000046645	-4.503	0.0001

note: the procedure reg used 0.08 seconds and 768k and printed page 8.

2 sas(r) log os sas 5.08 vs2/mvs job ext73704 step 16:34 thursday, april 3, 1986

2 sas(r) log os sas 5.08 vs2/mvs job ext/3704 step 16:34 thursday, april 3, 1986

```
486        proc reg; model cf=if79 if80 if81 if82 if83 if84 age5 out mu;
```

sas 16:34 thursday, april 3, 1986 9

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	9	2.17086654	0.24120739	7.850	0.0001
error	435	13.36695201	0.03072863		
c total	444	15.53781855			

root mse	0.1752958	r-square	0.1397
dep mean	0.6089259	adj r-sq	0.1219
c.v.	28.78771		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
mcc		[illegible]		-4.591	0.0001
intercep	1	0.78947130	0.04935741	15.995	0.0001
if79	1	-0.06460087	0.03149180	-2.052	0.0408
if80	1	-0.09376958	0.03202840	-2.615	0.0092
if81	1	-0.04393817	0.03160594	-1.390	0.1652
if82	1	-0.07437531	0.03086335	-2.410	0.0164
if83	1	-0.10112694	0.03076303	-3.287	0.0011
if84	1	-0.03133746	0.03012837	-1.040	0.2989
age5	1	0.02056596	0.006541122	3.144	0.0018
cct		[illegible]		-4.396	.0001

The end!

```
    root mse    0.1752958    r-square     0.1397
    dep mean    0.6089258    adj r-sq     0.1219
    c.v.         28.78771
```


parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.79947130	0.04935741	15.995	0.0001
if79	1	-0.06460087	0.03148180	-2.052	0.0408
if80	1	-0.09376858	0.03202840	-2.615	0.0092
if81	1	-0.04393817	0.03160594	-1.390	0.1652
if82	1	-0.07437531	0.03086335	-2.410	0.0164
if83	1	-0.10112694	0.03076303	-3.287	0.0011
if84	1	-0.03133746	0.03012837	-1.040	0.2989
age5	1	0.02056586	0.006541122	3.144	0.0018
out	1	-0.08824043	0.02007089	-4.396	0.0001
mw	1	-0.000205118	0.000044674	-4.591	0.0001

note: the procedure reg used 0.09 seconds and 768k and printed page 1.

```
475       proc reg; model cf=aft78 age5 out mw;
476         output out=two r=resid;
```


dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	4	1.76045603	0.44011401	14.056	0.0001
error	440	13.77736252	0.03131219		
c total	444	15.53781855			

```
    root mse    0.1769525    r-square     0.1133
    dep mean    0.6089258    adj r-sq     0.1052
    c.v.         29.05978
```

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.79328022	0.05068793	15.650	0.0001
aft78	1	-0.04305267	0.02185495	-1.970	0.0495
age5	1	0.01870021	0.007169611	2.608	0.0094
out	1	-0.08940160	0.02017953	-4.430	0.0001

note: the data set work.two has 461 observations and 23 variables. 101 obs/trk.

mw	1	-0.000210033	0.000046645	-4.503	0.0001

note: the procedure reg used 0.13 seconds and 769k and printed page 2.

```
477       proc sort; by w40 w44 year;
```

note: data set work.two has 461 observations and 23 variables. 101 obs/trk.
note: the procedure sort used 0.12 seconds and 1466k.

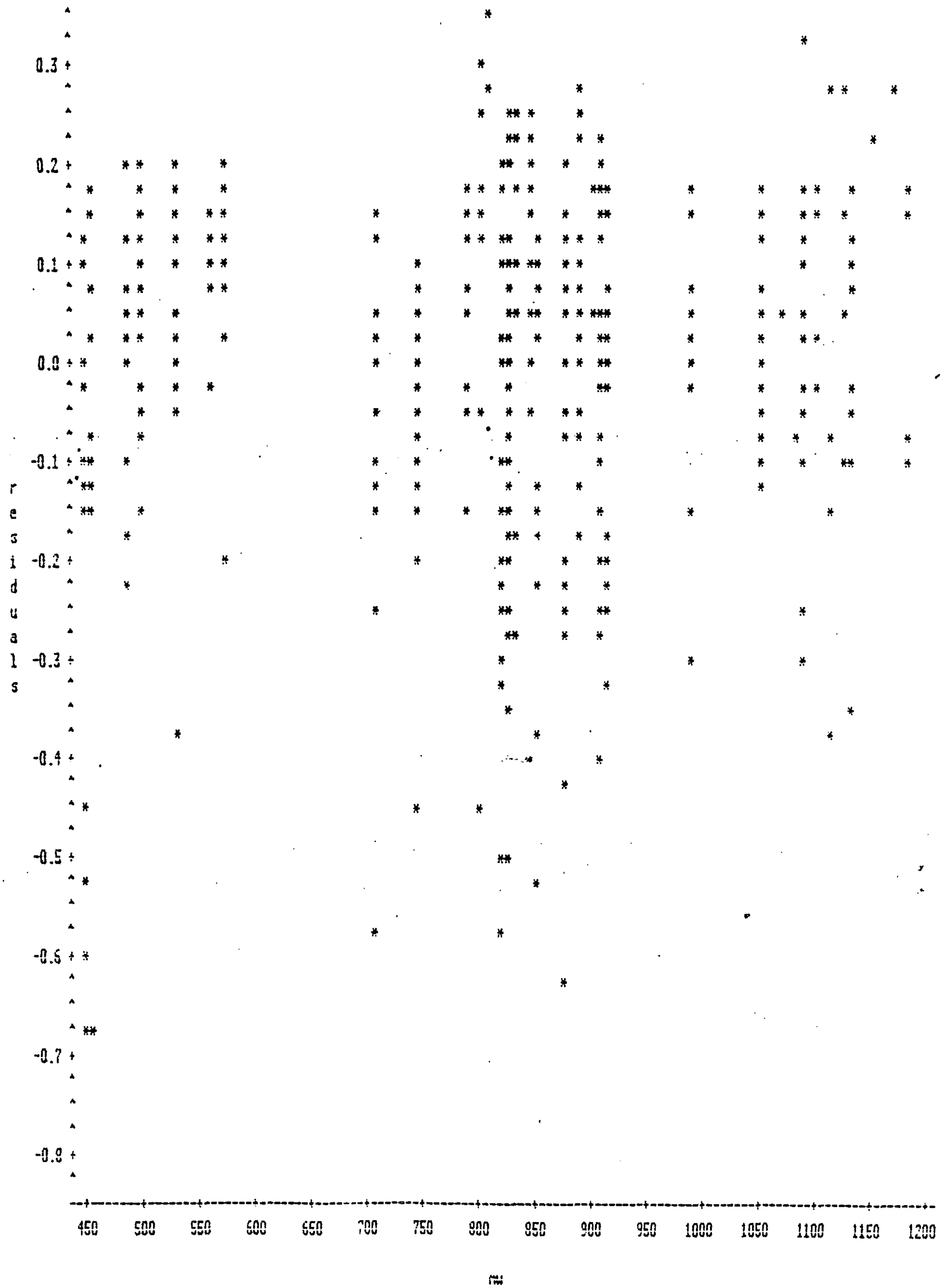
```
478       proc means; var resid; by w40 w44;
```

note: the procedure means used 0.07 seconds and 554K and printed page 3.

```
479        proc plot; plot resid*mw='  ' resid*age='*';
480
```


sas   17:13 thursday, april 3, 1986   4

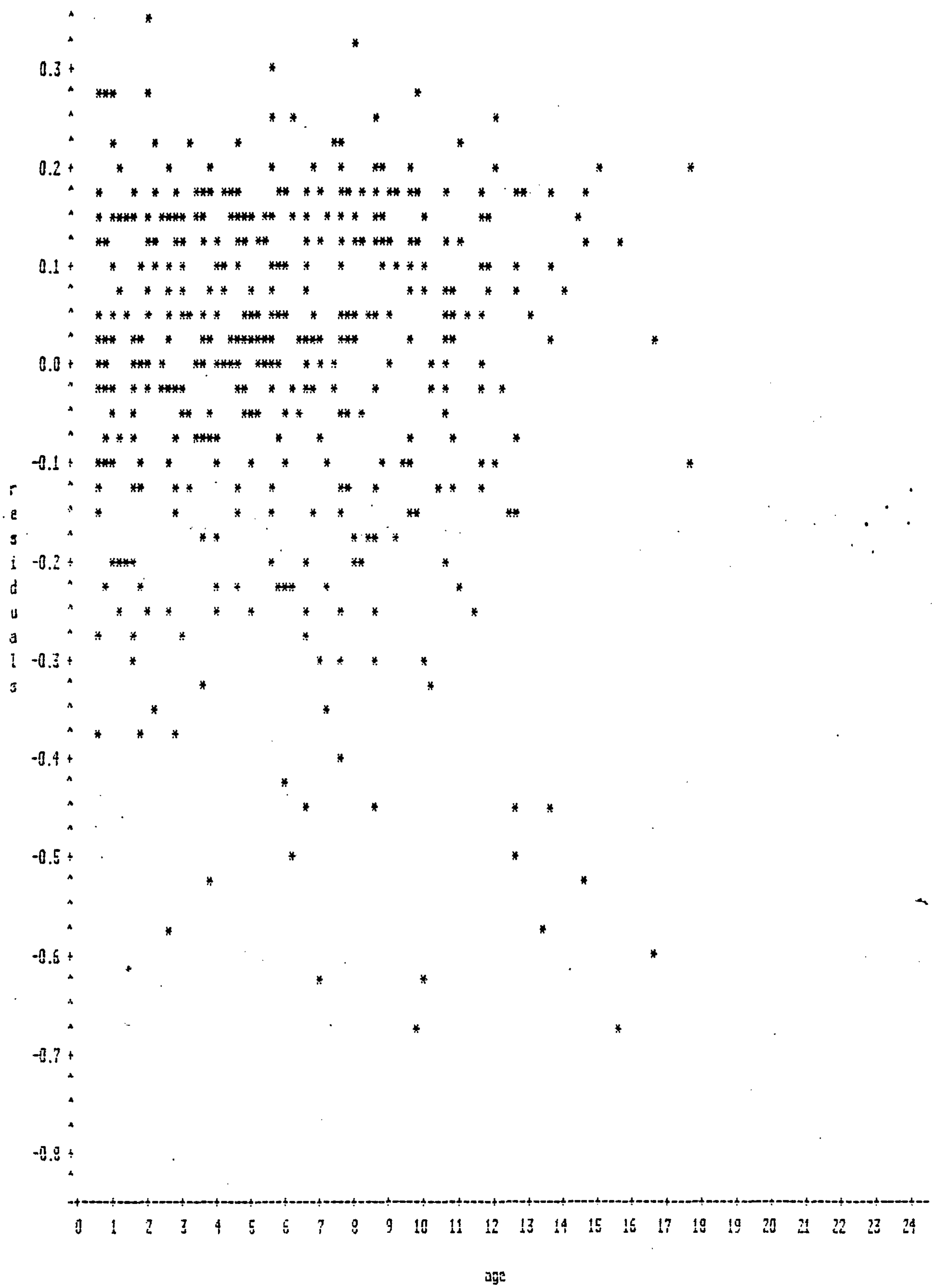
plot of resid*mw   symbol used is *



note: 16 obs had missing values   157 obs hidden

note: 16 obs had missing values 157 obs hidden

plot of resid*age symbol used is *



note: 16 obs had missing values 65 obs hidden
note: the procedure plot used 0.09 seconds and 554k and printed pages 4 to 5.

481 data three; set one;
482

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	5	2.17775762	0.43555152	14.373	0.0001
error	441	13.36344136	0.03030259		
c total	446	15.54119898			

root mse	0.1740754	r-square	0.1401
dep mean	0.6088747	adj r-sq	0.1304
c.v.	28.58995		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.71950177	0.03278632	21.945	0.0001
aft78	1	-0.04210059	0.02125225	-1.981	0.0482
age5	1	0.02050673	0.006835513	3.000	0.0029
out	1	-0.09648278	0.01988998	-4.851	0.0001
mw600	1	-0.12377868	0.02097422	-5.901	0.0001
age_10	1	-0.02352823	0.02473735	-0.951	0.3421

note: the procedure reg used 0.07 seconds and 758k and printed page 3.

487 proc reg; model cf=aft78 age5 out mw600 age_11;

sas 11:41 tuesday, april 8, 1986 4

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	5	2.18593089	0.43718618	14.436	0.0001
error	441	13.35526809	0.03028405		
c total	446	15.54119898			

root mse	0.1740231	r-square	0.1407
dep mean	0.6088747	adj r-sq	0.1309
c.v.	28.58111		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72114063	0.03288263	21.931	0.0001
aft78	1	-0.04169522	0.02119897	-1.967	0.0498
age5	1	0.02017858	0.006788137	2.973	0.0031
out	1	-0.09690027	0.01989916	-4.870	0.0001
mw600	1	-0.12483425	0.02104256	-5.932	0.0001
age_11	1	-0.03141027	0.02897605	-1.084	0.2790

note: the procedure reg used 0.08 seconds and 758k and printed page 4.

488 proc reg; model cf=aft78 age5 out mw600 age_12;

sas 11:41 tuesday, april 8, 1986 5

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	5	2.37601495	0.47520299	15.918	0.0001
error	441	13.16518403	0.02985303		
c total	446	15.54119898			

root mse	0.1727803	r-square	0.1529
dep mean	0.6088747	adj r-sq	0.1433
c.v.	28.37698		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72750412	0.03267628	22.264	0.0001
aft78	1	-0.03639306	0.02088791	-1.742	0.0822
age5	1	0.02039219	0.006725328	3.032	0.0026
out	1	-0.09814606	0.01973775	-4.973	0.0001
mu600	1	-0.13394480	0.02080402	-6.438	0.0001
age_12	1	-0.09573794	0.03482100	-2.749	0.0062

note: the procedure reg used 0.07 seconds and 760k and printed page 5.

2 sas(r) log os sas 5.08 vs2/mvs job ext73704 step 11:41 tuesday, april 8, 1986

489 proc reg; model cf=aft78 age5 out mu600 age_10 age_11 age_12;

sas 11:41 tuesday, april 8, 1986 6

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	7	2.43612053	0.34801722	11.658	0.0001
error	439	13.10507846	0.02985211		
c total	446	15.54119898			

root mse	0.1727776	r-square	0.1568
dep mean	0.6088747	adj r-sq	0.1433
c.v.	28.37655		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72593940	0.03269618	22.203	0.0001
aft78	1	-0.03958124	0.02115561	-1.871	0.0620
age5	1	0.01994264	0.006791034	2.937	0.0035
out	1	-0.09695567	0.01975712	-4.907	0.0001
mu600	1	-0.13067742	0.02106364	-6.204	0.0001
age_10	1	-0.008929313	0.03669126	-0.243	0.8078
age_11	1	0.06757259	0.05350865	1.263	0.2073

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	6	2.49416655	0.41569442	14.019	0.0001
error	440	13.04703244	0.02965235		
c total	446	15.54119898			

root mse	0.1721986	r-square	0.1605
dep mean	0.6088747	adj r-sq	0.1490
c.v.	28.28144		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72869976	0.03257170	22.372	0.0001
aft79	1	-0.04001571	0.02089698	-1.915	0.0562
age5	1	0.02157221	0.006728703	3.206	0.0014
out	1	-0.10004108	0.01969419	-5.080	0.0001
age_12	1	-0.08681256	0.03499063	-2.481	0.0135
mw600	1	-0.11007573	0.02393497	-4.599	0.0001
w44	1	-0.03800979	0.01904168	-1.996	0.0465

note: the procedure reg used 0.08 seconds and 768k and printed page 7.

```
491       proc means; var aft79 age5 out age_12 mw600 w44 if79 if80 if81 if82 if83
492         if84 if85;
```


variable	n	mean	standard deviation	minimum value	maximum value	std error of mean	sum	variance	c.v.
aft79	463	0.64578834	0.47879106	0.00000000	1.00000000	0.02225131	299.0000000	0.22924088	74.141
age5	463	3.88665227	1.50788972	0.50000000	5.00000000	0.07007758	1799.5200000	2.27373141	38.797
out	447	0.69096197	0.42467999	0.00000000	1.23400000	0.02008667	308.8600000	0.18035309	61.462
age_12	463	0.06479482	0.24642972	0.00000000	1.00000000	0.01145256	30.0000000	0.06072761	380.323
mw600	463	0.73002160	0.44442847	0.00000000	1.00000000	0.02065434	338.0000000	0.19751667	60.879
w44	463	0.53995680	0.49894000	0.00000000	1.00000000	0.02318771	250.0000000	0.24894112	92.404
if79	463	0.08207343	0.27477346	0.00000000	1.00000000	0.01276981	38.0000000	0.07550045	334.790
if80	463	0.08207343	0.27477346	0.00000000	1.00000000	0.01276981	38.0000000	0.07550045	334.790
if81	463	0.08639309	0.28124752	0.00000000	1.00000000	0.01307068	40.0000000	0.07910017	325.544
if82	463	0.09287257	0.29056774	0.00000000	1.00000000	0.01350383	43.0000000	0.08442961	312.867
if83	463	0.09503240	0.29357689	0.00000000	1.00000000	0.01364369	44.0000000	0.08618739	308.923
if84	463	0.10151188	0.30233200	0.00000000	1.00000000	0.01405056	47.0000000	0.09140464	297.929
if85	463	0.10583153	0.30795462	0.00000000	1.00000000	0.01431187	49.0000000	0.09483605	290.986

note: the procedure means used 0.11 seconds and 554k and printed page 8.

```
493       proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12 mw600 w44;
494       output out=four r=resid;
495
```


dep variable: cf
analysis of variance

```
493        proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12 mw600 u44;
494        output out=four r=resid;
495
```



```
dep variable: cf
analysis of variance

                      sum of          mean
source     df        squares        square      f value     prob>f

model      12     3.04310744    0.25359229        8.806     0.0001
error     434    12.49809154    0.02879745
c total   446    15.54119898

    root mse      0.1696981     r-square       0.1958
    dep mean      0.6088747     adj r-sq       0.1736
    c.v.           27.87077

parameter estimates

                      parameter        standard       t for h0:
variable   df          estimate           error     parameter=0      prob > *t*

intercep    1        0.73422583      0.03231742          22.719          0.0001
if79        1       -0.05838160      0.03187673          -1.831          0.0677
if80        1       -0.07134498      0.03276482          -2.177          0.0300
if81        1       -0.02953652      0.03244454          -0.910          0.3631
if82        1       -0.06153637      0.03171184          -1.940          0.0530
if83        1       -0.08218503      0.03181037          -2.584          0.0101
if84        1      -0.008069730      0.03103425          -0.260          0.7950
if85        1        0.04868744      0.03181068           1.531          0.1266
age5        1        0.02087643     0.006675643           3.127          0.0019
out         1       -0.09798465      0.01950422          -5.024          0.0001
age_12      1       -0.12026337      0.03583362          -3.356          0.0009
mw600       1       -0.12049804      0.02379692          -5.064          0.0001
note: the data set work.four has 463 observations and 28 variables. 83 obs/trk.
u44         1       -0.03376270      0.01879735          -1.796          0.0732
note: the procedure reg used 0.15 seconds and 768k and printed page 9.

496        data five; set four; if bw=1;

note: data set work.five has 75 observations and 28 variables. 83 obs/trk.
note: the data statement used 0.04 seconds and 430k.

497        proc plot; plot resid*year='*';
```



```
plot of resid*year    symbol used is *

      ^
  0.4 +
      ^
      ^
      ^
      ^
  0.3 +
      ^
      ^
      ^
```

root mse	0.1701238	r-square	0.1787
dep mean	0.6088747	adj r-sq	0.1694
c.v.	27.94069		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72917317	0.03195540	22.818	0.0001
yr79_83	1	-0.07056141	0.01710900	-4.124	0.0001
age5	1	0.02239370	0.006027097	3.716	0.0002
out	1	-0.09684035	0.01943102	-4.984	0.0001
mw600	1	-0.13584276	0.01976003	-6.875	0.0001
age_12	1	-0.11586360	0.03380731	-3.427	0.0007

note: the procedure reg used 0.08 seconds and 780k and printed page 8.

532 proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12 mw600;

sas 13:17 tuesday, april 8, 1986 9

dep variable: cf
analysis of variance

EQUATION 1

source	df	sum of squares	mean square	f value	prob>f
model	11	2.95020336	0.26820031	9.266	0.0001
error	435	12.59099562	0.02894482		
c total	446	15.54119898			

root mse	0.1701318	r-square	0.1899
dep mean	0.6088747	adj r-sq	0.1693
c.v.	27.942		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.73331328	0.03239600	22.636	0.0001
if79	1	-0.05584313	0.03192677	-1.749	0.0810
if80	1	-0.06789184	0.03279195	-2.070	0.0390
if81	1	-0.02666134	0.03248793	-0.821	0.4123
if82	1	-0.05898061	0.03176086	-1.857	0.0640
if83	1	-0.07962558	0.03185965	-2.499	0.0129
if84	1	-0.004556665	0.03105171	-0.147	0.8834
if85	1	0.05428410	0.03173861	1.710	0.0879
age5	1	0.01981053	0.006666206	2.972	0.0031
out	1	-0.09624960	0.01953006	-4.928	0.0001
age_12	1	-0.12904227	0.03558944	-3.626	0.0003
mw600	1	-0.14189557	0.02065295	-6.870	0.0001

note: the procedure reg used 0.09 seconds and 780k and printed page 9.
note: sas used 780k memory.

note: sas institute inc.
sas circle
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cary, n.c. 27511-8000
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*session costs: $3.81/$0.00

analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	4	2.43778506	0.60944626	20.558	0.0001
error	442	13.10341393	0.02964573		
c total	446	15.54119898			

root mse	0.1721794	r-square	0.1569
dep mean	0.6088747	adj r-sq	0.1492
c.v.	28.27829		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.71938704	0.03221212	22.333	0.0001
yr79_83	1	-0.06666122	0.01727738	-3.858	0.0001
age5	1	0.01889490	0.006011771	3.143	0.0018
out	1	-0.09330836	0.01963812	-4.751	0.0001
mw600	1	-0.12036658	0.01946956	-6.182	0.0001

note: the procedure reg used 0.08 seconds and 780k and printed page 7.

531 proc reg; model cf=yr79_83 age5 out mw600 age_12;

sas 13:17 tuesday, april 8, 1986 8

dep variable: cf
analysis of variance

EQUATION 2

source	df	sum of squares	mean square	f value	prob>f
model	5	2.77772581	0.55554516	19.195	0.0001
error	441	12.76347318	0.02894212		
c total	446	15.54119898			

root mse	0.1701238	r-square	0.1787
dep mean	0.6088747	adj r-sq	0.1694
c.v.	27.94069		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72917317	0.03195540	22.818	0.0001
yr79_83	1	-0.07056141	0.01710900	-4.124	0.0001
age5	1	0.02239370	0.006027097	3.716	0.0002
out	1	-0.09684035	0.01943102	-4.984	0.0001
mw600	1	-0.13584276	0.01976003	-6.875	0.0001
age_12	1	-0.11586360	0.03380731	-3.427	0.0007

note: the procedure reg used 0.08 seconds and 780k and printed page 8.

532 proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12 mw600;

sas 13:17 tuesday, april 8, 1986 9

dep variable: cf

analysis of variance

All data
EQUATION 1

Page 17

source	df	sum of squares	mean square	f value	prob>f
model	6	2.90633365	0.48438894	16.868	0.0001
error	440	12.63486533	0.02871560		
c total	446	15.54119898			

root mse	0.1694568	r-square	0.1870
dep mean	0.6088747	adj r-sq	0.1759
c.v.	27.83114		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.73187725	0.03185057	22.978	0.0001
yr79_83	1	-0.07159624	0.01704412	-4.201	0.0001
age5	1	0.02313512	0.006013670	3.847	0.0001
out	1	-0.10012290	0.01941136	-5.158	0.0001
mw600	1	-0.11407700	0.02267405	-5.031	0.0001
age_12	1	-0.10885552	0.03389244	-3.212	0.0014
w44	1	-0.03587917	0.01866693	-1.922	0.0552

note: the procedure reg used 0.07 seconds and 768k and printed page 1.

```
480        proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12
481          mw600 w44;
482
```


dep variable: cf
analysis of variance

All data

source	df	sum of squares	mean square	f value	prob>f
model	12	3.07188258	0.25599021	8.910	0.0001
error	434	12.46931641	0.02873114		
c total	446	15.54119898			

root mse	0.1695026	r-square	0.1977
dep mean	0.6088747	adj r-sq	0.1755
c.v.	27.83867		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.73574795	0.03230559	22.775	0.0001
if79	1	-0.05826619	0.03183987	-1.830	0.0679
if80	1	-0.07116639	0.03272638	-2.175	0.0302
if81	1	-0.02921724	0.03240835	-0.902	0.3678
if82	1	-0.06154001	0.03167219	-1.943	0.0527
if83	1	-0.08183278	0.03177482	-2.575	0.0103
if84	1	-0.007829391	0.03099735	-0.253	0.8007
if85	1	0.05104866	0.03175901	1.607	0.1087
age5	1	0.02087819	0.006665224	3.132	0.0019
out	1	-0.10004849	0.01950963	-5.128	0.0001
age_12	1	-0.12145015	0.03579999	-3.392	0.0008

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	6	3.04970880	0.50828480	19.538	0.0001
error	427	11.10857113	0.02601539		
c total	433	14.15827994			

root mse	0.1612929	r-square	0.2154
dep mean	0.6129032	adj r-sq	0.2044
c.v.	26.3162		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.74585292	0.03067203	24.317	0.0001
yr79_83	1	-0.06436848	0.01654269	-3.891	0.0001
age5	1	0.02211689	0.005771125	3.832	0.0001
out	1	-0.09405419	0.01877817	-5.009	0.0001
mw600	1	-0.12664695	0.02198399	-5.761	0.0001
age_12	1	-0.01159561	0.03562299	-0.326	0.7450
w44	1	-0.04730842	0.01784645	-2.651	0.0083

note: the procedure reg used 0.08 seconds and 768k and printed page 3.

```
485       proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12
486         mw600 w44;
487
```

sas 13:46 friday, april 11, 1986 4

dep variable: cf
analysis of variance

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source	df	sum of squares	mean square	f value	prob>f
model	12	3.15446355	0.26287196	10.057	0.0001
error	421	11.00381639	0.02613733		
c total	433	14.15827994			

root mse	0.1616704	r-square	0.2228
dep mean	0.6129032	adj r-sq	0.2006
c.v.	26.37781		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.74785140	0.03109162	24.053	0.0001
if79	1	-0.06381800	0.03088633	-2.066	0.0394
if80	1	-0.06841058	0.03173699	-2.156	0.0317
if81	1	-0.02553540	0.03141598	-0.813	0.4168
if82	1	-0.05850233	0.03069328	-1.906	0.0573
if83	1	-0.08189055	0.03073803	-2.664	0.0080
if84	1	-0.009948020	0.02996781	-0.332	0.7401
if85	1	0.02695919	0.03073071	0.877	0.3808
age5	1	0.02109829	0.006443897	3.274	0.0011

```
age_12    1    -0.01726242     0.03753057        -0.460        0.6458
mw600     1    -0.12945711     0.02292565        -5.647        0.0001
w44       1    -0.04596710     0.01799964        -2.554        0.0110
note: the procedure reg used 0.08 seconds and 768k and printed page 4.
```



```
2         sas(r) log   os sas 5.08         vs2/mvs job ext73704 step               13:46 friday, april 11, 1986

488        data four; set two;
489          if id=6 then delete;

note: data set work.four has 449 observations and 24 variables. 97 obs/trk.
note: the data statement used 0.05 seconds and 438k.

490        proc reg; model cf=yr79_83 age5 out mw600 age_12 w44 ce;


sas                                                                            13:46 friday, april 11, 1986    5

dep variable: cf
analysis of variance

                   sum of         mean
source    df      squares       square      f value      prob>f

model      7   3.05945734   0.43706533       16.270      0.0001
error    426  11.44357554   0.02686285
c total  433  14.50303288

     root mse     0.1638989     r-square       0.2110
     dep mean     0.6149493     adj r-sq       0.1980
     c.v.          26.65243

parameter estimates

                    parameter       standard      t for h0:
variable  df         estimate          error    parameter=0     prob > ^t^

intercep   1       0.71840794     0.03124083         22.996         0.0001
yr79_83    1      -0.07732383     0.01671339         -4.626         0.0001
age5       1       0.02451769    0.005877962          4.171         0.0001
out        1      -0.10291444     0.01902420         -5.410         0.0001
mw600      1      -0.12104464     0.02225759         -5.438         0.0001
age_12     1      -0.09964395     0.03397749         -2.933         0.0035
w44        1      -0.01611172     0.01845224         -0.873         0.3831
ce         1       0.07333213     0.02164250          3.388         0.0008
note: the procedure reg used 0.07 seconds and 768k and printed page 5.
```

No Publication

```
491        proc reg; model cf=yr79_83 age5 out mw600 age_12 ce;


sas                                                                            13:46 friday, april 11, 1986    6

dep variable: cf
analysis of variance

                   sum of         mean
source    df      squares       square      f value      prob>f

model      6   3.03897696   0.50649616       18.865      0.0001
error    427  11.46405592   0.02684791
c total  433  14.50303288
```

No Publication

c.v. 26.64501

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.71707807	0.03119500	22.987	0.0001
yr79_83	1	-0.07714964	0.01670755	-4.618	0.0001
age5	1	0.02432730	0.005872282	4.143	0.0001
out	1	-0.10241636	0.01901036	-5.387	0.0001
mw600	1	-0.13076522	0.01926804	-6.787	0.0001
age_12	1	-0.10261517	0.03379725	-3.036	0.0025
ce	1	0.07658867	0.02131278	3.594	0.0004

note: the procedure reg used 0.07 seconds and 768k and printed page 6.

```
proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12
  mw600 w44 ce;
```

sas 13:46 friday, april 11, 1986 7

Nic Tollison

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	13	3.16882750	0.24375596	9.033	0.0001
error	420	11.33420539	0.02698620		
c total	433	14.50303288			

root mse	0.1642748	r-square	0.2185
dep mean	0.6149493	adj r-sq	0.1943
c.v.	26.71355		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.71774653	0.03182775	22.551	0.0001
if79	1	-0.07193065	0.03136072	-2.294	0.0223
if80	1	-0.08436547	0.03229318	-2.612	0.0093
if81	1	-0.04858714	0.03199638	-1.519	0.1296
if82	1	-0.07931066	0.03127156	-2.536	0.0116
if83	1	-0.10321012	0.03140878	-3.286	0.0011
if84	1	-0.02350915	0.03054615	-0.770	0.4420
if85	1	0.02049028	0.03132803	0.654	0.5134
age5	1	0.02480373	0.006584621	3.767	0.0002
out	1	-0.10299240	0.01915116	-5.378	0.0001
age_12	1	-0.10121623	0.03592131	-2.818	0.0051
mw600	1	-0.12118558	0.02333692	-5.193	0.0001
w44	1	-0.01536443	0.01854507	-0.828	0.4079
ce	1	0.07296955	0.02178808	3.349	0.0009

note: the procedure reg used 0.09 seconds and 768k and printed page 7.

```
proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12
  mw600 ce;
```

495 mw600 ce;
496

sas 13:46 friday, april 11, 1986 8

No Palisades

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	12	3.15030423	0.26252535	9.735	0.0001
error	421	11.35272865	0.02696610		
c total	433	14.50303288			

root mse	0.1642136	r-square	0.2172
dep mean	0.6149493	adj r-sq	0.1949
c.v.	26.7036		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.71672413	0.03179197	22.544	0.0001
if79	1	-0.07105570	0.03133125	-2.268	0.0238
if80	1	-0.08315913	0.03224832	-2.579	0.0103
if81	1	-0.04769983	0.03196654	-1.492	0.1364
if82	1	-0.07860857	0.03124843	-2.516	0.0123
if83	1	-0.10249014	0.03138506	-3.266	0.0012
if84	1	-0.02253439	0.03051212	-0.739	0.4606
if85	1	0.02229624	0.03124046	0.714	0.4758
age5	1	0.02447166	0.006569962	3.725	0.0002
out	1	-0.10248486	0.01913423	-5.356	0.0001
age_12	1	-0.10463518	0.03567019	-2.933	0.0035
mw600	1	-0.13077834	0.02025443	-6.457	0.0001
ce	1	0.07594878	0.02148128	3.536	0.0005

note: the procedure reg used 0.08 seconds and 768k and printed page 8.

497 data five; set three;
498 if id=6 then delete;

note: data set work.five has 431 observations and 24 variables. 97 obs/trk.
note: the data statement used 0.05 seconds and 438k.

499 proc reg; model cf=yr79_83 age5 out mw600 age_12 w44 ce;

sas 13:46 friday, april 11, 1986 9

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	7	3.16427757	0.45203965	18.795	0.0001
error	413	9.93322708	0.02405140		
c total	420	13.09750465			

root mse	0.1550851	r-square	0.2416
dep mean	0.6192998	adj r-sq	0.2287
c.v.	25.04242		

analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	7	3.16427757	0.45203965	18.795	0.0001
error	413	9.93322708	0.02405140		
c total	420	13.09750465			

root mse	0.1550851	r-square	0.2416
dep mean	0.6192898	adj r-sq	0.2287
c.v.	25.04242		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.73117695	0.02991773	24.440	0.0001
yr79_83	1	-0.07060874	0.01612150	-4.380	0.0001
age5	1	0.02346429	0.005606709	4.185	0.0001
out	1	-0.09645443	0.01830140	-5.270	0.0001
mw600	1	-0.13074865	0.02141151	-6.106	0.0001
age_12	1	0.005373720	0.03574602	0.150	0.8806
w44	1	-0.02837636	0.01754759	-1.617	0.1066
ce	1	0.06838158	0.02050689	3.335	0.0009

note: the procedure reg used 0.08 seconds and 768k and printed page 9.

```
500        proc reg; model cf=yr79_83 age5 out mw600 w44 ce;
```


dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	6	3.16373402	0.52728900	21.975	0.0001
error	414	9.93377062	0.02399462		
c total	420	13.09750465			

root mse	0.154902	r-square	0.2416
dep mean	0.6192898	adj r-sq	0.2306
c.v.	25.01284		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.73154766	0.02978071	24.564	0.0001
yr79_83	1	-0.07080823	0.01604781	-4.412	0.0001
age5	1	0.02359949	0.005527571	4.269	0.0001
out	1	-0.09662865	0.01824309	-5.297	0.0001
mw600	1	-0.13148851	0.02081361	-6.317	0.0001
w44	1	-0.02804765	0.01739027	-1.613	0.1075
ce	1	0.06828203	0.02047139	3.335	0.0009

note: the procedure reg used 0.07 seconds and 768k and printed page 10.

```
501        proc reg; model cf=yr79_83 age5 out mw600 ce;
```

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```
note: the procedure reg used 0.07 seconds and 768k and printed page 10.

501        proc reg; model cf=yr79_83 age5 out mw600 ce;
```


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EQUATION 2

dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	5	3.10131825	0.62026365	25.751	0.0001
error	415	9.99618639	0.02408720		
c total	420	13.09750465			

root mse	0.1552005	r-square	0.2368
dep mean	0.6192898	adj r-sq	0.2276
c.v.	25.06105		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72823617	0.02976711	24.464	0.0001
yr79_83	1	-0.07031368	0.01607581	-4.374	0.0001
age5	1	0.02307776	0.005528733	4.174	0.0001
out	1	-0.09548602	0.01826447	-5.228	0.0001
mw600	1	-0.14715365	0.01844385	-7.978	0.0001
ce	1	0.07425277	0.02017329	3.681	0.0003

```
note: the procedure reg used 0.07 seconds and 768k and printed page 11.

502        proc reg; model cf=if79 if80 if81 if82 if83 if84 if85 age5 out age_12
503          mw600 w44 ce;
```


dep variable: cf
analysis of variance

source	df	sum of squares	mean square	f value	prob>f
model	13	3.25148825	0.25011448	10.339	0.0001
error	407	9.84601639	0.02419169		
c total	420	13.09750465			

root mse	0.1555368	r-square	0.2483
dep mean	0.6192898	adj r-sq	0.2242
c.v.	25.11535		

parameter estimates

variable	df	parameter estimate	standard error	t for h0: parameter=0	prob > ^t^
intercep	1	0.72890575	0.03040728	23.971	0.0001
if79	1	-0.07794745	0.03021552	-2.580	0.0102
if80	1	-0.08152611	0.03109863	-2.622	0.0091
if81	1	-0.04484847	0.03080082	-1.456	0.1461
if82	1	-0.07652222	0.03008893	-2.543	0.0114

Turbine Blades

Blade failures have been the most consequential turbine problem in terms of unit Availability and Capacity Factor losses. The impact of these problems, however, have varied for the different types of turbines. Turbine manufacturers for the units comprising this report's data base are as follows:

Westinghouse Turbines

40 Inch Blades

Calvert Cliffs 2
Ginna
Kewaunee 1
Point Beach 1 and 2
Prairie Island 1 and 2

44 Inch Blades - Generation 1

Cooper 1
Indian Point 2 and 3
Maine Yankee
Palisades
Robinson 2
Salem 1
Surry 1 and 2
Turkey Point 3 and 4

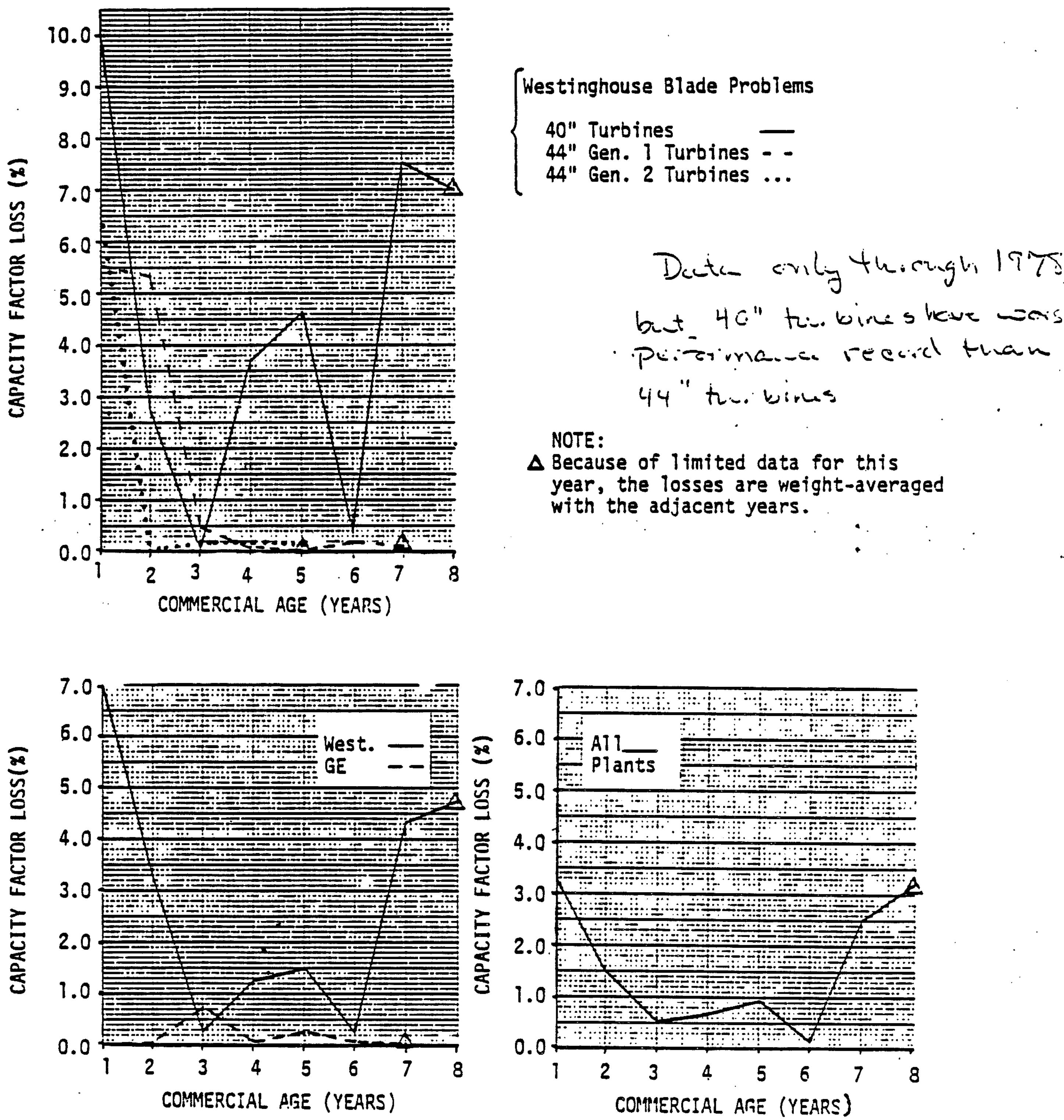
44 Inch Blades - Generation 2

Arkansas 1
Beaver Valley 1
Crystal River 3
Farley 1
Rancho Seco
St. Lucie 1
Zion 1 and 2

General Electric Turbines

Browns Ferry 1, 2, and 3
Brunswick 1 and 2
Calvert Cliffs 1
D.C. Cook 1
Davis Besse 1
Dresden 2 and 3
Duane Arnold
Fitzpatrick
Fort Calhoun 1
Hatch 1
Millstone Point 1 and 2
Monticello
Oconee 1, 2, and 3
Peach Bottom 2 and 3
Pilgrim 1
Quad Cities 1 and 2
Three Mile Island 1
Trojan
Vermont Yankee

It is apparent from the data given in the preceding section of this report that units with Westinghouse turbines have encountered more frequent and much more lengthy outages caused by turbine blade problems than have units with GE turbines. These outages have averaged 586.7 EFPHs lost per outage at units with Westinghouse turbines and only 79.7 EFPHs lost per outage at units with GE turbines. The majority of outages reported as GE turbine blade problems have been relatively brief shutdowns for vibration problems or balancing. GE turbines in this report's data base have experienced only one blade failure that resulted in a lengthy outage. Westinghouse turbines, however, have had many lengthy blade failures. Losses caused by those blade problems are plotted in Figures 7-31 and 7-32, and a summary of the turbine blade failures for the different types of turbines follows:



Data only through 1978 but 40" turbines have worse performance record than 44" turbines

FIGURE 7-31: LOSSES FROM TURBINE BLADE PROBLEMS (Including vibration and balancing)

BEFORE THE

NEW MEXICO PUBLIC SERVICE COMMISSION

PUBLIC SERVICE OF NEW MEXICO

CASE No. 2004

Testimony of

Paul Chernick

on Behalf of the

New Mexico Attorney General

May 7, 1986

ANALYSIS AND INFERENCE, INC. RESEARCH AND CONSULTING

10 POST OFFICE SQUARE, SUITE 970 – BOSTON, MASSACHUSETTS 02109 – (617) 542-0611

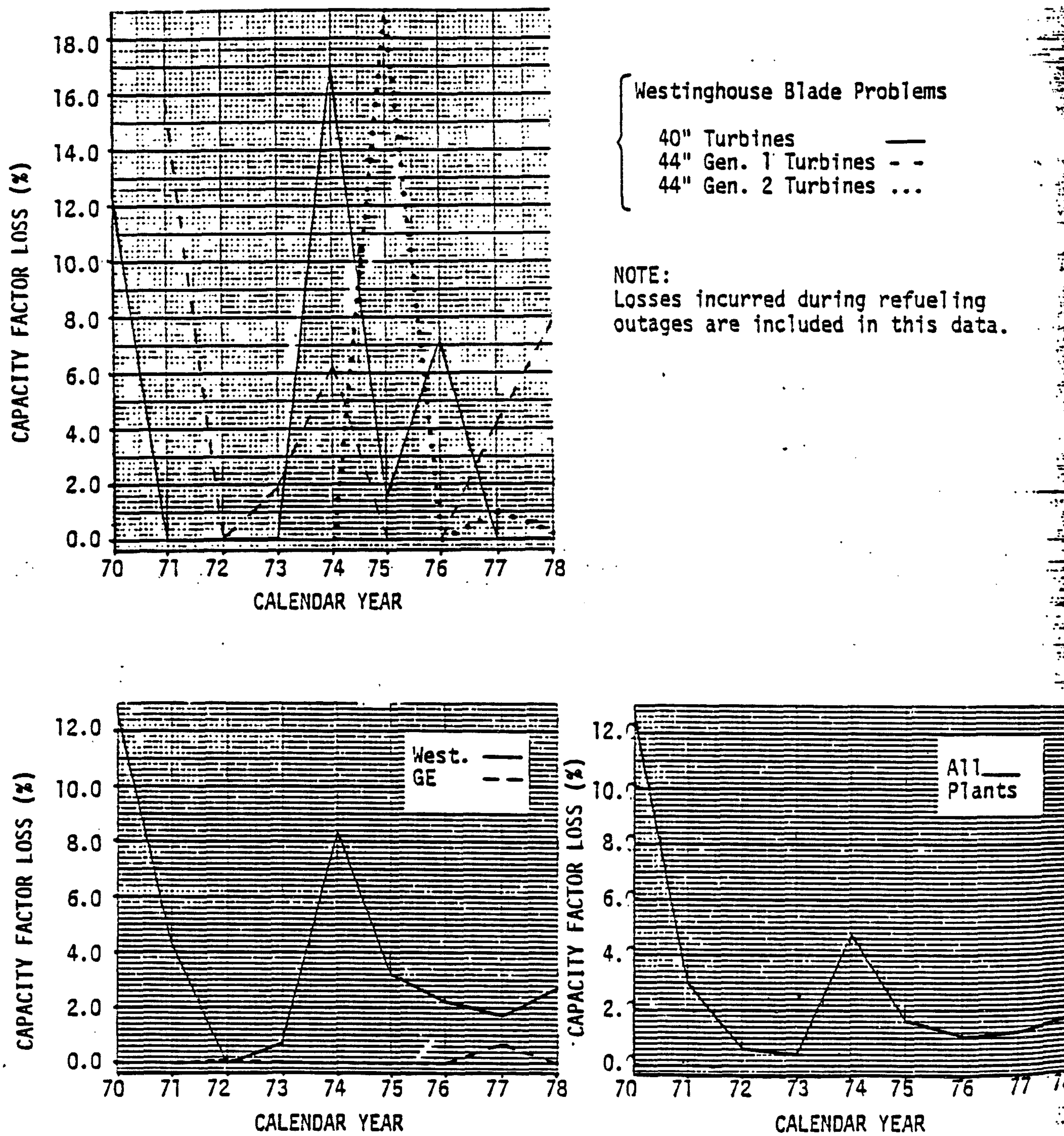


FIGURE 7-32: LOSSES FROM
TURBINE BLADE PROBLEMS
(Including vibration and balancing)

Nuclear Unit Operating Experience: 1980 Through 1982 Update

NP-3480
Research Project 2183-4

Final Report, April 1984

Prepared by

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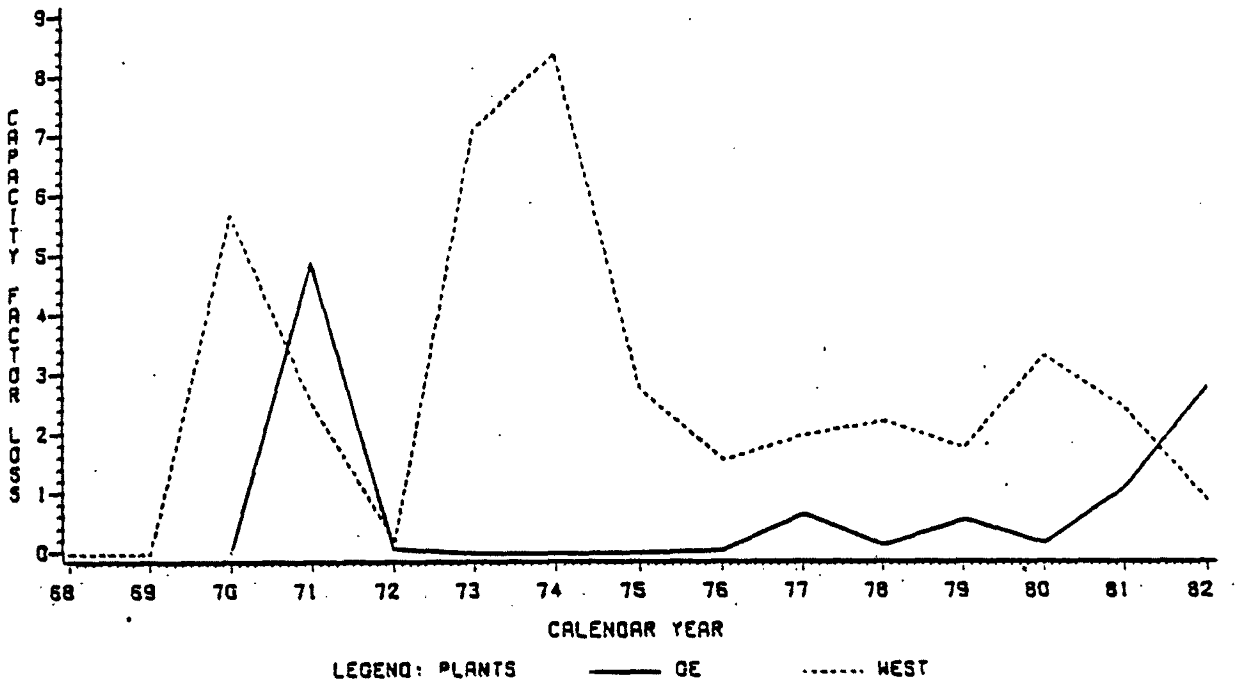
EPRI Project Manager
F. E. Gelhaus

System Performance Program
Nuclear Power Division

FIGURE 4-13
TURBINE BLADES AND ROTORS BY VENDOR
CAPACITY FACTOR LOSS BY CALENDAR YEAR



Data through 1982, Westinghouse ~~turbines~~ have clearly had a larger negative effect on capacity factors than other turbines

TABLE 6.2: PWR CAPACITY FACTOR REGRESSIONS

	Equation 1		Equation 2	
	Coef	t-stat	Coef	t-stat
CONSTANT	73.19%	23.0	72.82%	24.5
MW600 [1]	-11.41%	-5.0	-14.72%	-8.0
AGE5 [2]	2.31%	3.8	2.31%	4.2
AGE_12 [3]	-10.89%	-3.2	--	--
OUT [4]	-10.01%	-5.2	-9.55%	-5.2
W44 [5]	-3.59%	-1.9	--	--
YR79_83 [7]	-7.16%	-4.2	-7.03%	-4.4
CE [8]	--	--	7.43%	3.7
ADJUSTED R-SQ		0.176		0.228
F STATISTIC		16.9		25.8
OBSERVATIONS [8]		447		421

Notes: Equation 1 was run on all data. Equation 2 excludes data from Palisades and San Onofre 1.

[1] MW600 = 1, if Design Electrical Rating (DER) > 600 MW; 0 otherwise.
[2] AGE5 = minimum of AGE (years from COD to middle of current year), and 5.
[3] AGE_12 = 1, if AGE >= 12; 0 otherwise.
[4] OUT = number of refuelings in year, including other single outages lasting more than 3 months (OUT usually equals 0 or 1).
[5] W44 = 1, if unit contains Westinghouse 44" turbine; 0 otherwise.
[6] Indicator = 1 in this year; 0 otherwise.
[7] YR79-83 = 1, if between 1978 and 1984; 0 otherwise.
[8] CE = 1, if Combustion Engineering is the NSSS; 0 otherwise.
[9] Full calendar years of PWR operation, 1973-85.