# A Numerical Comparison of International Light Water Reactor Performance 1975 to 1984

by

Christopher T. Wilson

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by

CHRISTOPHER T. WILSON
B.S. Nuclear Engineering, University of Michigan
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Signature of Author: Christopher T. Wilson
Dept. of Nuclear Engin., 9 May, 1986

Certified by: ______________________________
Dr. Kent F. Hansen, Thesis Supervisor

Accepted by: ______________________________
Allan F. Henry, Chairman
Nuclear Engineering Dept. Graduate Committee

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ABSTRACT

A numerical comparison of international light water reactor operating performance from 1975 to 1984 was carried out in an attempt to identify trends and discrepancies in PWR and BWR performance.

The countries examined were: France, the Federal Republic of Germany, Japan, Sweden, Switzerland, and the United States. Reactor performance losses for each country were broken down into many categories for examination and comparison including: Fuel, Reactor Coolant System, Steam Generators, Refueling, Turbines, Generators, Condensers, Circulatory/Service/Component Cooling Water Systems, Economic, Human, Regulatory, and Unknown. Additionally, losses were also distinguished as forced or scheduled. All loss categories were plotted as functions of both time and reactor age.

It was found that from 1975 to 1984 the Swiss PWR and BWR performance was the highest averaging 85.8% and 88.0% respectively. The lowest PWR performance was in Sweden averaging 54.4%. Germany was found to have the lowest BWR performance averaging 51.1%.

For the PWR's, differences in regulatory, steam generator, and economic losses were found to be the common contributors to low performance. For BWR's, differences in regulatory, reactor coolant system, and fuel losses were found to be the common contributors to low performance.

Time and age dependent trends were observed for losses in many of the loss categories.

Thesis supervisor: Dr. Kent F. Hansen

Title: Professor of Nuclear Engineering

## DEDICATION

To my wife Amy, for her loving support and understanding without which I would have never had the motivation and courage to complete this work.

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The nuclear plant performance data was provided by many who deserve acknowledgement. The U.S. performance data contained in the OPEC-2 database compiled by S.M. Stoller Corporation, was kindly provided by the Institute of Nuclear Power Operations. French nuclear power plant data was provided by Electricite de France. The German data was compiled by Mr. Ulrich Lorenz at the Technische Universität Berlin. Japanese data was provided by Mr. Sadaoki Miyaoka, the Director of the Nuclear Information Center at the Central Research Institute of the Electric Power Industry (CRIEPI) in Japan. Swedish nuclear plant performance data was provided by Mr. Thomas Eckered, the Managing Director of the Swedish Nuclear Safety Board. Finally, the Swiss data was provided by Mr. H. Wenger, the Station Superintendent at the Beznau Nuclear Power Station.

Part of the work on this thesis was performed during a six month visit at the Technishe Universität Berlin. Special thanks go to the Stiftung Luftbrückendank which kindly provided a scholarship that allowed my wife and I to go to Berlin. The six months spent in Berlin was an experience that will not be forgotten. Professor Dietmar Winje at TUB, who served as my advisor-away-from-home, deserves thanks as well. Thanks also to my friend and colleague Ulrich Lorenz, also at TUB, who made my stay ever more pleasant.

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## 1.0 Introduction and Background

With the cost for installing nuclear capacity escalating, there is strong motivation to increase the performance of existing nuclear plants. An average increase of 20% in U.S. nuclear output is equivalent to building approximately eight 1000 $MW_e$ power plants.* This level of performance is certainly achievable based on the performance of nuclear facilities in other countries. Whether this can be accomplished in the U.S. with the current structure of nuclear industry has yet to be seen.

Over the past decade, there have been large differences in nuclear power plant performance around the world. In some countries the performance has been excellent, while in others, it has been unsatisfactory. This variation is not just between countries, but also between individual plants within those countries. In many cases the level of performance that had been originally expected was not achieved.

In order to begin to increase performance it is necessary to know and understand what the U.S. performance losses are and why they differ from the losses in other countries. Once the losses are fully understood, changes in

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* Using the net electrical ratings of the 77 plants listed in Table C.10 of Appendix C, with a 20% increase in the average capacity factor of ≈ 60%.

design, construction, operations, and regulation can be made to facilitate improved performance. The correlation between these factors and plant performance can only be determined through the examination of the discrepancies in performance.

This thesis describes work that was done to identify and compare discrepancies in nuclear power plant performance in six countries. Both the acquisition of the performance data and the comparison of specific losses and data characterizations are discussed. The most significant differences in performance are highlighted in the summary and conclusions.

## 1.1 Scope

This study examined commercial nuclear power plant performance in six countries from 1975 to 1984. The six countries examined were France, the Federal Republic of Germany, Japan, Sweden, Switzerland, and the United States. Only light water reactors with a net electrical rating of greater than 300 $MW_e$ were considered. Table 1.1 contains a summary of the nuclear power plants included in the study. A detailed listing of the plants can be found in Tables C.5 through C.10 in Appendix C.

Table 1.1 - Summary of Nuclear Power Plants Included in Study

| | | |
|---|---|---|
| **France:** | | |
| | Total Number of PWR's: | 28 |
| | PWR plant-years experience: | 62.0 |
| **Federal Republic of Germany:** | | |
| | Total Number of PWR's: | 7 |
| | PWR plant-years experience: | 54.6 |
| | Total Number of BWR's: | 4 |
| | BWR plant-years experience: | 27.7 |
| **Japan:** | | |
| | Total Number of PWR's: | 11 |
| | PWR plant-years experience: | 71.5 |
| | Total Number of BWR's: | 13 |
| | BWR plant-years experience: | 82.1 |
| **Sweden:** | | |
| | Total Number of PWR's: | 3 |
| | PWR plant-years experience: | 14.2 |
| | Total Number of BWR's: | 7 |
| | BWR plant-years experience: | 52.3 |
| **Switzerland:** | | |
| | Total Number of PWR's: | 3 |
| | PWR plant-years experience: | 25.0 |
| | Total Number of BWR's: | 1 |
| | BWR plant-years experience: | 10.0 |
| **United States:** | | |
| | Total Number of PWR's: | 52 |
| | PWR plant-years experience: | 396.0 |
| | Total Number of BWR's: | 25 |
| | BWR plant-years experience: | 210.8 |

## 1.2 Participants

This project was a collaborative effort between the Massachusetts Institute of Technology Energy Laboratory and the Technische Universität Berlin in the Federal Republic of Germany.

## 1.3 Performance Indices

There were two measures of performance used in this study, capacity and energy availability. Both are measures of electrical output or potential electrical output relative to the maximum theoretical output.

The capacity factor (CF), a measure of the actual electrical output of the plant, is the ratio of the total megawatt-hours generated during a given time period to the product of the net electrical rating of the plant and the number of hours in the time period. Mathematically:

$$CF = \frac{[NEG]}{[NER] \cdot [PL]}$$

where:

NEG = Net Electrical Generation (Megawatt-Hours)

NER = Net Electrical Rating (Megawatts)

PL = Period Length (Hours).

However, capacity includes losses arising from causes external to the plant. These causes include predominantly economic and non-economic grid related events such as grid maintenance, load rejection, load following, spinning reserve, and other distribution system problems. The impact on the capacity from these external causes varies between countries. To be consistent, it is desireable to eliminate the effect of external causes on plant performance. This then results in a measure of performance where the plants are penalized only for losses caused by plant originated problems. This performance index is called energy availability. The energy availability factor is then equal to the capacity factor plus the ratio of the externally caused losses to the product of the net electrical rating of the plant and the number of hours in the time period. Mathematically:

$$EAF = CF + \frac{[ECGL]}{[NER] \cdot [PL]}$$

where:

ECGL = Externally Caused Generation Losses (Megawatt-Hours).

In most countries, energy availability and capacity differ very little. In this project, energy availability was preferred as a performance index because it is a measure of performance potential, and eliminates the influence of economic and non-economic grid losses. For three of the countries being studied only capacity was available. Table 1.2 lists the performance index used for each country.

Table 1.2 - Performance Indices Used

| Country: | Index: |
| --- | --- |
| France | Energy Availability |
| Germany | Energy Availability |
| Japan | Capacity |
| Sweden | Capacity |
| Switzerland | Capacity |
| United States | Energy Availability |

## 1.4 Data

In this section, background information for the performance data from each country will be given. This information includes a description of the data categories used, the sources of the data, statistics, and finally, a subsection on inconsistencies in the data. Further details about the data for each country can be found in Appendix C.

### 1.4.1 Data Categories

In order to identify the differences in plant performance, capacity losses have to be disaggregated in sufficient detail to allow disparities to be easily identified. To accomplish this the data was broken down by type of plant, type of outage, and specific systems and/or operations categories. The selection of these categories was patterned after those chosen in two similar studies, "Disparities in Nuclear Power Plant Performance in the United States and the Federal Republic of Germany"[1] and "Nuclear Unit Operating Experience: 1980 - 1982 Update".[2] Table 1.3 lists the performance loss categories selected while Table 1.4 lists the systems and operations assignments used for the U.S. data. Significant deviations from these assignments are mentioned in later sections and in Appendix C. A brief description of each category follows.

## Table 1.3 - Performance Loss Categories

### Forced Outages

- Nuclear Steam Supply System
  - Fuel
  - RCS
  - SG
  - Refuel
  - Other
- Balance of Plant
  - Turbine
  - Generator
  - Condenser
  - CW/SW/CCW
  - Other
- Economic
- Human
- Other

### Scheduled Outages

- Nuclear Steam Supply System
  - Fuel
  - RCS
  - SG
  - Refuel
  - Other
- Balance of Plant
  - Turbine
  - Generator
  - Condenser
  - CW/SW/CCW
  - Other
- Economic
- Human
- Other

### Regulatory Outages

### Unknown Outages

## Table 1.4 - Listing of System Category Assignments

### Condenser

Auxiliary Feedwater System
Condensate System
Condenser
Feedwater System
Makeup Water System

### CW/SW/CCW

Circulating Water System
Component Cooling Water System
Service Water System

### Economic

- Fuel Economic
  - Coastdown to Refueling and Fuel Depletion
  - Fuel Conservation
- Grid Economic*
  - Load Following
  - Low System Demand and Spinning Reserve
- Thermal Efficiency Losses

### Fuel

BWR PreConditioning Interim Operating Management - Recommendations (PCIOMR)
Fuel Densification
Fuel Failure
Fuel Failure - Off Gas Limits
RCS Activity

### Generator

### Human

Maintenance Error
Operator Error
Personnel Involvement Suspected to Have Precipitated Event
Testing Error

* (no penalty for energy availability)

## Table 1.4 - (Continued)

### Other BOP

- Auxiliary Systems
  - Auxiliary Boiler
  - Off-Gas Systems
  - Fire Protection Systems
  - Instrument/Service Air or Nitrogen Systems
  - Meteorological Systems
  - Process Computer
  - Radioactive Waste Systems
  - Seismic Instruments
- Electrical
  - Cable Routing
  - Cable Splices and Electrical Connectors
  - Cable and Cable Insulation Fires
- Electrical Systems
  - Safety Related Equipment
  - Switchgear/Buses
- Structures
  - Auxiliary Building
  - Control Building
  - Main Steam Tunnel

### Other NSSS

- Chemical & Volume Control System
- Containment System
- Core Cooling System
- Main Steam System
- Reactor Core
  - BWR Control Rod Changes
  - Burnable Poison Problems
  - Core D/P
  - Control Rod Guide Tube & Nut
  - Control Rod Repatch
  - Foreign Object in Core
  - Poison Curtain Changes
  - Poison Curtain Vibrations
  - LPRM Vibrations
- Reactor Trip System
- Reactor Water Cleanup System
- Safety Injection System

Table 1.4 - (Continued)

Other (non BOP OTHER or NSSS OTHER)

- Initial Plant Startup/Operator Training
- Paired Unit Impact
- Refueling Maintenance
- Utility Grid (Non Economic)*
  - Grid Maintenance
  - Loss of Offsite Power or Other Electrical Disturbance
  - Loss/Rejection of Load

Reactor Coolant System

Refueling

- Core Physics Tests
- Refueling
- Refueling Equipment Problems

Regulatory

- BWR Fuel Limits
  - Maximum Critical Power Ratio
  - Maximum Average Planer Heat Generation Rate
  - General Thermal Limits
- EPA Discharge Limit
- Excessive Fish Kill
- Licensing Proceedings and Hearings
- Regulatory/Operational Limit
- Regulatory Requirement to Inspect for Deficiency
- Regulatory Requirement to Modify Equipment
- Safety Restrictions
  - ECCS Peaking Factor (PWR)
  - EOL Scram Reactivity/Rod Worth Restrictions
  - Core Tilt/Xenon Restriction
  - BWR Thermal Limits
  - Thermal Power Restriction
  - Reactivity Coefficient
- Unavailability of Safety Related Equipment

Steam Generators

Turbines

Undefined Failure

* (no penalty for energy availability)

#### 1.4.1.1 Outage Types

There were four outage types chosen for this study: forced, scheduled, regulatory and unknown. The definitions of these categories varied from country to country. An attempt was made to use consistent definitions but this was not always possible since the data was compiled by different people and organizations. The definitions of forced and scheduled outages varied greatly and therefore most comparisons in this report are for combined forced and scheduled outages. The outage type definitions given here are those that were used for the U.S. The specific definitions used to compile the data for each country, if known, can be found in Appendix C.

*Forced outages* are defined as those outages that cannot be postponed beyond the next weekend.

*Scheduled outages* are those outages which can be postponed beyond the next weekend.

*Regulatory outages* are all outages that result from regulatory operating limits, requirements for inspection or modification, licensing proceedings and hearings, and the unavailability of safety related equipment.

*Unknown outages* are all the outages in which it is not possible to determine whether the outage was forced, scheduled or regulatory. This category applies mostly to the U.S. where adequate records were not always kept in the earlier years.

#### 1.4.1.2 General Systems and Operations Categories

The general systems and operations categories divide the performance data into one of two major system groups or one of two operational losses. The two major systems groups are the Nuclear Steam Supply System (NSSS) and the Balance Of Plant (BOP). The two operating loss categories are economic losses and human losses.

*NSSS* losses are all losses that are associated with systems, equipment, and operations within the NSSS. The NSSS is defined as all systems, equipment, and operations that differentiate nuclear plants from conventional power stations. This includes all steam piping up to the turbine inlet, and all feedwater piping beginning at the condenser outlet.

*BOP* losses are all losses resulting from systems and equipment not included in the NSSS. Specifically, for steam and feedwater piping it begins at the turbine inlet and ends at the condenser outlet.

*Economic* losses are defined to be all losses whose impact is primarily financial. These include thermal efficiency losses, losses arising from fuel cycle extension and conservation, and all economic grid losses. Thermal efficiency losses were placed in this category because their impact is only economical; there is no equipment failure or malfunction. Fuel cycle extension and fuel conservation are economic losses because they are managerial decisions to delay refueling and not a failure of plant equipment. Economic grid losses, consisting of low system demand, spinning reserve, and load following losses, are economic losses because it is the grid dispatcher's decision not to utilize the plant. When calculating energy availability losses, all economic and non-economic grid losses were not included because their causes are external to the plant.

*Human* losses are those that arise from human error in either testing, maintenance or operations.

#### 1.4.1.3 Specific Systems and Operations Categories

Within the NSSS and BOP categories, plant outages were broken down into lower levels representing specific systems or operations. The NSSS losses were divided into fuel, reactor coolant system (RCS), steam generators (SG), refueling, and other NSSS losses. BOP losses were broken down into losses associated with the turbines, generator, condenser, circulating water, service water and component cooling water systems (CW/SW/CCW), and other BOP losses. A description of each follows.

*Fuel* losses are all losses that are directly related to the fuel. This includes preconditioning in BWR's, fuel densification, and fuel depletion. It does not include reactivity control systems or other core related problems.

*Reactor Coolant System* losses include all losses arising from equipment associated with the RCS and support systems.

*Steam Generator* losses are those associated with the SG components and support systems.

*Refueling* losses are only those losses arising from the movement of fuel in the core and other supporting activities. It does not include maintenance performed during the refueling outage. However, the reporting of refueling losses has been inconsistent, with a substantial amount of maintenance work reported in refueling. The amount of maintenance masked in refueling varies from plant to plant and from country to country.

*Other NSSS* losses are all NSSS losses that do not fit into any of the previous NSSS categories.

*Turbine* losses include all those resulting from problems with the turbine components and support systems.

*Generator* losses are those losses associated with the generator components and support systems.

*Condenser* losses include losses from both the condenser and its support systems, as well as from the condensate, feedwater, auxiliary feedwater, and makeup water systems.

*CW/SW/CCW* losses are all those arising from problems with the circulating water, service water, component cooling water systems, and supporting systems. Thermal discharge limits are considered regulatory losses.

*Other BOP* losses are all those that could not be placed in any of the above BOP categories.

### 1.4.2 Sources

The data used in this study was obtained from different sources and with the cooperation of many people. In obtaining the data, it was specifically agreed that, if possible, all data and findings would be presented in aggregate form so that the performance of no single plant could be distinguished from the others. What follows below is a brief listing of the sources of the data used in this study.

The French nuclear plant data was provided courtesy of Electricite de France. West German nuclear data was compiled from various issues of Atomwirtschaft[3-19] and provided by our colleagues at the Technische Universität Berlin. The Japanese data was acquired from the Director of the Nuclear Information Center at the Central Research Institute of the Electric Power Industry (CRIEPI) in Japan. The Swedish reactor data was obtained from the Managing Director of the Swedish Nuclear Safety Board of the Swedish Utilities (R.K.S.). Nuclear power plant data for the Swiss facilities was provided by the Station Superintendent at the Beznau Nuclear Power Station in Doettingen, Switzerland. Finally, the U.S. performance data was obtained from the

OPEC-2 database which is compiled by the S.M. Stoller Corporation and was provided through the courtesy of the Institute of Nuclear Power Operations.

### 1.4.3 Statistics

In this report an attempt has been made to identify plausible similarities and differences in nuclear power plant performance in six countries. The statistical significance of the results can be determined by performing the appropriate statistical analysis. Due to a lack of time and the ability to do such, the statistical analysis of the data and observations presented in this report is left for further study.

### 1.4.4 Data Inconsistencies

In this subsection the major inconsistencies in the data for six countries are briefly discussed. These points are important to remember when making comparisons, as the validity and significance of observations made could be affected by them. These differences will also be mentioned elsewhere in this report when they are pertinent. Detailed information concerning any inconsistencies in the data can be found in Appendix C.

The first important difference in the data is that two performance indices are used, capacity and energy availability. Although they are very similar, the difference between them is important in several cases. As mentioned previously, the energy availability does not take into account grid related performance losses. Because of this, the energy availability factor is greater than the capacity factor by an amount equal to all the grid losses. In addition, economic capacity losses will be greater than the energy availability economic losses by an amount which is equal to all the economic grid losses such as load following. All other types of losses are unaffected by the definitions of capacity and energy availability. In this report, energy availability and capacity will sometimes both be referred to as capacity. *It is up to the reader to keep in mind that when comparing capacity factors or economic losses, two different performance indices, capacity and energy availability, are being used.*

In Japan, Sweden, and Switzerland, where capacity was used, it can be assumed that the differences between capacity and energy availability are negligible. In the United States, where energy availability was used, grid related losses are small and the difference is also negligible. Finally, in France and Germany, where energy availability was the index, the difference between capacity and energy availability is significant and is discussed in the following two paragraphs.

In France, energy availability differs from capacity because the French use their reactors for load following. The difference amounts to approximately 4.6 percentage points. The load following is necessitated by the large percentage of the total installed capacity that nuclear power represents in France.

In Germany, the two indices differ because there is an agreement between the West German utilities and the West German coal companies requiring the utilities to use a certain percentage of coal to generate electricity. In some instances this requires that a nuclear station be shut down or operated at reduced output. The resulting loss is an economic grid loss and is subtracted from the capacity losses.

Another important discrepancy in the reported data concerns the definition of forced and scheduled outages used to compile the data. The definitions used for scheduled outages range from any outage that can be postponed beyond the next weekend (U.S.), to any outage that is planned at least three months in advance. As a result, comparisons of forced and scheduled outages between countries must be made carefully.

During the collection of the data from the different countries a decision was made to create a separate category for condensers. It was not possible to inform all of the people collecting the international data that a new category had been created. Therefore, condenser losses were not available for Japan, Sweden, and Switzerland. The condenser losses for these countries was put in Balance of Plant "OTHER". This has no real effect upon the data except that the BOP OTHER losses for these countries will be larger than they might have been otherwise.

The final discrepancy in the data pertains to the Swiss data and its collection. For two of the three Swiss PWR's, refueling maintenance losses were not reported under refueling losses. Instead they were placed in the appropriate system category. As a result, all Swiss PWR losses may indicate a greater loss in a system category than would exist if these maintenance losses had been included in refueling. Likewise, the Swiss PWR refueling losses appear to be unusually low since some of the maintenance losses are not included. Only the Swiss PWR capacity factors and all of the Swiss BWR data are not affected by this problem.

## 2.0 Performance Losses by Country

In this chapter of the report, performance data for each country is presented and briefly examined. Aggregated data tables are given first, followed by plots of capacity factor distributions, plots of losses by outage type, and finally, plots of losses associated with the NSSS and BOP. No discussion of the data in the aggregated data tables will be given. They are provided only as a reference to aid in the examination of the figures in this chapter and in Chapter 3. However, some guidelines and notes to be used when interpreting the data and examining the figures in this chapter are given below. An understanding of the composition of the data for each country is also necessary to prevent misinterpretation. Information on the data composition can be found in Section 1.4 and in Appendix C.

Correct interpretation of data requires that the statistical significance of all observations be analyzed. As mentioned in Section 1.4.3, the statistical analysis has been left for future study. However, the number of plants over which the data has been averaged has been tabulated in Tables 2.1 and 2.2 by year and by age to aid in the interpretation of the data. *It is up to the reader to determine the statistical significance of trends and observations made in this report.*

All of the data used in this study was provided as a function of calendar year. In order to present the data by

## Table 2.1 - Number of Nuclear Plant Data Points by Year

| Country | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 |
|---|---|---|---|---|---|---|---|---|---|---|
| France | | | | | | | | | | |
| PWR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 19 | 24 |
| Germany | | | | | | | | | | |
| PWR | 3 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 7 |
| BWR | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 4 | 4 | 4 |
| Japan | | | | | | | | | | |
| PWR | 4 | 5 | 6 | 6 | 8 | 8 | 9 | 10 | 10 | 11 |
| BWR | 3 | 5 | 5 | 9 | 10 | 10 | 10 | 11 | 11 | 13 |
| Sweden | | | | | | | | | | |
| PWR | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 |
| BWR | 2 | 4 | 4 | 5 | 5 | 5 | 7 | 7 | 7 | 7 |
| Switzerland | | | | | | | | | | |
| PWR | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| BWR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| United States | | | | | | | | | | |
| PWR | 27 | 30 | 36 | 39 | 40 | 41 | 46 | 47 | 49 | 52 |
| BWR | 18 | 19 | 21 | 21 | 22 | 22 | 22 | 22 | 23 | 25 |

## Table 2.2 - Number of Nuclear Plant Data Points by Reactor Age

| Country | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| France | | | | | | | | | | | | | | | | | |
| PWR | 8 | 14 | 14 | 13 | 6 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Germany | | | | | | | | | | | | | | | | | |
| PWR | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 0 |
| BWR | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Japan | | | | | | | | | | | | | | | | | |
| PWR | 9 | 9 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| BWR | 11 | 10 | 10 | 9 | 10 | 9 | 5 | 5 | 5 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| Sweden | | | | | | | | | | | | | | | | | |
| PWR | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BWR | 5 | 6 | 6 | 6 | 5 | 5 | 5 | 4 | 4 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Switzerland | | | | | | | | | | | | | | | | | |
| PWR | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| BWR | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| United States | | | | | | | | | | | | | | | | | |
| PWR | 37 | 36 | 41 | 37 | 38 | 38 | 35 | 34 | 29 | 26 | 15 | 11 | 6 | 5 | 3 | 2 | 2 |
| BWR | 14 | 12 | 17 | 19 | 20 | 21 | 21 | 21 | 19 | 16 | 10 | 10 | 5 | 3 | 2 | 0 | 0 |

reactor age, it had to be converted. Unfortunately, only the calendar year in which an outage occurred was provided with the data. Therefore the calculation of reactor age had to be based on calendar age. This was accomplished by calculating the age by one of two different ways, depending upon the date of first commercial operation.

The first method of calculation was for plants that had their commercial operation date in the first half of the year, prior to July 1. In this case, the calendar year in which the plant first went into commercial operation was counted as the first year. As an example, for a plant with a commercial operation date of 3/1/75, the data for 1975 was considered its first year of operation or AGE = 1.

The second method of calculation was for plants that had their commercial operation date after June 30. For these plants, the data for the calendar year in which they first went into commercial operation was not counted. For example, a nuclear plant with a commercial operation date of 9/1/78 had 1979 counted as its first year of operation or AGE = 1. The 1978 data was not used.

All aggregate averages by reactor age, irrespective of the age calculation method used, were calculated by weighting each individual data point to account for the partial years of commercial operation (see Appendix B for weighting method).

A limitation exists in the interpretation of performance data as a function of plant age. This limitation arises from the fact that only 10 years of data was collected for any given plant. The performance data spans reactors from 1 to 17 years of age. As a result, the reactors contributing data to ages 11 and above do not contribute to the data in the younger ages. This means that the data in ages 1 through 7 are primarily from new plants while the data in the older ages is from old plants. In the ages in between, the data is from a mixture of both old and new plants. Since nuclear plant technology, operating policies, and regulatory climate are a function of time and not plant age, the missing data from the older plants may not follow the same trends as the new plants exhibit. Thus, it cannot always be determined whether an observation made is a function of plant age or the state of the nuclear industry at that time. Therefore, when comparing data from the two extremes of the age range, only observations relative to their respective performance during the 10 year period can be made. In this report, age dependent observations will be made. It is up to the reader to decide upon the validity of these observations.

This chapter also contains tables and figures containing average capacity or energy availability factors as functions of calendar year and reactor age. In addition, the standard deviation of the mean is also tabulated. The capacity factors and standard deviations in the tables were weighted to account for those nuclear plants coming online in the middle of the calendar year. The calculation of the standard deviation was done using the population method which yields more meaningful values when the number of data points is low. One assumption made in calculating the standard deviations was that the distribution of capacity factors was Gaussian, which may not always be correct. The true shape of the distribution was not determined and is left for further study. The equations used for these calculations are given in Appendix B.

## 2.1 France

In this section the performance losses for the French nuclear power plants are presented and briefly examined. Energy availability was the performance index used to describe the French losses.

### 2.1.1 Aggregated Data

The French PWR performance data is tabulated by year in Table 2.3 and by reactor age in Table 2.4. Table 2.5 contains the average PWR energy availability factors and standard deviations as a function of year and reactor age. There were no BWR's operating in France at the time of this study. The scheduled outages were only available in aggregate form and so only the total scheduled loss is tabulated.

### 2.1.2 Capacity Factor Distribution

The French PWR energy availability factor distribution as a function of time is plotted in Figure 2.1. For the last three years the average energy availability has increased from 63.1% to 81.6%, with an average of 73.1%. In addition, the figure shows that the yearly standard deviation of the mean has been steadily decreasing as performance increased. As the maximum performance of 100% is approached, all of the plants must be close to the average, since the ability of the high performance plants to compensate for those below the average becomes diminished. The magnitude of the standard deviation in 1982 indicates that some of the plants performed exceptionally that year while others performed poorly.

The PWR energy availability factor distribution by reactor age is shown graphically in Figure 2.2. No age dependence is exhibited in the PWR performance or in the standard deviations.

### 2.1.3 Losses by Outage Type

In this subsection, forced, scheduled, and regulatory losses for the French nuclear plants are displayed and examined as functions of time and age.

Forced, scheduled and regulatory losses are plotted over time in Figure 2.3 for the French PWR's. Consistent with Figure 2.1, the total losses decrease over time. The figure also shows that both the forced and scheduled losses have decreased over time. The forced outages, which accounted for an average of 32.0% of the total losses, were almost entirely responsible for the decrease in total losses from 1982 to 1983. The specific category responsible for the reduction was forced NSSS OTHER losses. Improvements in the scheduled outages, which represented 66.2% of the total average loss, were the cause of the reduction of total losses from 1983 to 1984. The specific scheduled loss category showing the reduction in losses cannot be determined as the scheduled losses were not available in disaggregate form. There have been no reported French regulatory losses.

The same loss categories are plotted as a function of age in Figure 2.4. The forced, scheduled, and total losses fluctuate over age and do not exhibit an age dependency.

### 2.1.4 NSSS and BOP Losses

The losses in the Nuclear Steam Supply System (NSSS) and the Balance of Plant (BOP) cannot be examined for the French nuclear power plants because the data was not available in completely disaggregated form.

# Table 2.3
## French PWR Energy Availabilty Losses By Year

ENERGY AVAIL. LOSSES 1980 - 1984 — FRANCE ALL PWR'S

04/22/86

| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| DATA: | | | ( 0) | ( 0) | (19) | (19) | (24) |
| FORCED | NSSS | FUEL | | | 0.000 | 0.000 | 0.000 |
| | | RCS | | | 0.014 | 0.001 | 0.000 |
| | | SG | | | 0.003 | 0.005 | 0.006 |
| | | REFUEL | | | 0.000 | 0.000 | 0.000 |
| | | OTHER | | | 0.076 | 0.007 | 0.002 |
| | | | | | 0.093 | 0.013 | 0.009 |
| | BOP | TURBINE | | | 0.005 | 0.009 | 0.005 |
| | | GEN | | | 0.009 | 0.008 | 0.004 |
| | | COND | | | 0.004 | 0.004 | 0.001 |
| | | CW/SW/CCW | | | 0.001 | 0.002 | 0.001 |
| | | OTHER | | | 0.019 | 0.008 | 0.010 |
| | | | | | 0.038 | 0.031 | 0.021 |
| | ECONOMIC | | | | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | 0.001 | 0.001 | 0.001 |
| | OTHER | | | | 0.027 | 0.017 | 0.017 |
| | TOTAL | | | | 0.159 | 0.061 | 0.047 |
| SCHEDULED | NSSS | FUEL | | | | | |
| | | RCS | | | | | |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | | | | | |
| | | | | | | | |
| | BOP | TURBINE | | | | | |
| | | GEN | | | | | |
| | | COND | | | | | |
| | | CW/SW/CCW | | | | | |
| | | OTHER | | | | | |
| | | | | | | | |
| | ECONOMIC | | | | | | |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | | | 0.204 | 0.210 | 0.132 |
| REGULATORY | | | | | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | | 0.006 | 0.004 | 0.005 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | | | 0.369 | 0.276 | 0.184 |
| ** ENERGY AVAIL. FACTOR ** | | | | | 0.631 | 0.724 | 0.816 |

Table 2.3 - (Continued)

ENERGY AVAIL. LOSSES FRANCE
1975 - 1984 ALL PWR'S

04/22/86 DATA:24 PLANTS 62 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 |
| | | RCS | 0.005 |
| | | SG | 0.005 |
| | | REFUEL | 0.000 |
| | | OTHER | 0.026 |
| | | | ------ |
| | | | 0.036 |
| | BOP | TURBINE | 0.006 |
| | | GEN | 0.007 |
| | | COND | 0.003 |
| | | CW/SW/CCW | 0.001 |
| | | OTHER | 0.012 |
| | | | ------ |
| | | | 0.029 |
| | ECONOMIC | | 0.000 |
| | HUMAN | | 0.001 |
| | OTHER | | 0.020 |
| | TOTAL | | 0.086 |
| SCHEDULED | NSSS | FUEL | |
| | | RCS | |
| | | SG | |
| | | REFUEL | |
| | | OTHER | |
| | | | ------ |
| | BOP | TURBINE | |
| | | GEN | |
| | | COND | |
| | | CW/SW/CCW | |
| | | OTHER | |
| | | | ------ |
| | ECONOMIC | | |
| | HUMAN | | |
| | OTHER | | |
| | TOTAL | | 0.178 |
| REGULATORY | | | 0.000 |
| UNKNOWN | | | 0.005 |

** TOTAL ENERGY AVAIL. LOSS ** 0.269

** ENERGY AVAIL. FACTOR ** 0.731

## Table 2.4
## French PWR Energy Availabilty Losses
## By Reactor Age

ENERGY AVAIL. LOSSES BY REACTOR AGE — FRANCE
1975 - 1984 — ALL PWR'S

04/22/86

| | | | DATA: | ( 8) | (14) | (14) | (13) | ( 6) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.013 | 0.012 | 0.001 | 0.000 | 0.000 |
| | | SG | | 0.000 | 0.003 | 0.005 | 0.011 | 0.007 |
| | | REFUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.005 | 0.030 | 0.004 | 0.039 | 0.096 |
| | | | | 0.018 | 0.045 | 0.010 | 0.050 | 0.103 |
| | BOP | TURBINE | | 0.014 | 0.008 | 0.005 | 0.003 | 0.002 |
| | | GEN | | 0.015 | 0.005 | 0.011 | 0.003 | 0.000 |
| | | COND | | 0.002 | 0.003 | 0.006 | 0.003 | 0.001 |
| | | CW/SW/CCW | | 0.003 | 0.001 | 0.002 | 0.000 | 0.001 |
| | | OTHER | | 0.015 | 0.012 | 0.008 | 0.007 | 0.026 |
| | | | | 0.049 | 0.029 | 0.032 | 0.016 | 0.030 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 |
| | OTHER | | | 0.037 | 0.030 | 0.016 | 0.009 | 0.011 |
| | TOTAL | | | 0.107 | 0.105 | 0.057 | 0.076 | 0.145 |
| SCHEDULED | NSSS | FUEL | | | | | | |
| | | RCS | | | | | | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | | | | | |
| | | | | | | | | |
| | BOP | TURBINE | | | | | | |
| | | GEN | | | | | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | | | | | |
| | | OTHER | | | | | | |
| | | | | | | | | |
| | ECONOMIC | | | | | | | |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.122 | 0.299 | 0.147 | 0.143 | 0.130 |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.006 | 0.004 | 0.005 | 0.004 | 0.006 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | | 0.235 | 0.408 | 0.209 | 0.223 | 0.281 |
| ** ENERGY AVAIL. FACTOR ** | | | | 0.765 | 0.592 | 0.791 | 0.777 | 0.719 |

Table 2.4 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE FRANCE
1975 - 1984 ALL PWR'S

04/08/86

| | | | DATA: ( 5) | ( 2) | ( 0) | ( 0) | ( 0) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | | | |
| | | RCS | 0.000 | 0.000 | | | |
| | | SG | 0.001 | 0.006 | | | |
| | | REFUEL | 0.000 | 0.000 | | | |
| | | OTHER | 0.003 | 0.002 | | | |
| | | | 0.004 | 0.008 | | | |
| | BOP | TURBINE | 0.007 | 0.004 | | | |
| | | GEN | 0.009 | 0.000 | | | |
| | | COND | 0.000 | 0.000 | | | |
| | | CW/SW/CCW | 0.001 | 0.000 | | | |
| | | OTHER | 0.016 | 0.002 | | | |
| | | | 0.033 | 0.006 | | | |
| | ECONOMIC | | 0.000 | 0.000 | | | |
| | HUMAN | | 0.001 | 0.000 | | | |
| | OTHER | | 0.019 | 0.012 | | | |
| | TOTAL | | 0.057 | 0.026 | | | |
| SCHEDULED | NSSS | FUEL | | | | | |
| | | RCS | | | | | |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | | | | | |
| | | | | | | | |
| | BOP | TURBINE | | | | | |
| | | GEN | | | | | |
| | | COND | | | | | |
| | | CW/SW/CCW | | | | | |
| | | OTHER | | | | | |
| | | | | | | | |
| | ECONOMIC | | | | | | |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.192 | 0.101 | | | |
| REGULATORY | | | 0.000 | 0.000 | | | |
| UNKNOWN | | | 0.006 | 0.004 | | | |

** TOTAL ENERGY AVAIL. LOSS ** 0.255 0.131

** ENERGY AVAIL. FACTOR ** 0.745 0.869

Table 2.5 - French Capacity Factor Distributions

| By Year | PWR Mean | PWR σ | PWR # Data | BWR Mean | BWR σ | BWR # Data |
|---|---|---|---|---|---|---|
| 75 | | | | | | |
| 76 | | | | | | |
| 77 | | | | | | |
| 78 | | | | | | |
| 79 | | | | | | |
| 80 | | | | | NA | |
| 81 | | | | | | |
| 82 | 0.631 | 0.201 | 19 | | | |
| 83 | 0.724 | 0.111 | 19 | | | |
| 84 | 0.816 | 0.073 | 24 | | | |

| By Age | PWR Mean | PWR σ | PWR # Data | BWR Mean | BWR σ | BWR # Data |
|---|---|---|---|---|---|---|
| 1 | 0.765 | 0.092 | 8 | | | |
| 2 | 0.591 | 0.174 | 14 | | | |
| 3 | 0.791 | 0.072 | 14 | | | |
| 4 | 0.777 | 0.118 | 13 | | | |
| 5 | 0.719 | 0.224 | 6 | | | |
| 6 | 0.745 | 0.095 | 5 | | | |
| 7 | 0.869 | 0.012 | 2 | | | |
| 8 | | | | | | |
| 9 | | | | | NA | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| 13 | | | | | | |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |

Figure 2.1
French PWR Capacity Factor Distribution
By Year

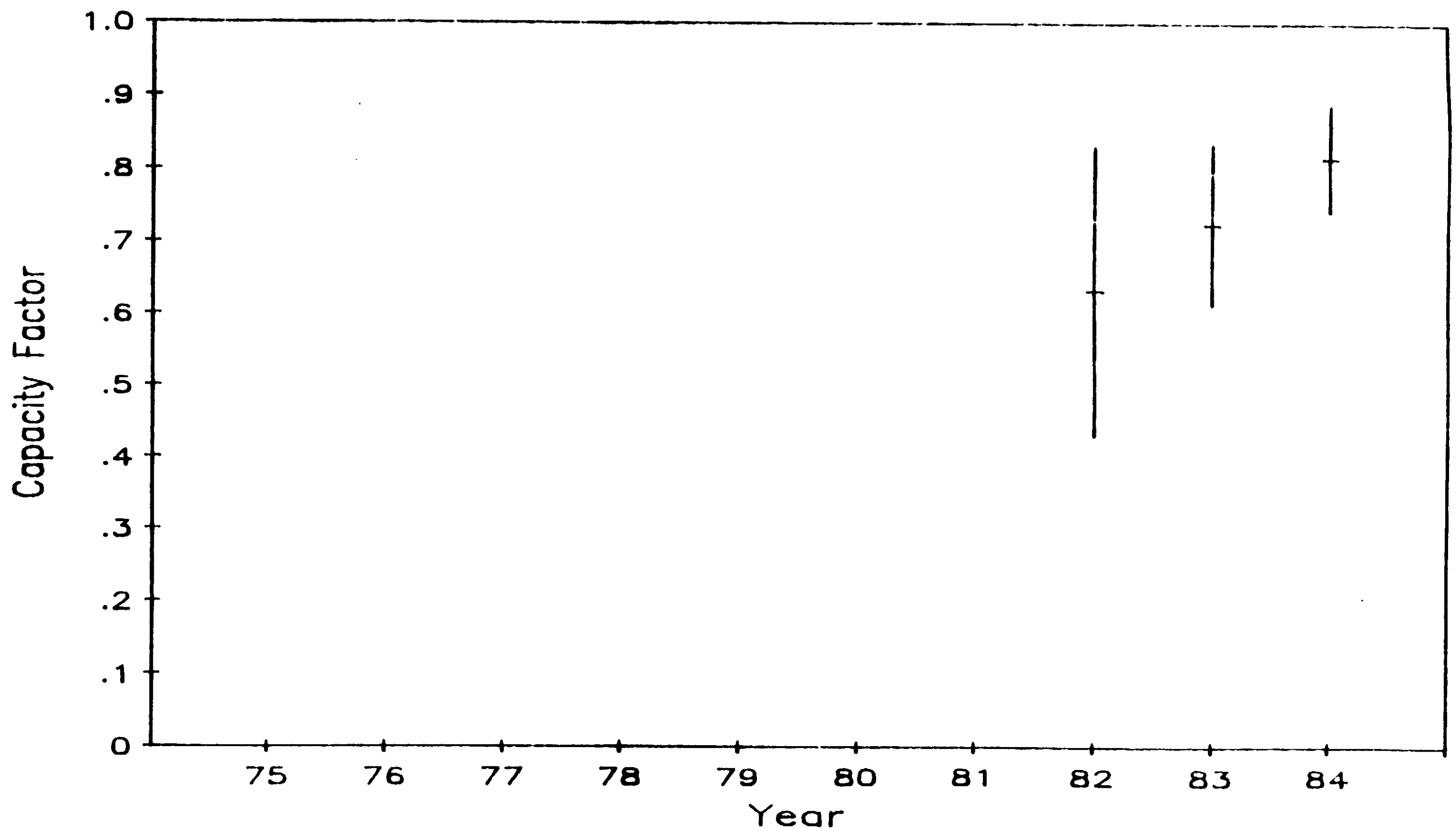
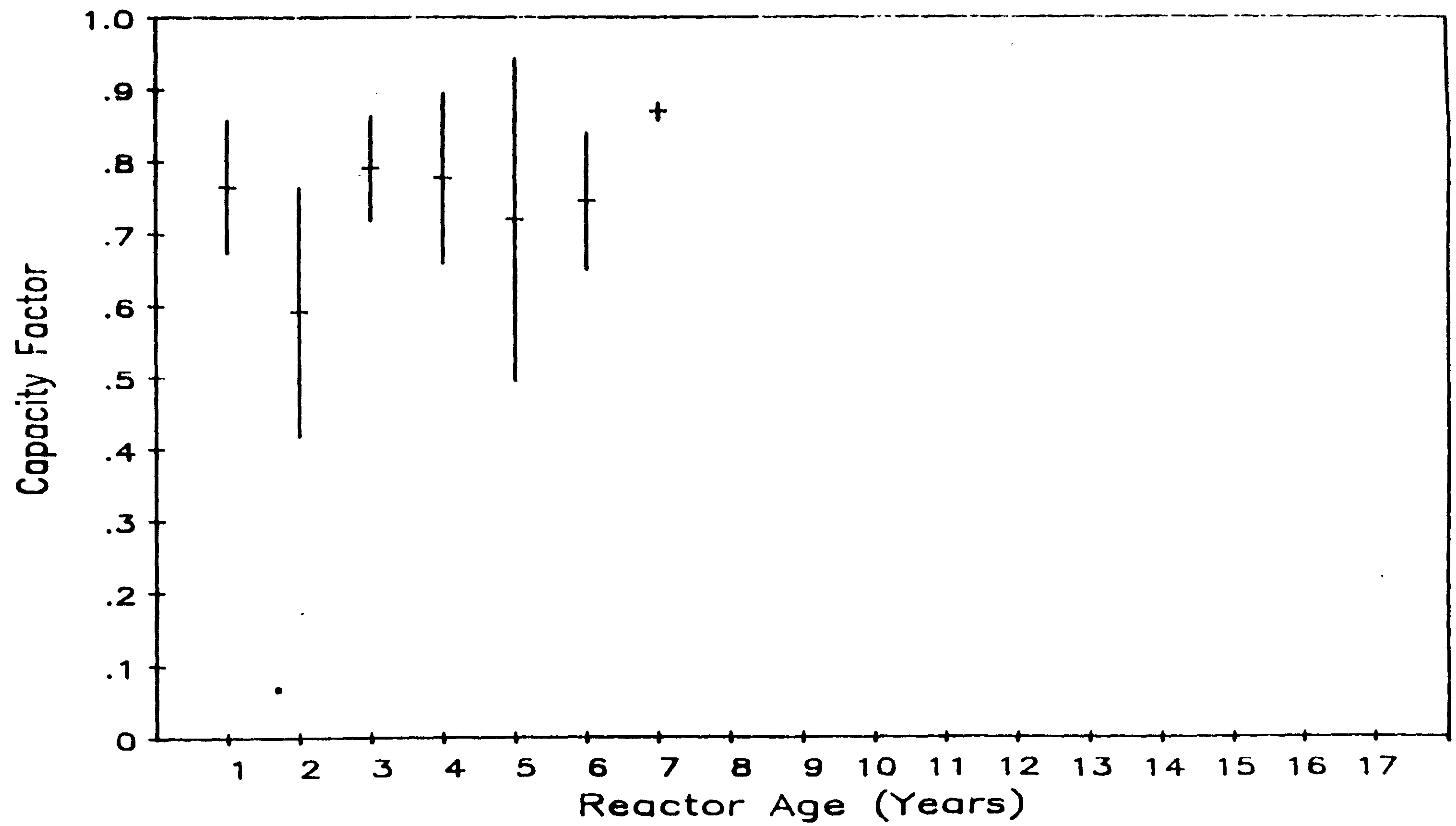
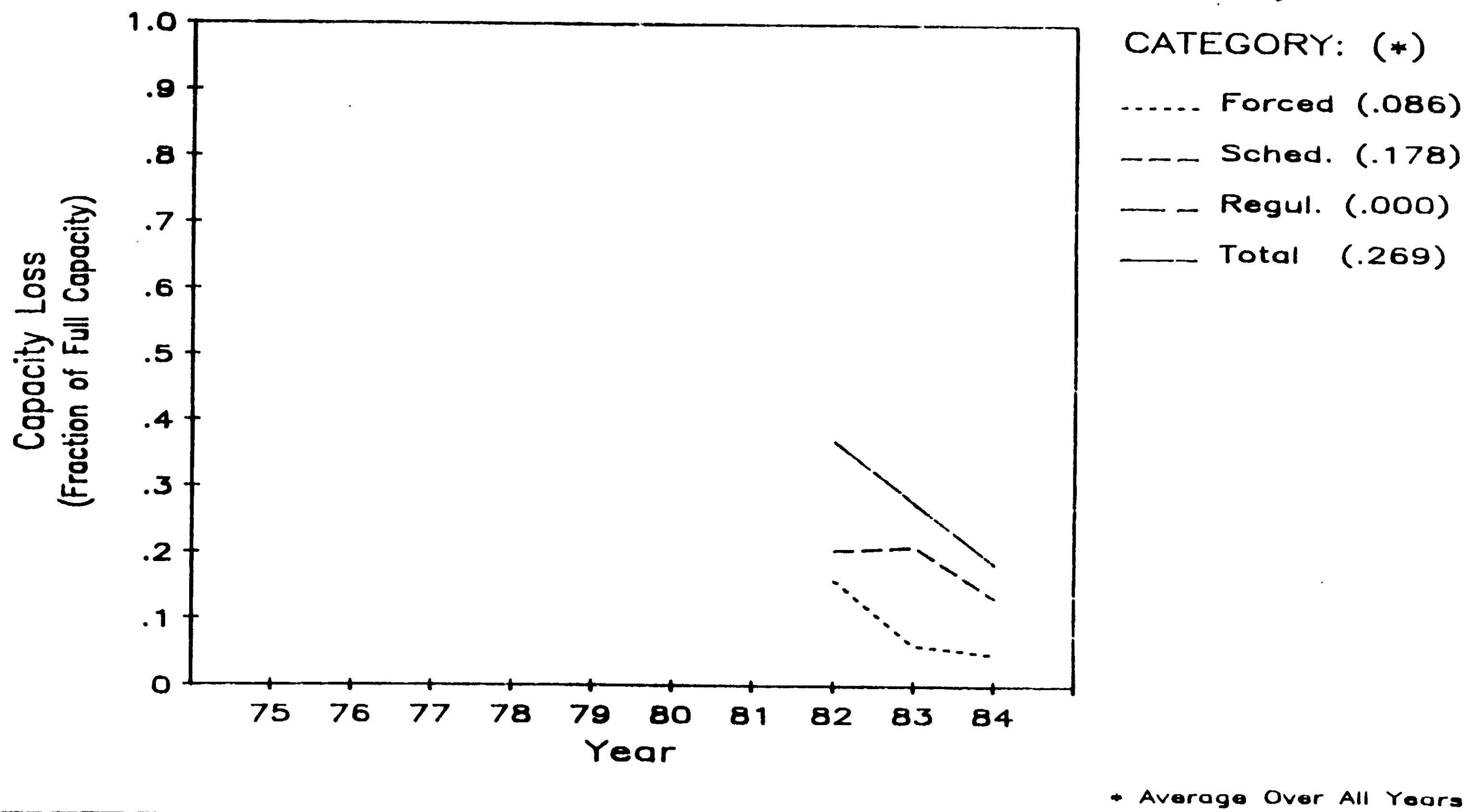


Figure 2.2
French PWR Capacity Factor Distribution
By Reactor Age



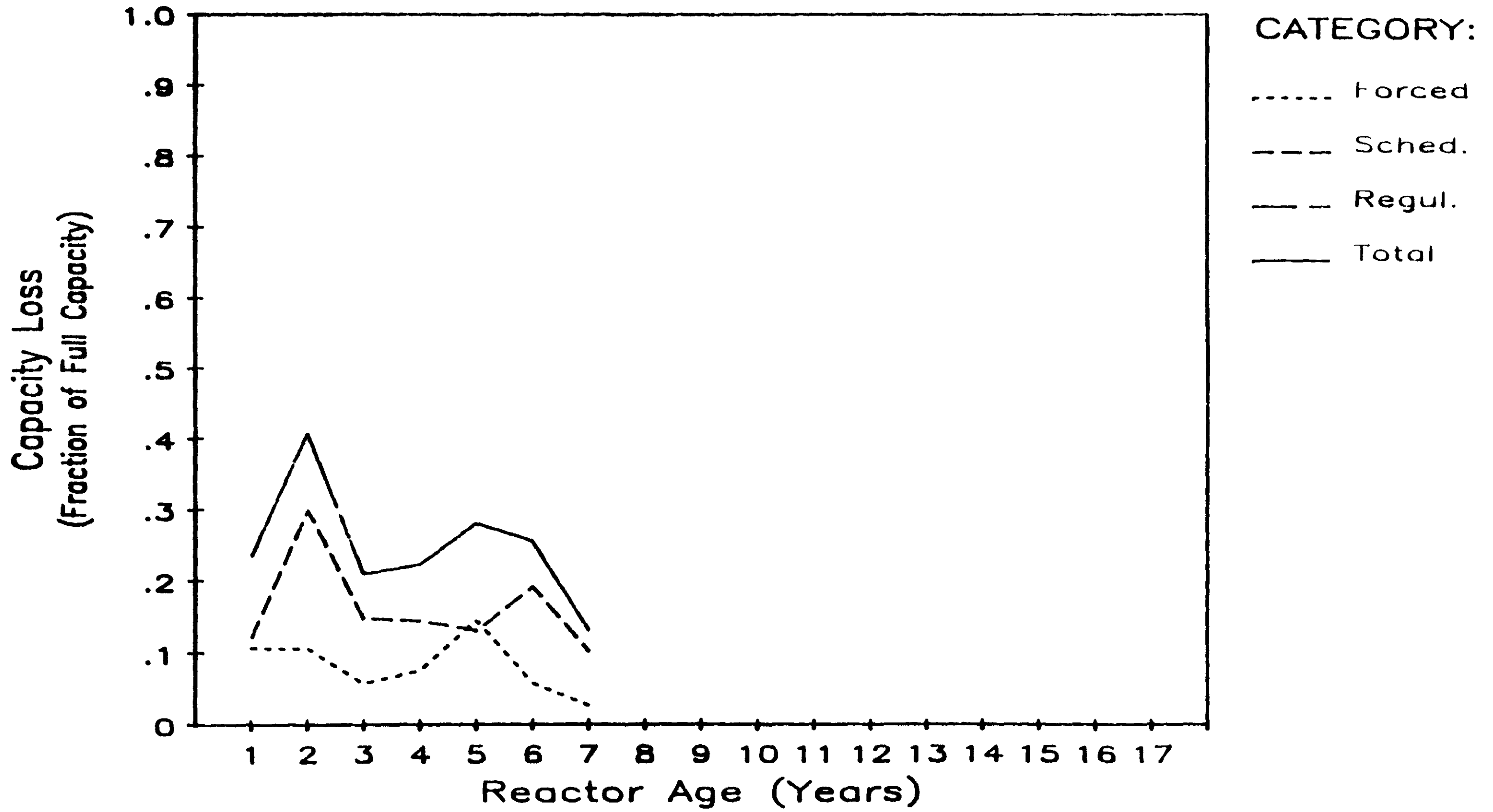
## Figure 2.3

French PWR Capacity Losses By Year
Forced, Scheduled, and Regulatory



## Figure 2.4

French PWR Capacity Losses By Reactor Age
Forced, Scheduled, and Regulatory



## 2.2 Germany

In this section the performance losses for the German nuclear power plants are presented and briefly examined. Energy availability was the performance index used to describe the German losses.

### 2.2.1 Aggregated Data

Performance losses for the German PWR's are tabulated by calendar year and by reactor age in Table 2.6 and Table 2.7 respectively. BWR energy availability losses are given by calendar year in Table 2.8 and by reactor age in Table 2.9. Finally, the mean and the standard deviation of the energy availability factors are tabulated by year and by age in Table 2.10.

### 2.2.2 Capacity Factor Distribution

The German PWR energy availability factor distribution is plotted over time in Figure 2.5. The figure displays a dip in the performance between 1975 and 1984 with the bottom occurring in 1979. The cause of this drop was an increase in refueling losses during this period. The average energy availability factor for the 10 years was 78.2%. The average magnitude of the standard deviations is smaller than that of the French PWR's with no trend over time visible. They do, however, show the same general correlation between performance and the magnitude of the standard deviation.

The energy availability as a function of age for the German PWR's is given in Figure 2.6. A slight increase in performance with age is observable amid the fluctuation shown. This trend is probably not significant since the number of plants at each age is not large and because the magnitude of the trend is small. The standard deviations display a trend of decreasing magnitudes with age. This was caused by the decrease in the number of plants making up the data at each age.

The energy availability over time is plotted in Figure 2.7 for the German BWR's. The performance for these plants shows a very large drop in performance, from 88.7% in 1975 to 30.1% in 1979. From 1980 the performance began to climb back to its previous level. The causes of these tremendous losses were large outages for pipe replacements made under the Basis Safety Concept discussed in Appendix C. In addition, several of large regulatory losses also contributed at a couple of plants. The standard deviations shown indicate that between 1979 and 1983, large variations in performance occurred between plants in a given year. Thus, the impact of the Basis Safety Concept over time was not uniformly distributed among the BWR's.

The same BWR energy availability data are shown as a function of age in Figure 2.8. The Basis Safety Concept pipe replacement losses occurred during a limited period of time, and were not dependent upon plant age. The data points showing relatively low performance, with or without large standard deviations, represent the ages where the pipe replacements occurred. Thus, no age dependency is observable.

### 2.2.3 Losses by Outage Type

In this subsection, forced, scheduled, and regulatory losses for the German nuclear plants are displayed and examined as functions of time and age.

Forced, scheduled, and regulatory losses for German PWR's are plotted versus time in Figure 2.9. Forced losses averaged 2.3% over the 10 years, representing 10.6% of the total losses. Forced outages generally were not a problem in the German PWR's with the exception of 1977 and 1983. In 1977 the forced losses were larger as a result of outages at three plants that averaged 10% each, including a 9.7% generator loss at one particular plant. The scheduled losses, averaging 18.5% over the entire period, represent 84.9% of the average total loss of 21.8%. There is a wide peak in the scheduled losses spanning 1978 to 1981. This peak was a result of increased refueling losses in those years. The cause for the increased refueling outages is not known. Regulatory losses have been low, averaging less than 1.0%, or 4.1% of the total losses. There are no time dependent trends visible in this figure.

The same PWR losses are plotted by reactor age in Figure 2.10. Overall, the German losses exhibit a slight improvement over age with approximately 5% variation occurring between ages. The scheduled outages represent an average 85% of the total losses and therefore show the same trend as the total losses. This trend, however, is probably insignificant due to its small magnitude and the amount of fluctuation present. The regulatory losses have only affected PWR's through age 8, even though some plants are up to 16 years old.

Forced, scheduled, and regulatory losses by year for German BWR's are shown graphically in Figure 2.11. Overall, the total losses have been large, with an average total loss over the 10 year period of 48.9%. The large total losses have had contributions from all three of the categories shown with none of them showing a significant trend. Scheduled losses have been the largest contributor, averaging 62.8% of the total. The figure shows that scheduled losses were generally constant at 11.5% from 1975 to 1978 but then began to increase steeply to 54.3% in 1982. The cause of this increase was large outages for pipe replacement under the Basis Safety Concept. Forced outages contributed to the large total loss in 1977 and 1978 as a result of a large reactor cooling system outage in 1977 at one plant and a large NSSS OTHER loss in 1978 at another. Regulatory losses have also played a role in the overall losses with large losses at several plants in 1979 and 1980.

Figure 2.12 displays the German BWR losses as a function of age. A large amount of fluctuation is visible in the scheduled outages as a result of the pipe replacements which were time and not age dependent. The forced outages show an age dependence with losses decreasing with plant age. This can be attributed to reductions in losses in several NSSS categories. The regulatory losses fluctuate with age and do not exhibit any age dependency.

### 2.2.4 NSSS and BOP Losses

In this subsection the losses in the Nuclear Steam Supply System (NSSS) and the Balance of Plant (BOP) are displayed and examined as functions of time and reactor age for the German nuclear power plants.

NSSS and BOP losses are plotted by year for the German PWR's in Figure 2.13. NSSS losses have been the largest contributor to the total representing 78.9%. Refueling was the largest part of this, averaging 88.4% of the total NSSS loss. Losses in the reactor coolant system were responsible for an average of 4.7% of the NSSS losses. The peak in the NSSS losses shown in 1979 and 1980 was the result of large refuelings at several plants. The BOP losses have generally been small, averaging 1.9% per year or only 8.7% of the total losses. Several peaks are shown in 1977, 1981, and 1983 which were caused primarily by generator problems. Over the 10 year period, generator problems accounted for 52.6% of all the BOP losses. The condensers and turbines were each responsible for 15.8% of all BOP losses during the same period. Neither the NSSS or BOP exhibit a time dependent trend in PWR's.

The PWR losses are plotted against reactor age in Figure 2.14. This picture shows that the BOP losses are age dependent as almost all of the BOP losses occur prior to age 10. After age 9, nearly all of the total losses are can be attributed to the NSSS. The NSSS losses fluctuate and generally decrease with age.

NSSS and BOP losses are plotted by year in Figure 2.15 for the German BWR's. This figure shows a large separation between the NSSS and Total losses. The average NSSS contribution to the total losses was 65.8%. Refueling losses accounted for 36.6% of the NSSS losses and the reactor coolant system 54.3%. The large fraction contributed by the reactor coolant system was the result of the pipe replacements performed under the Basis Safety Concept. The BOP losses averaged 2.7% per year or 5.5% of all losses. The primary contributors to the BOP losses were the turbines with 40.7% and the condensers which were responsible for 33.3%. Neither the NSSS or BOP losses were dependent on time.

The NSSS and BOP losses are plotted by age in Figure 2.16 for the German BWR's. The NSSS losses display a large amount of variation in this figure and exhibit no trend. The variation was the result of the pipe replacements which were time, not age, dependent. As with the PWR's, the BWR BOP losses decrease with age. The magnitude of the decrease is small and exhibits fluctuation from year to year. The fluctuation present indicates that the improvement in the BOP losses was the result of a general reduction in all BOP categories.

Table 2.6
German PWR Energy Availability Losses
By Year

ENERGY AVAIL. LOSSES GERMANY
1975 - 1979 ALL PWR'S

04/15/86

| | | | | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|
| | | | DATA: | ( 3) | ( 4) | ( 5) | ( 5) | ( 6) |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.002 | 0.006 | 0.005 | 0.002 | 0.001 |
| | | SG | | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | | REFUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.021 | 0.001 | 0.000 |
| | | | | 0.002 | 0.006 | 0.027 | 0.004 | 0.001 |
| | BOP | TURBINE | | 0.001 | 0.000 | 0.013 | 0.000 | 0.001 |
| | | GEN | | 0.000 | 0.000 | 0.021 | 0.005 | 0.000 |
| | | COND | | 0.001 | 0.000 | 0.005 | 0.002 | 0.000 |
| | | CW/SW/CCW | | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.022 | 0.000 | 0.000 |
| | | | | 0.008 | 0.000 | 0.060 | 0.007 | 0.001 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.000 | 0.002 | 0.004 | 0.000 | 0.000 |
| | TOTAL | | | 0.011 | 0.008 | 0.099 | 0.012 | 0.002 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.001 | 0.000 | 0.006 |
| | | RCS | | 0.015 | 0.002 | 0.000 | 0.023 | 0.016 |
| | | SG | | 0.000 | 0.004 | 0.007 | 0.001 | 0.000 |
| | | REFUEL | | 0.084 | 0.145 | 0.123 | 0.162 | 0.194 |
| | | OTHER | | 0.000 | 0.027 | 0.001 | 0.001 | 0.006 |
| | | | | 0.099 | 0.177 | 0.132 | 0.187 | 0.222 |
| | BOP | TURBINE | | 0.003 | 0.007 | 0.001 | 0.000 | 0.001 |
| | | GEN | | 0.000 | 0.001 | 0.007 | 0.001 | 0.001 |
| | | COND | | 0.014 | 0.000 | 0.001 | 0.000 | 0.001 |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.018 | 0.008 | 0.009 | 0.002 | 0.002 |
| | ECONOMIC | | | 0.007 | 0.000 | 0.002 | 0.006 | 0.090 |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 |
| | TOTAL | | | 0.123 | 0.185 | 0.144 | 0.195 | 0.317 |
| REGULATORY | | | | 0.001 | 0.026 | 0.002 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.006 | 0.002 | 0.001 | 0.002 | 0.000 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | | 0.141 | 0.222 | 0.246 | 0.208 | 0.319 |
| ** ENERGY AVAIL. FACTOR ** | | | | 0.859 | 0.778 | 0.754 | 0.792 | 0.681 |

## Table 2.6 - (Continued)

ENERGY AVAIL. LOSSES GERMANY
1980 - 1984 ALL PWR'S

04/15/86

| | | | DATA:( 6) | ( 6) | ( 7) | ( 7) | ( 7) |
|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 |
| | | SG | 0.000 | 0.002 | 0.000 | 0.012 | 0.015 |
| | | REFUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.002 | 0.000 | 0.001 |
| | | | 0.001 | 0.003 | 0.002 | 0.013 | 0.016 |
| | BOP | TURBINE | 0.000 | 0.006 | 0.000 | 0.001 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.045 | 0.001 |
| | | COND | 0.000 | 0.002 | 0.000 | 0.001 | 0.000 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | | 0.000 | 0.009 | 0.001 | 0.046 | 0.001 |
| | ECONOMIC | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | TOTAL | | 0.002 | 0.012 | 0.003 | 0.059 | 0.017 |
| SCHEDULED | NSSS | FUEL | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.004 | 0.005 | 0.002 | 0.003 | 0.000 |
| | | SG | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | 0.276 | 0.152 | 0.117 | 0.139 | 0.103 |
| | | OTHER | 0.004 | 0.004 | 0.000 | 0.002 | 0.000 |
| | | | 0.286 | 0.164 | 0.120 | 0.144 | 0.103 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 |
| | | GEN | 0.001 | 0.011 | 0.000 | 0.000 | 0.000 |
| | | COND | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| | | | 0.001 | 0.012 | 0.002 | 0.001 | 0.002 |
| | ECONOMIC | | 0.005 | 0.005 | 0.000 | 0.015 | 0.015 |
| | HUMAN | | | | | | |
| | OTHER | | 0.004 | 0.001 | 0.000 | 0.002 | 0.002 |
| | TOTAL | | 0.296 | 0.183 | 0.122 | 0.161 | 0.123 |
| REGULATORY | | | 0.007 | 0.006 | 0.007 | 0.004 | 0.028 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.305 | 0.200 | 0.132 | 0.226 | 0.169 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.695 | 0.800 | 0.868 | 0.774 | 0.831 |

## Table 2.6 - (Continued)

ENERGY AVAIL. LOSSES 1975 - 1984 — GERMANY, ALL PWR'S

04/15/86 — DATA: 7 PLANTS — 56 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 |
| | | RCS | 0.002 |
| | | SG | 0.004 |
| | | REFUEL | 0.000 |
| | | OTHER | 0.002 |
| | | | 0.008 |
| | BOP | TURBINE | 0.002 |
| | | GEN | 0.008 |
| | | COND | 0.001 |
| | | CW/SW/CCW | 0.000 |
| | | OTHER | 0.002 |
| | | | 0.014 |
| | ECONOMIC | | 0.001 |
| | HUMAN | | |
| | OTHER | | 0.001 |
| | TOTAL | | 0.023 |
| SCHEDULED | NSSS | FUEL | 0.001 |
| | | RCS | 0.006 |
| | | SG | 0.001 |
| | | REFUEL | 0.152 |
| | | OTHER | 0.004 |
| | | | 0.164 |
| | BOP | TURBINE | 0.001 |
| | | GEN | 0.002 |
| | | COND | 0.001 |
| | | CW/SW/CCW | 0.000 |
| | | OTHER | 0.000 |
| | | | 0.005 |
| | ECONOMIC | | 0.015 |
| | HUMAN | | |
| | OTHER | | 0.001 |
| | TOTAL | | 0.185 |
| REGULATORY | | | 0.009 |
| UNKNOWN | | | 0.001 |

** TOTAL ENERGY AVAIL. LOSS ** 0.218

** ENERGY AVAIL. FACTOR ** 0.782

## Table 2.7
## German PWR Energy Availability Losses By Reactor Age

ENERGY AVAIL. LOSSES BY REACTOR AGE — GERMANY
1975 - 1984 — ALL PWR'S

04/15/86

| | | DATA: | ( 5) | ( 5) | ( 5) | ( 5) | ( 5) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.002 | 0.004 | 0.005 | 0.000 | 0.000 |
| | | SG | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.024 | 0.001 | 0.001 | 0.001 | 0.000 |
| | | | 0.026 | 0.005 | 0.006 | 0.001 | 0.000 |
| | BOP | TURBINE | 0.001 | 0.006 | 0.012 | 0.002 | 0.001 |
| | | GEN | 0.001 | 0.000 | 0.000 | 0.015 | 0.000 |
| | | COND | 0.006 | 0.003 | 0.000 | 0.001 | 0.002 |
| | | CW/SW/CCW | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.023 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | | 0.034 | 0.009 | 0.013 | 0.018 | 0.003 |
| | ECONOMIC | | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.004 | 0.002 | 0.000 | 0.000 | 0.001 |
| | TOTAL | | 0.065 | 0.017 | 0.027 | 0.019 | 0.004 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.007 | 0.004 | 0.000 |
| | | RCS | 0.010 | 0.023 | 0.000 | 0.000 | 0.017 |
| | | SG | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | 0.083 | 0.191 | 0.210 | 0.198 | 0.109 |
| | | OTHER | 0.001 | 0.000 | 0.001 | 0.000 | 0.003 |
| | | | 0.094 | 0.214 | 0.218 | 0.202 | 0.129 |
| | BOP | TURBINE | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 |
| | | GEN | 0.006 | 0.002 | 0.003 | 0.001 | 0.000 |
| | | COND | 0.007 | 0.001 | 0.001 | 0.003 | 0.000 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.014 | 0.004 | 0.006 | 0.006 | 0.001 |
| | ECONOMIC | | 0.000 | 0.002 | 0.052 | 0.016 | 0.042 |
| | HUMAN | | | | | | |
| | OTHER | | 0.004 | 0.002 | 0.000 | 0.001 | 0.002 |
| | TOTAL | | 0.111 | 0.222 | 0.276 | 0.225 | 0.175 |
| REGULATORY | | | 0.005 | 0.017 | 0.010 | 0.006 | 0.002 |
| UNKNOWN | | | 0.001 | 0.002 | 0.000 | 0.004 | 0.001 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.182 | 0.258 | 0.313 | 0.254 | 0.182 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.818 | 0.742 | 0.687 | 0.746 | 0.818 |

## Table 2.7 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE
1975 - 1984

GERMANY
ALL PWR'S

04/15/86

| | | | DATA: | ( 4) | ( 5) | ( 5) | ( 3) | ( 3) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.001 | 0.001 | 0.003 | 0.000 | 0.000 |
| | | SG | | 0.000 | 0.001 | 0.000 | 0.027 | 0.041 |
| | | REFUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | | | 0.001 | 0.002 | 0.004 | 0.027 | 0.041 |
| | BOP | TURBINE | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | | 0.000 | 0.053 | 0.000 | 0.032 | 0.001 |
| | | COND | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | | | 0.000 | 0.055 | 0.000 | 0.032 | 0.001 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.001 | 0.056 | 0.005 | 0.059 | 0.043 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.003 | 0.003 | 0.002 | 0.000 | 0.003 |
| | | SG | | 0.000 | 0.004 | 0.003 | 0.012 | 0.001 |
| | | REFUEL | | 0.218 | 0.104 | 0.121 | 0.157 | 0.177 |
| | | OTHER | | 0.002 | 0.000 | 0.000 | 0.002 | 0.001 |
| | | | | 0.223 | 0.111 | 0.126 | 0.171 | 0.182 |
| | BOP | TURBINE | | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 |
| | | GEN | | 0.000 | 0.013 | 0.000 | 0.000 | 0.000 |
| | | COND | | 0.002 | 0.000 | 0.002 | 0.000 | 0.001 |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | | | 0.002 | 0.013 | 0.006 | 0.000 | 0.001 |
| | ECONOMIC | | | 0.000 | 0.011 | 0.011 | 0.009 | 0.009 |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.227 | 0.136 | 0.143 | 0.180 | 0.192 |
| REGULATORY | | | | 0.008 | 0.004 | 0.044 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | | 0.236 | 0.197 | 0.192 | 0.240 | 0.235 |
| ** ENERGY AVAIL. FACTOR ** | | | | 0.764 | 0.803 | 0.808 | 0.760 | 0.765 |

## Table 2.7 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE — GERMANY
1975 - 1984 — ALL PWR'S

04/15/86

| | | | DATA: | ( 2) | ( 2) | ( 2) | ( 1) | ( 1) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 11 | 12 | 13 | 14 | 15 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.010 | 0.000 |
| | | | | 0.000 | 0.000 | 0.000 | 0.010 | 0.000 |
| | BOP | TURBINE | | 0.001 | 0.000 | 0.002 | 0.000 | 0.000 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.007 | 0.000 |
| | | OTHER | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | | | 0.001 | 0.001 | 0.002 | 0.007 | 0.000 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.001 | 0.001 | 0.002 | 0.018 | 0.000 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.006 | 0.004 | 0.003 | 0.000 | 0.018 |
| | | SG | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | | 0.130 | 0.173 | 0.118 | 0.149 | 0.298 |
| | | OTHER | | 0.000 | 0.009 | 0.009 | 0.000 | 0.004 |
| | | | | 0.136 | 0.186 | 0.130 | 0.149 | 0.320 |
| | BOP | TURBINE | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 |
| | ECONOMIC | | | 0.011 | 0.006 | 0.010 | 0.000 | 0.001 |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.003 | 0.005 | 0.001 | 0.000 | 0.000 |
| | TOTAL | | | 0.150 | 0.198 | 0.143 | 0.149 | 0.321 |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | | 0.151 | 0.199 | 0.145 | 0.167 | 0.321 |
| ** ENERGY AVAIL. FACTOR ** | | | | 0.849 | 0.801 | 0.855 | 0.833 | 0.679 |

## Table 2.7 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE — GERMANY
1975 - 1984 — ALL PWR'S

04/15/86 — DATA: ( 1) ( 0) ( 0) ( 0) ( 0)

| | | | AGE: 16 | 17 |
|---|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 | |
| | | RCS | 0.000 | |
| | | SG | 0.000 | |
| | | REFUEL | 0.000 | |
| | | OTHER | 0.000 | |
| | | | 0.000 | |
| | BOP | TURBINE | 0.000 | |
| | | GEN | 0.000 | |
| | | COND | 0.000 | |
| | | CW/SW/CCW | 0.002 | |
| | | OTHER | 0.000 | |
| | | | 0.002 | |
| | ECONOMIC | | 0.000 | |
| | HUMAN | | | |
| | OTHER | | 0.000 | |
| | TOTAL | | 0.002 | |
| SCHEDULED | NSSS | FUEL | 0.000 | |
| | | RCS | 0.000 | |
| | | SG | 0.000 | |
| | | REFUEL | 0.108 | |
| | | OTHER | 0.000 | |
| | | | 0.108 | |
| | BOP | TURBINE | 0.000 | |
| | | GEN | 0.000 | |
| | | COND | 0.000 | |
| | | CW/SW/CCW | 0.000 | |
| | | OTHER | 0.000 | |
| | | | 0.000 | |
| | ECONOMIC | | 0.026 | |
| | HUMAN | | | |
| | OTHER | | 0.012 | |
| | TOTAL | | 0.146 | |
| REGULATORY | | | 0.000 | |
| UNKNOWN | | | 0.000 | |

** TOTAL ENERGY AVAIL. LOSS ** 0.148

** ENERGY AVAIL. FACTOR ** 0.852

## Table 2.8
## German BWR Energy Availability Losses
## By Year

ENERGY AVAIL. LOSSES
1975 - 1979

GERMANY
ALL BWR'S

04/15/86

| | | | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| | | DATA: | ( 1) | ( 1) | ( 2) | ( 2) | ( 3) |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.003 | 0.184 | 0.020 | 0.006 |
| | | SG | | | | | |
| | | REFUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.011 | 0.000 | 0.275 | 0.008 |
| | | | 0.000 | 0.014 | 0.184 | 0.295 | 0.015 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.062 | 0.004 |
| | | GEN | 0.000 | 0.000 | 0.001 | 0.003 | 0.000 |
| | | COND | 0.000 | 0.000 | 0.002 | 0.005 | 0.001 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.000 | 0.000 | 0.004 | 0.070 | 0.013 |
| | ECONOMIC | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.000 | 0.000 | 0.000 | 0.010 | 0.000 |
| | TOTAL | | 0.000 | 0.014 | 0.188 | 0.375 | 0.028 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.000 | 0.099 | 0.113 | 0.098 | 0.201 |
| | | OTHER | 0.113 | 0.010 | 0.004 | 0.006 | 0.001 |
| | | | 0.113 | 0.108 | 0.118 | 0.104 | 0.201 |
| | BOP | TURBINE | 0.000 | 0.020 | 0.000 | 0.000 | 0.009 |
| | | GEN | 0.000 | 0.004 | 0.000 | 0.000 | 0.001 |
| | | COND | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| | | OTHER | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | | 0.000 | 0.024 | 0.001 | 0.000 | 0.019 |
| | ECONOMIC | | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| | HUMAN | | | | | | |
| | OTHER | | 0.000 | 0.000 | 0.001 | 0.002 | 0.001 |
| | TOTAL | | 0.113 | 0.132 | 0.119 | 0.106 | 0.222 |
| REGULATORY | | | 0.000 | 0.200 | 0.104 | 0.100 | 0.432 |
| UNKNOWN | | | 0.000 | 0.000 | 0.015 | 0.002 | 0.017 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.113 | 0.346 | 0.427 | 0.583 | 0.699 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.887 | 0.654 | 0.573 | 0.417 | 0.301 |

Table 2.8 - (Continued)

ENERGY AVAIL. LOSSES — GERMANY
1980 - 1984 — ALL BWR'S

04/15/86

| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| | | DATA: | ( 4) | ( 4) | ( 4) | ( 4) | ( 4) |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.002 | 0.005 | 0.001 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.006 | 0.007 | 0.008 | 0.000 | 0.001 |
| | | | 0.006 | 0.008 | 0.013 | 0.001 | 0.001 |
| | BOP | TURBINE | 0.001 | 0.003 | 0.002 | 0.002 | 0.016 |
| | | GEN | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 |
| | | COND | 0.008 | 0.033 | 0.005 | 0.001 | 0.002 |
| | | CW/SW/CCW | 0.010 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.012 | 0.003 | 0.000 | 0.009 | 0.000 |
| | | | 0.032 | 0.040 | 0.008 | 0.013 | 0.017 |
| | ECONOMIC | | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 |
| | HUMAN | | | | | | |
| | OTHER | | 0.002 | 0.001 | 0.001 | 0.002 | 0.000 |
| | TOTAL | | 0.039 | 0.050 | 0.021 | 0.015 | 0.026 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.165 | 0.206 | 0.432 | 0.302 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.085 | 0.148 | 0.072 | 0.095 | 0.152 |
| | | OTHER | 0.013 | 0.002 | 0.001 | 0.004 | 0.004 |
| | | | 0.263 | 0.356 | 0.505 | 0.401 | 0.156 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.000 | 0.010 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | CW/SW/CCW | 0.000 | 0.001 | 0.002 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.002 | 0.001 | 0.002 | 0.000 | 0.010 |
| | ECONOMIC | | 0.026 | 0.017 | 0.030 | 0.009 | 0.020 |
| | HUMAN | | | | | | |
| | OTHER | | 0.001 | 0.022 | 0.005 | 0.003 | 0.001 |
| | TOTAL | | 0.293 | 0.396 | 0.543 | 0.414 | 0.186 |
| REGULATORY | | | 0.268 | 0.054 | 0.014 | 0.002 | 0.000 |
| UNKNOWN | | | 0.008 | 0.000 | 0.004 | 0.005 | 0.000 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.608 | 0.500 | 0.581 | 0.436 | 0.212 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.392 | 0.500 | 0.419 | 0.564 | 0.788 |

Table 2.8 - (Continued)

ENERGY AVAIL. LOSSES 1975 - 1984 — GERMANY, ALL BWR'S

04/15/86 — DATA: 4 PLANTS — 29 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 |
| | | RCS | 0.016 |
| | | SG | |
| | | REFUEL | 0.000 |
| | | OTHER | 0.024 |
| | | | 0.040 |
| | BOP | TURBINE | 0.008 |
| | | GEN | 0.001 |
| | | COND | 0.008 |
| | | CW/SW/CCW | 0.002 |
| | | OTHER | 0.003 |
| | | | 0.022 |
| | ECONOMIC | | 0.001 |
| | HUMAN | | |
| | OTHER | | 0.002 |
| | TOTAL | | 0.065 |
| SCHEDULED | NSSS | FUEL | 0.000 |
| | | RCS | 0.159 |
| | | SG | |
| | | REFUEL | 0.118 |
| | | OTHER | 0.005 |
| | | | 0.282 |
| | BOP | TURBINE | 0.003 |
| | | GEN | 0.000 |
| | | COND | 0.001 |
| | | CW/SW/CCW | 0.001 |
| | | OTHER | 0.000 |
| | | | 0.005 |
| | ECONOMIC | | 0.015 |
| | HUMAN | | |
| | OTHER | | 0.005 |
| | TOTAL | | 0.307 |
| REGULATORY | | | 0.113 |
| UNKNOWN | | | 0.005 |

** TOTAL ENERGY AVAIL. LOSS ** 0.489

** ENERGY AVAIL. FACTOR ** 0.511

## Table 2.9
## German BWR Energy Availability Losses By Reactor Age

ENERGY AVAIL. LOSSES BY REACTOR AGE — GERMANY
1975 - 1984 — ALL BWR'S

04/15/86

| | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| | | DATA: | ( 4) | ( 4) | ( 4) | ( 4) | ( 4) |
| | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.098 | 0.011 | 0.005 | 0.004 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.008 | 0.137 | 0.011 | 0.003 | 0.004 |
| | | | 0.106 | 0.148 | 0.016 | 0.007 | 0.004 |
| | BOP | TURBINE | 0.004 | 0.007 | 0.025 | 0.001 | 0.004 |
| | | GEN | 0.000 | 0.002 | 0.001 | 0.001 | 0.000 |
| | | COND | 0.004 | 0.013 | 0.029 | 0.006 | 0.001 |
| | | CW/SW/CCW | 0.006 | 0.009 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.013 | 0.000 | 0.000 | 0.009 | 0.002 |
| | | | 0.027 | 0.031 | 0.055 | 0.017 | 0.007 |
| | ECONOMIC | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.000 | 0.007 | 0.000 | 0.001 | 0.000 |
| | TOTAL | | 0.133 | 0.187 | 0.071 | 0.025 | 0.011 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.175 | 0.206 | 0.000 | 0.189 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.071 | 0.118 | 0.195 | 0.181 | 0.078 |
| | | OTHER | 0.003 | 0.004 | 0.003 | 0.000 | 0.014 |
| | | | 0.249 | 0.328 | 0.198 | 0.370 | 0.092 |
| | BOP | TURBINE | 0.011 | 0.000 | 0.000 | 0.001 | 0.000 |
| | | GEN | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | 0.006 | 0.002 | 0.000 | 0.000 | 0.000 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.019 | 0.002 | 0.000 | 0.002 | 0.000 |
| | ECONOMIC | | 0.000 | 0.009 | 0.000 | 0.002 | 0.043 |
| | HUMAN | | | | | | |
| | OTHER | | 0.002 | 0.001 | 0.002 | 0.005 | 0.021 |
| | TOTAL | | 0.270 | 0.341 | 0.201 | 0.380 | 0.157 |
| REGULATORY | | | 0.057 | 0.049 | 0.300 | 0.259 | 0.053 |
| UNKNOWN | | | 0.022 | 0.000 | 0.004 | 0.008 | 0.002 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.482 | 0.577 | 0.576 | 0.672 | 0.223 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.518 | 0.423 | 0.424 | 0.328 | 0.777 |

## Table 2.9 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE — GERMANY
1975 - 1984 — ALL BWR'S

04/15/86

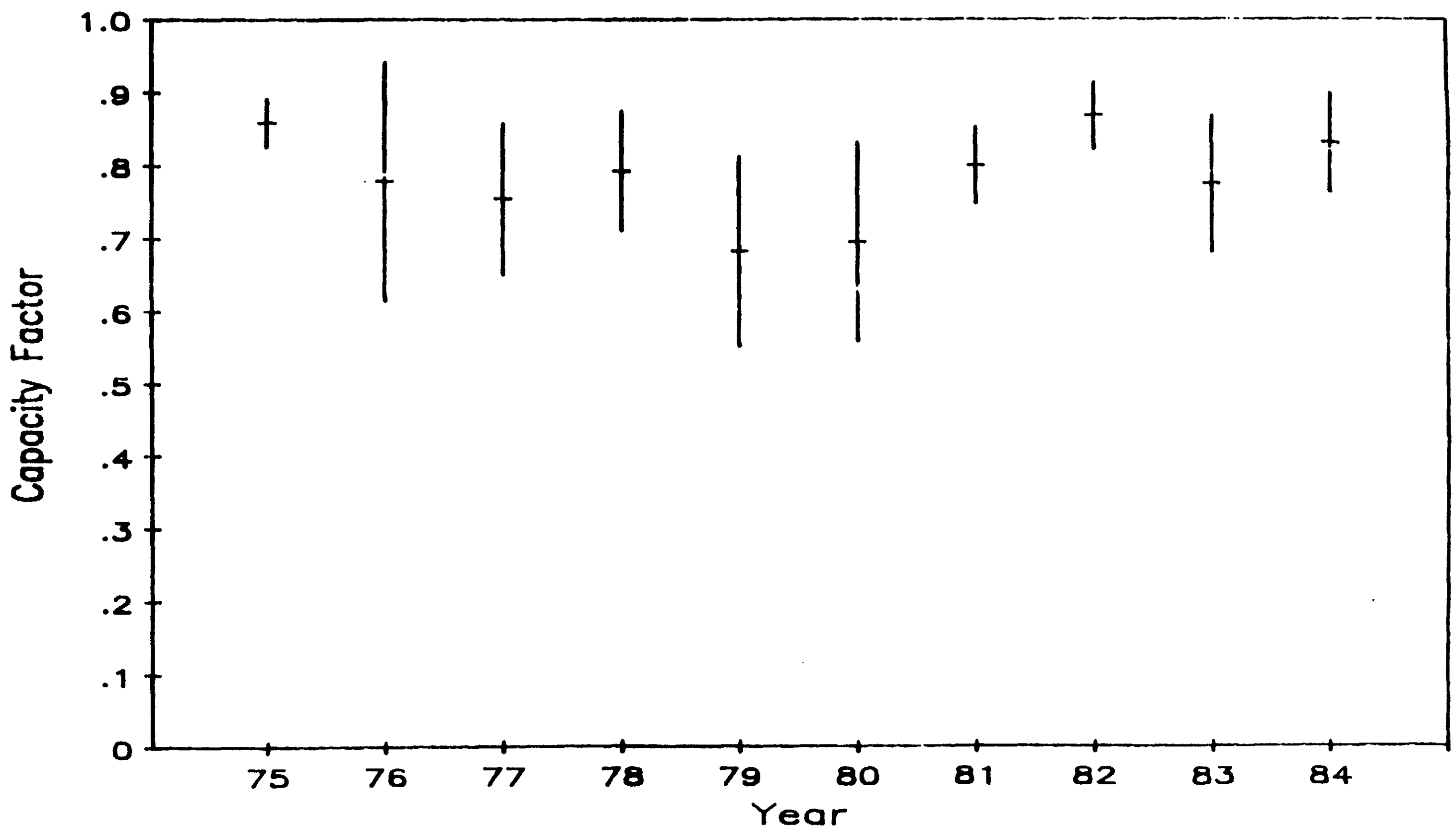
| | | | DATA: ( 3) | ( 2) | ( 2) | ( 1) | ( 0) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | RCS | 0.001 | 0.001 | 0.000 | 0.000 | |
| | | SG | | | | | |
| | | REFUEL | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | OTHER | 0.006 | 0.001 | 0.002 | 0.000 | |
| | | | 0.007 | 0.002 | 0.002 | 0.000 | |
| | BOP | TURBINE | 0.022 | 0.000 | 0.001 | 0.000 | |
| | | GEN | 0.000 | 0.001 | 0.000 | 0.000 | |
| | | COND | 0.002 | 0.000 | 0.000 | 0.000 | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | OTHER | 0.001 | 0.000 | 0.000 | 0.000 | |
| | | | 0.025 | 0.001 | 0.001 | 0.000 | |
| | ECONOMIC | | 0.000 | 0.000 | 0.013 | 0.000 | |
| | HUMAN | | | | | | |
| | OTHER | | 0.000 | 0.002 | 0.004 | 0.000 | |
| | TOTAL | | 0.033 | 0.005 | 0.021 | 0.000 | |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | RCS | 0.139 | 0.533 | 0.357 | 0.000 | |
| | | SG | | | | | |
| | | REFUEL | 0.084 | 0.083 | 0.071 | 0.162 | |
| | | OTHER | 0.002 | 0.001 | 0.001 | 0.012 | |
| | | | 0.225 | 0.617 | 0.429 | 0.174 | |
| | BOP | TURBINE | 0.000 | 0.000 | 0.006 | 0.027 | |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | COND | 0.001 | 0.000 | 0.000 | 0.000 | |
| | | CW/SW/CCW | 0.002 | 0.003 | 0.000 | 0.000 | |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | | 0.003 | 0.003 | 0.006 | 0.027 | |
| | ECONOMIC | | 0.021 | 0.050 | 0.013 | 0.002 | |
| | HUMAN | | | | | | |
| | OTHER | | 0.001 | 0.001 | 0.004 | 0.000 | |
| | TOTAL | | 0.251 | 0.672 | 0.452 | 0.203 | |
| REGULATORY | | | 0.071 | 0.027 | 0.000 | 0.000 | |
| UNKNOWN | | | 0.001 | 0.001 | 0.006 | 0.000 | |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.356 | 0.705 | 0.479 | 0.203 | |
| ** ENERGY AVAIL. FACTOR ** | | | 0.644 | 0.295 | 0.521 | 0.797 | |

## Table 2.10 - German Capacity Factor Distributions

| By Year | PWR Mean | PWR σ | PWR # Data | BWR Mean | BWR σ | BWR # Data |
|---|---|---|---|---|---|---|
| 75 | 0.859 | 0.033 | 3 | 0.887 | 0.000 | 1 |
| 76 | 0.778 | 0.164 | 4 | 0.654 | 0.000 | 1 |
| 77 | 0.754 | 0.104 | 5 | 0.573 | 0.078 | 2 |
| 78 | 0.792 | 0.082 | 5 | 0.417 | 0.070 | 2 |
| 79 | 0.681 | 0.131 | 6 | 0.301 | 0.287 | 3 |
| 80 | 0.695 | 0.137 | 6 | 0.392 | 0.236 | 4 |
| 81 | 0.800 | 0.052 | 6 | 0.500 | 0.210 | 4 |
| 82 | 0.868 | 0.046 | 7 | 0.419 | 0.194 | 4 |
| 83 | 0.774 | 0.094 | 7 | 0.564 | 0.280 | 4 |
| 84 | 0.831 | 0.068 | 7 | 0.788 | 0.036 | 4 |

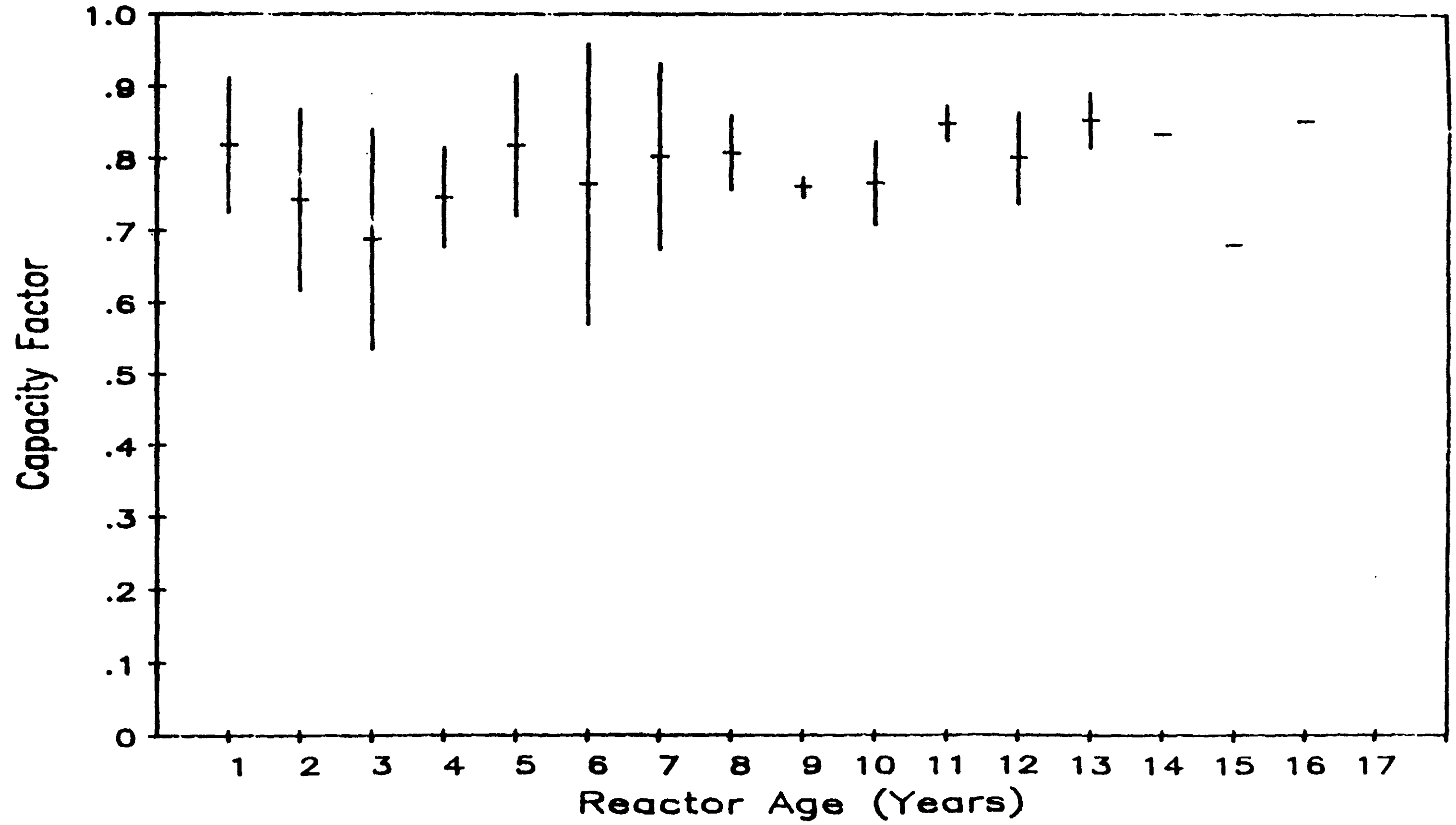
| By Age | PWR Mean | PWR σ | PWR # Data | BWR Mean | BWR σ | BWR # Data |
|---|---|---|---|---|---|---|
| 1 | 0.818 | 0.093 | 5 | 0.519 | 0.194 | 4 |
| 2 | 0.742 | 0.126 | 5 | 0.423 | 0.193 | 4 |
| 3 | 0.687 | 0.153 | 5 | 0.424 | 0.253 | 4 |
| 4 | 0.746 | 0.069 | 5 | 0.328 | 0.235 | 4 |
| 5 | 0.818 | 0.098 | 5 | 0.778 | 0.115 | 4 |
| 6 | 0.764 | 0.195 | 4 | 0.643 | 0.074 | 3 |
| 7 | 0.803 | 0.129 | 5 | 0.295 | 0.047 | 2 |
| 8 | 0.808 | 0.052 | 5 | 0.520 | 0.269 | 2 |
| 9 | 0.760 | 0.014 | 3 | 0.797 | 0.000 | 1 |
| 10 | 0.766 | 0.058 | 3 | | | |
| 11 | 0.849 | 0.024 | 2 | | | |
| 12 | 0.801 | 0.063 | 2 | | | |
| 13 | 0.854 | 0.038 | 2 | | | |
| 14 | 0.833 | 0.000 | 1 | | | |
| 15 | 0.679 | 0.000 | 1 | | | |
| 16 | 0.852 | 0.000 | 1 | | | |
| 17 | | | | | | |

Figure 2.5
German PWR Capacity Factor Distribution
By Year



## Figure 2.6

German PWR Capacity Factor Distribution By Reactor Age



## Figure 2.7
German BWR Capacity Factor Distribution
By Year

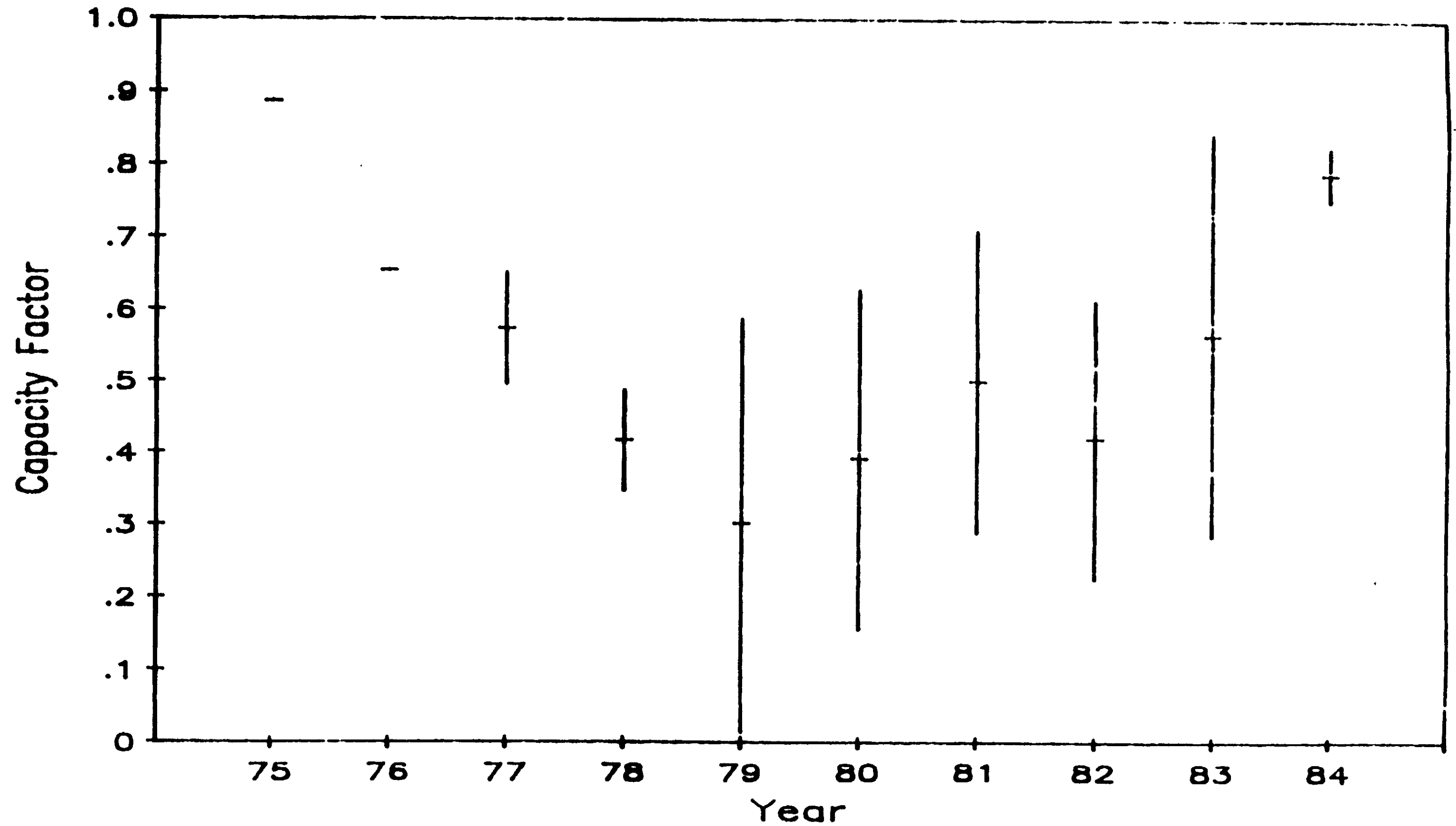


Figure 2.8
German BWR Capacity Factor Distribution
By Reactor Age

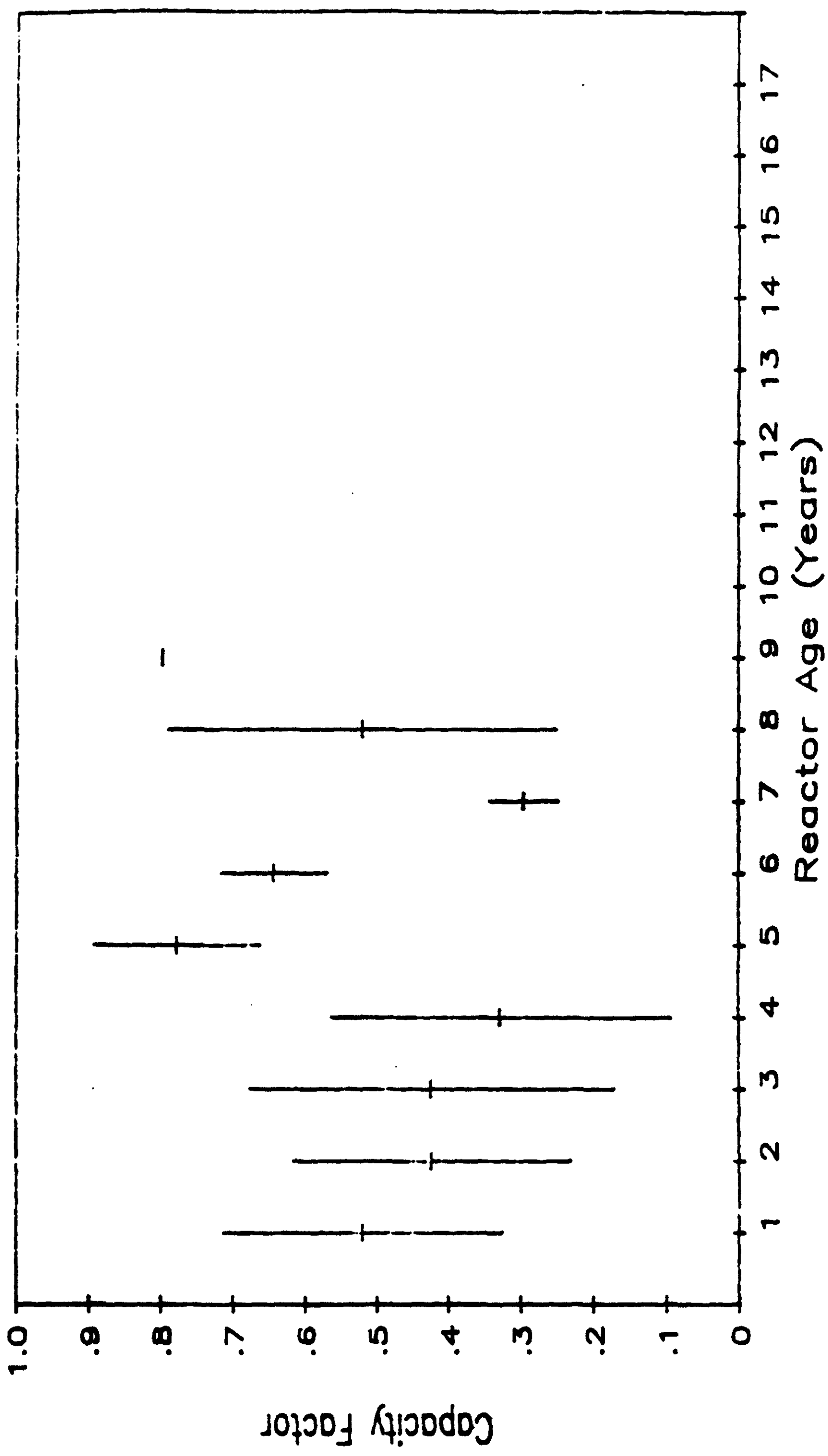


Figure 2.9

German PWR Capacity Losses By Year
Forced, Scheduled, and Regulatory

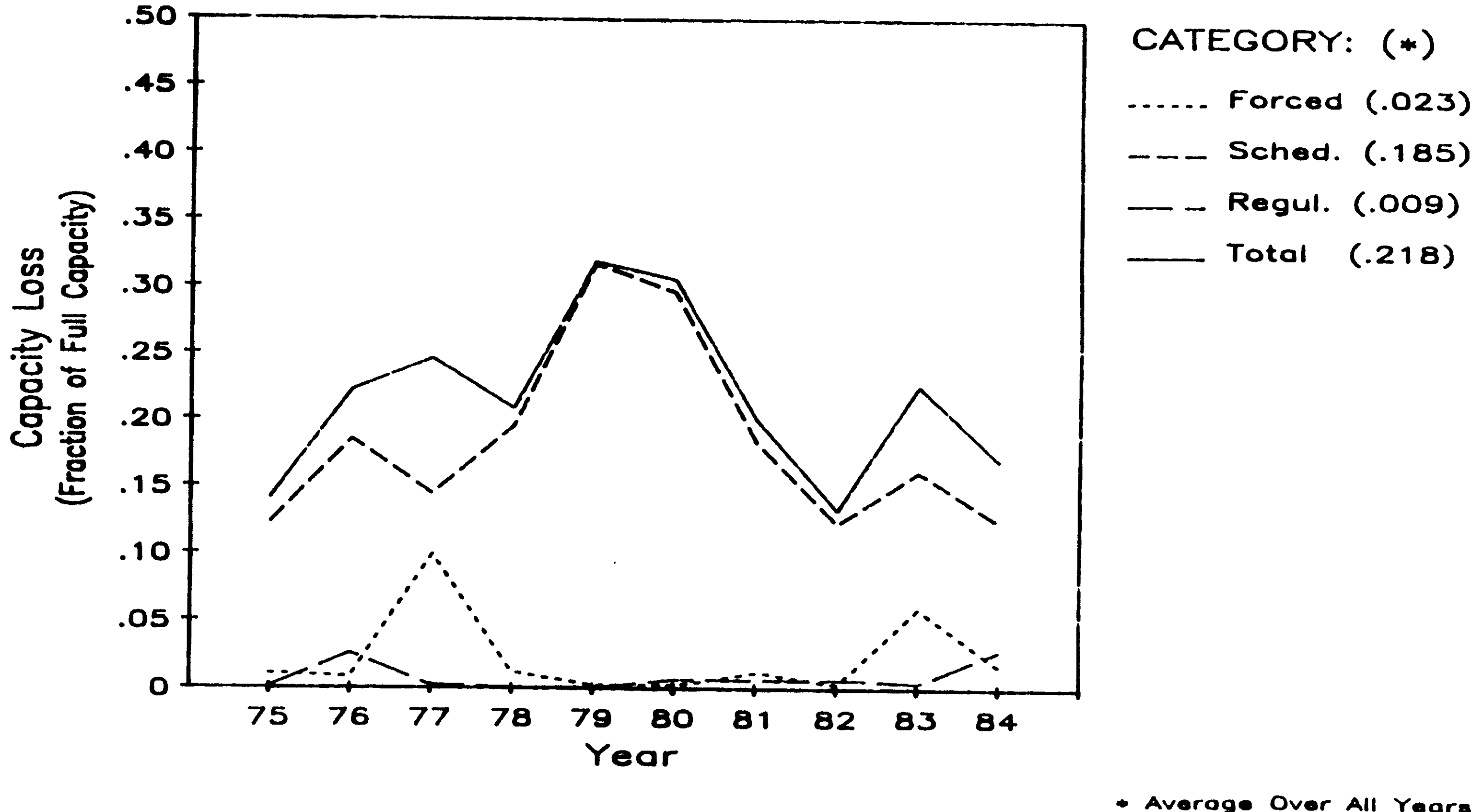
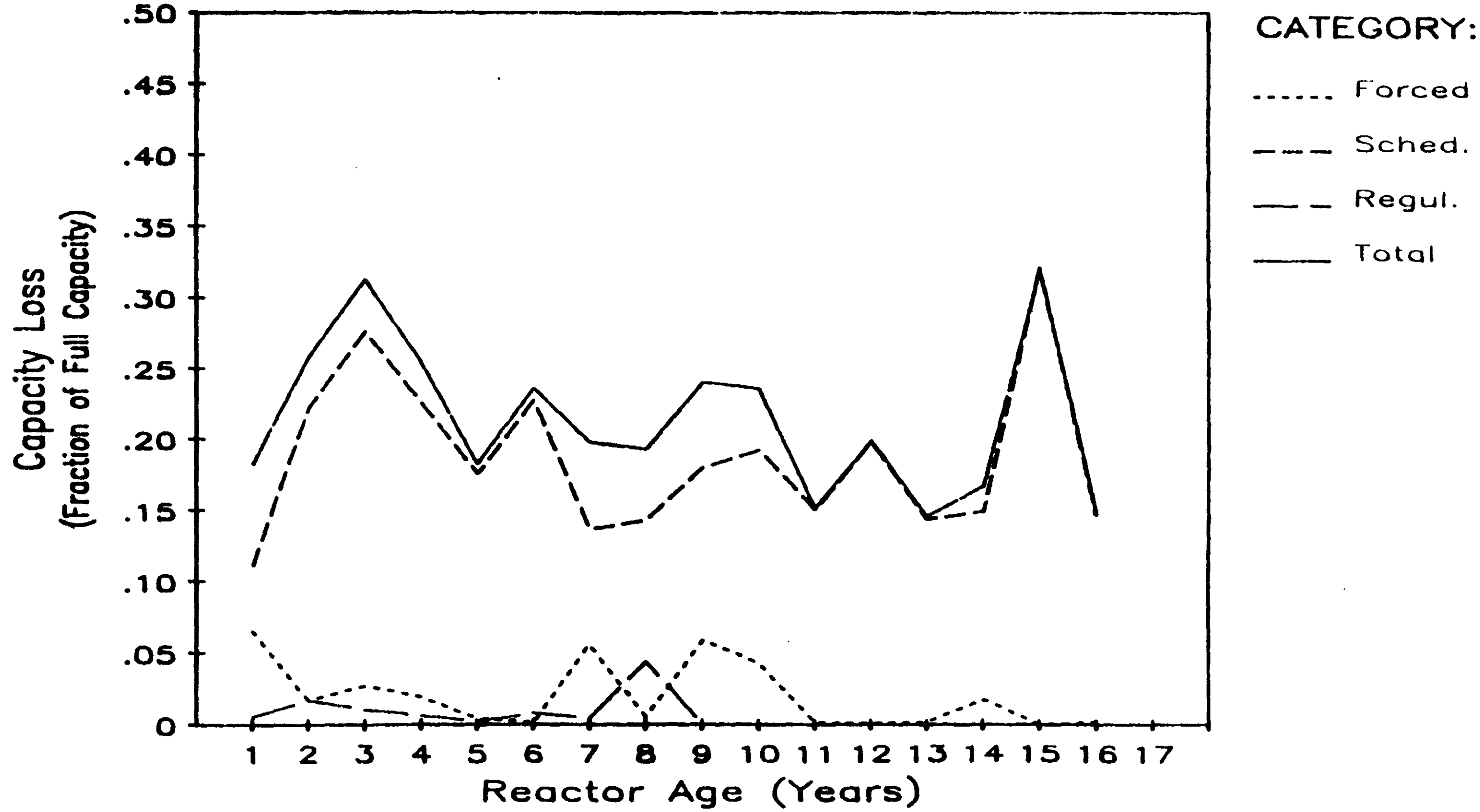


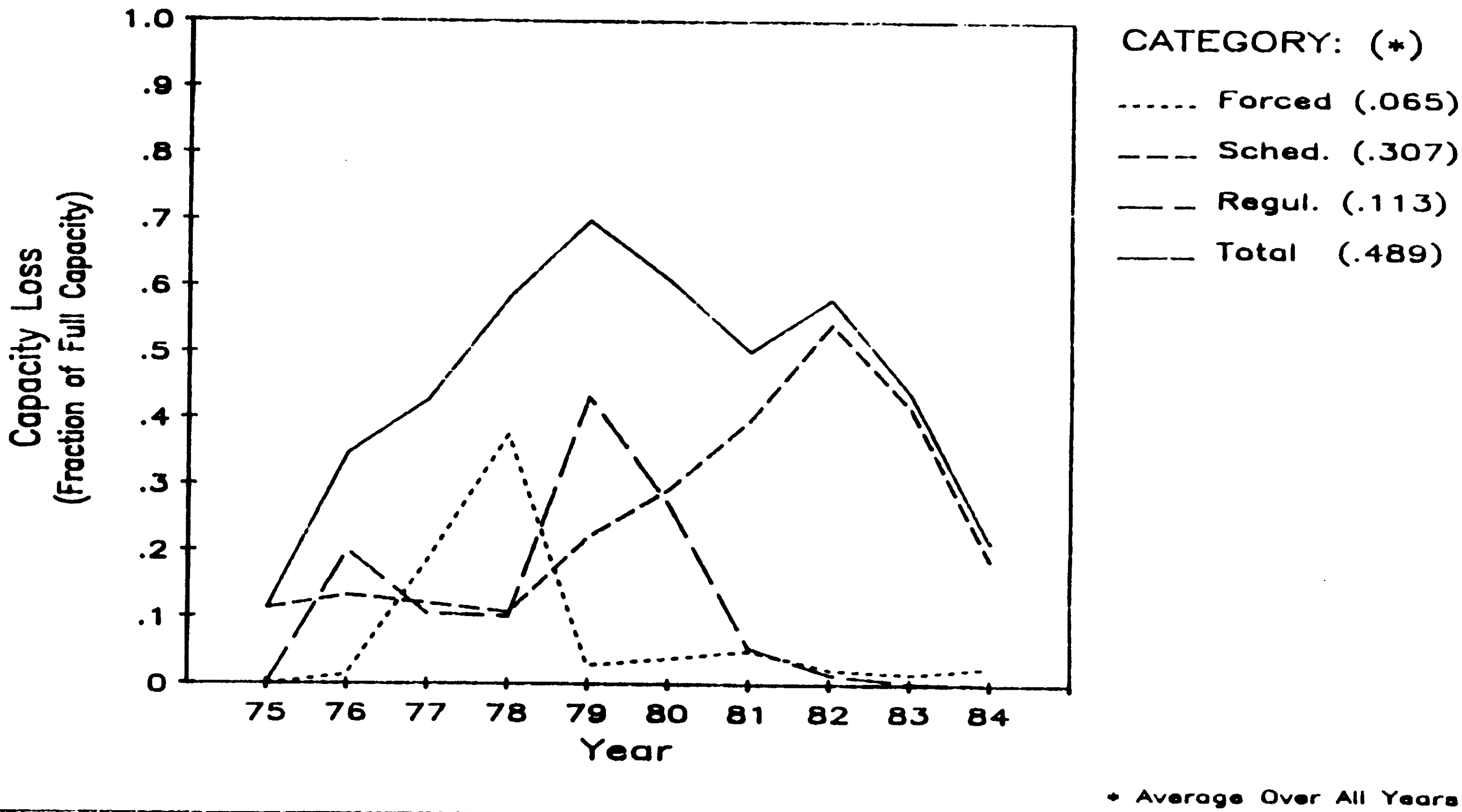
Figure 2.10

German PWR Capacity Losses By Rx Age
Forced, Scheduled, and Regulatory



## Figure 2.11

German BWR Capacity Losses By Year
Forced, Scheduled, and Regulatory



## Figure 2.12
### German BWR Capacity Losses By Rx Age
### Forced, Scheduled, and Regulatory

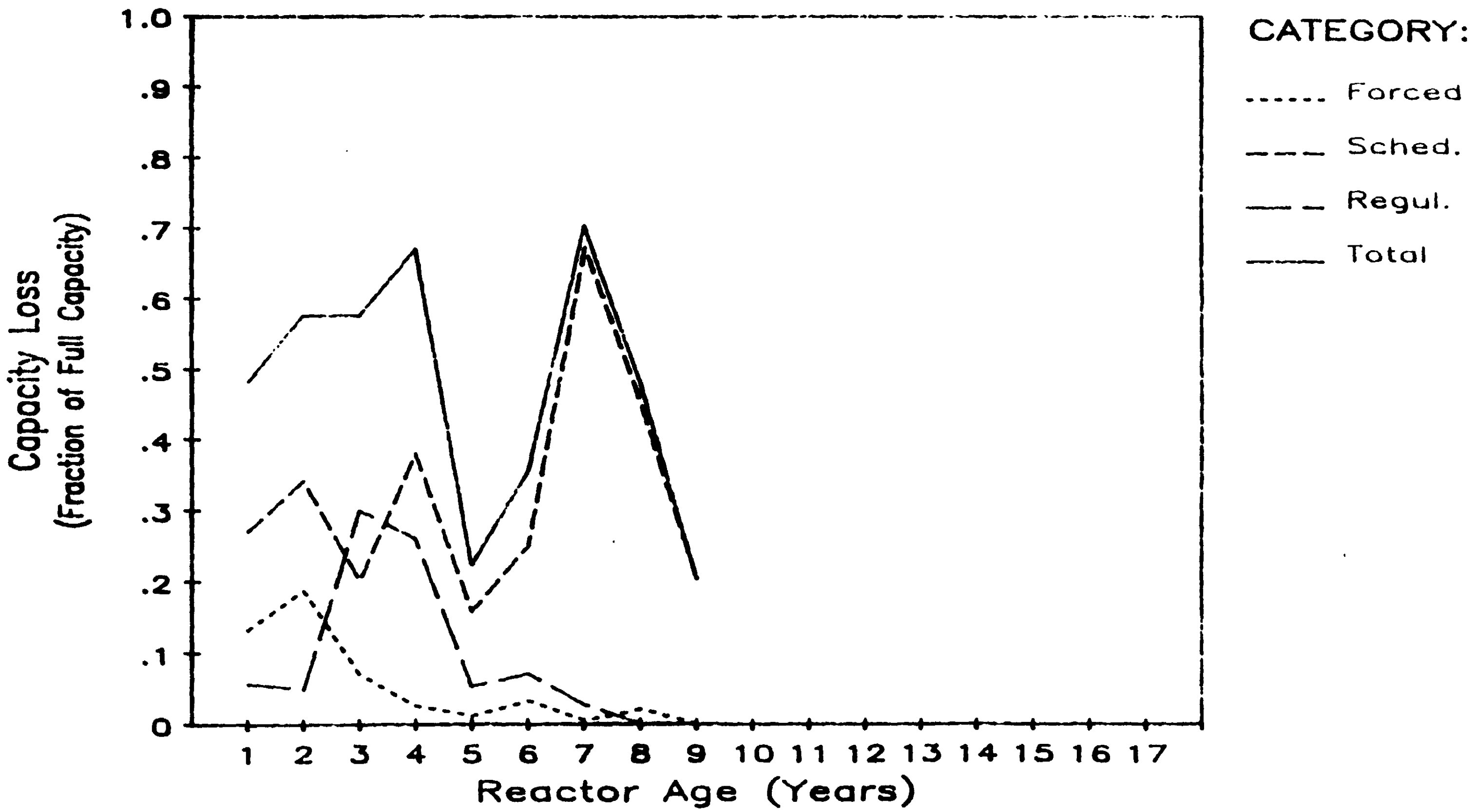
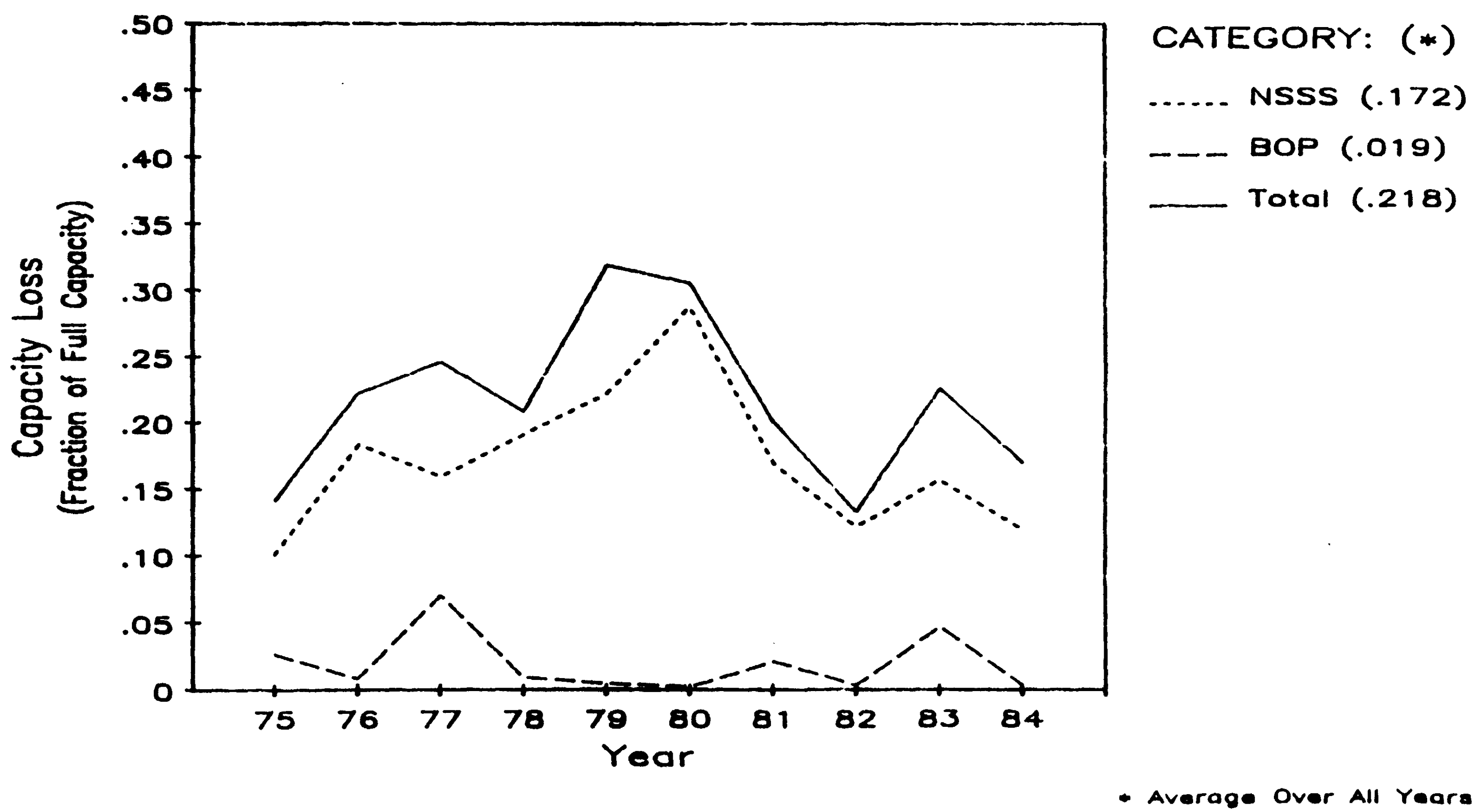
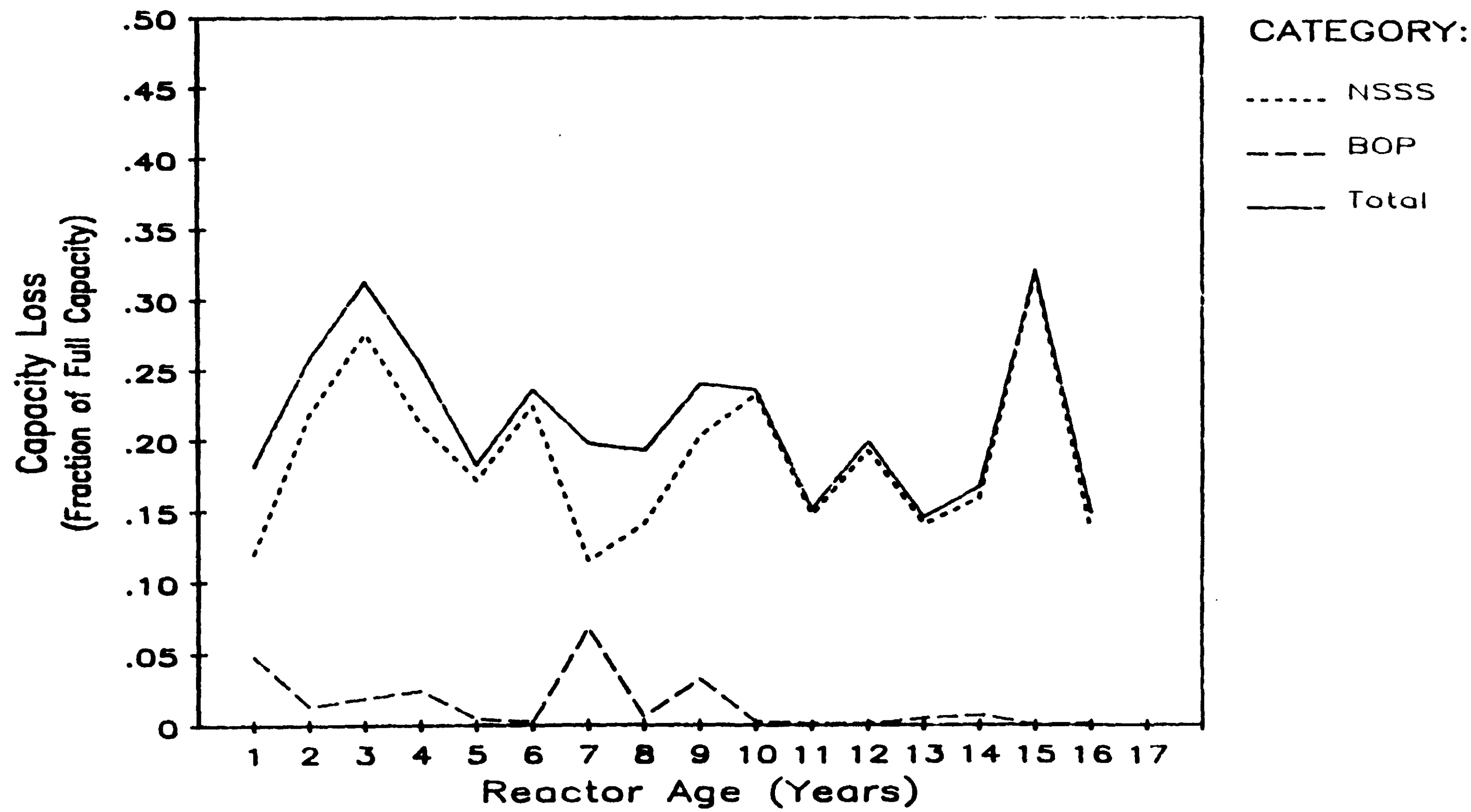


Figure 2.13
German PWR Capacity Losses By Year
NSSS and BOP

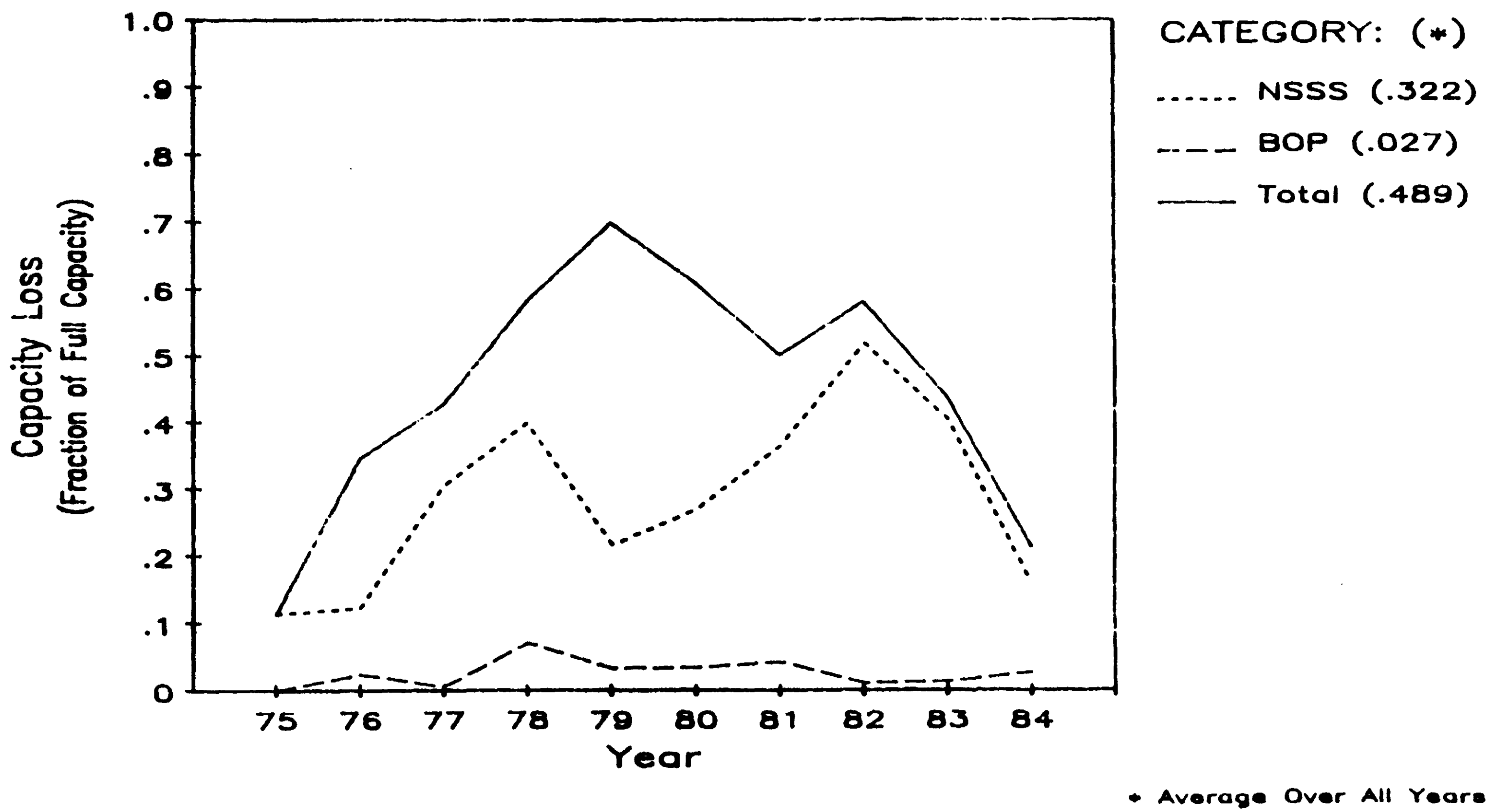


## Figure 2.14

German PWR Capacity Losses By Rx Age
NSSS and BOP



## Figure 2.15
German BWR Capacity Losses By Year
NSSS and BOP



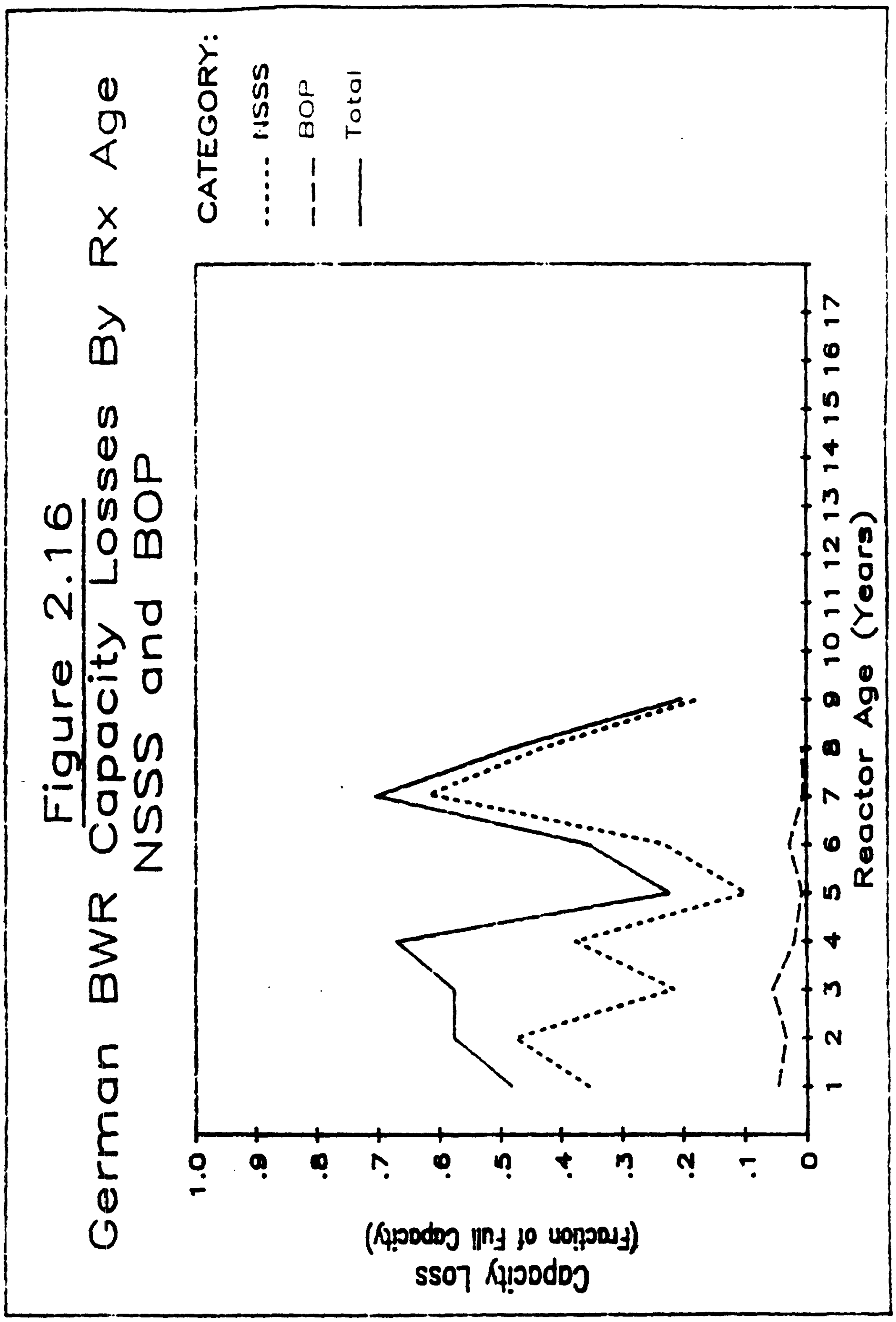



Figure 2.16
German BWR Capacity Losses By Rx Age
NSSS and BOP

## 2.3 Japan

In this section the performance losses for the Japanese nuclear power plants are presented and briefly examined. Capacity was the performance index used to describe the Japanese losses.

### 2.3.1 Aggregated Data

The Japanese PWR capacity losses as a function of calendar year and reactor age are tabulated in Table 2.11 and Table 2.12. The BWR capacity losses are tabulated by year in Table 2.13 and as a function of reactor age in Table 2.14. The mean and the standard deviations of the capacity factors are tabulated by year and by reactor age in Table 2.15.

### 2.3.2 Capacity Factor Distribution

Japanese PWR capacity factors are plotted against time in Figure 2.17. The Japanese plants have had an average energy availability of 63.3% over the ten year period. Performance from 1975 to 1979 fluctuated from year to year with several years having large standard deviations. The large standard deviation in 1975 was the result of a 92.4%

loss for refueling at a single plant. A different plant with an 89.6% refueling loss accounts for the deviation in 1977. The low performance in 1979 is the result of large refueling losses at many of the plants which may have resulted from the accident at Three Mile Island that year. Since then the performance has increased as a result of reductions in refueling losses. The standard deviation over these years has remained relatively constant.

The PWR capacity factors are displayed as a function of age in Figure 2.18 and exhibit no age dependency. The standard deviations have been relatively constant with an average of 0.158.

Capacity factors for the Japanese BWR's are plotted over time in Figure 2.19. Performance has averaged 61.0% during the 10 year period shown. Large refueling outages at 2 out of 3 BWR's contributed to the 28.1% capacity factor in 1975. In 1977 large refueling losses at 3 out of 5 plants resulted in an average capacity factor of 25.8%. The cause for these large refuelings is unknown. The large standard deviations for these two years were because the remainder of the plants in those years did not perform as poorly. From 1979 on, BWR performance has improved as a result of reductions in refueling losses.

The BWR capacity factors are shown by age in Figure 2.20. The capacity factors and standard deviations fluctuate with age but neither exhibits any age dependency.

### 2.3.3 Losses by Outage Type

In this subsection, forced, scheduled, and regulatory losses for the Japanese nuclear plants are displayed and examined as functions of time and age.

In Figure 2.21, the forced, scheduled and regulatory losses are displayed over time for the Japanese PWR's. Japanese losses have generally been large, averaging 36.7% over the 10 years studied. From 1979 to 1984, the performance of the Japanese PWR's steadily improved. The scheduled losses comprised the largest fraction of the total losses, with a 10 year average of 34.0%. This represents 92.3% of the total. Scheduled losses have been high as a result of mandatory shutdowns for inspection and maintenance which are usually performed during refueling outages. Reductions in the size of these mandatory outages since 1979 account for the increase in performance exhibited. The other scheduled losses are small as a result of the large amount of maintenance performed. Forced outages have been small, averaging 2.6% over the 10 year period. In addition, the forced losses show a time dependent decrease. The cause of this trend cannot be assigned to any one category; it arises from a general reduction in forced outage losses in several categories. The Japanese have not reported regulatory losses in any of their PWR's.

The PWR's losses are shown as a function of reactor age in Figure 2.22. None of the outage categories studied shows an age dependent trend in this figure. The large peaks in both forced and scheduled losses at age 11 were caused by a steam generator repair and a large refueling at one plant.

BWR outage categories are plotted over time in Figure 2.23. As the figure illustrates, the total and scheduled losses fluctuated prior to 1978 and then began to decrease from year to year. The scheduled outages represented 96.4% of the total losses and followed the total loss curve closely. The reason for this was the large mandatory refueling outages for inspection and maintenance that were required each year, similar to the PWR's. Forced outages have been relatively constant with a 10 year average of 1.4%. As with the PWR's, there were no regulatory losses reported.

Finally, in Figure 2.24, the BWR outage categories are plotted by reactor age. The figure shows fluctuation in the total losses with an increasing tendency with age. This trend is probably insignificant due to its small magnitude and the fluctuation that is present from year to year. Forced outages are small and exhibit a slight decrease with age. This trend is also probably insignificant as a result of its small magnitude. The small peak in the forced outages at ages 12 and 13 was from turbine losses at one plant.

### 2.3.4 NSSS and BOP Losses

In this subsection the losses in the Nuclear Steam Supply System (NSSS) and the Balance of Plant (BOP) are displayed and examined as functions of time and reactor age for Japanese nuclear power plants.

Japanese PWR NSSS and BOP losses are shown graphically by year in Figure 2.25. The NSSS losses, which on average made up over 94% of the total losses, show fluctuation prior to 1980 and a decrease in magnitude thereafter. Large refueling outages for inspection and maintenance were responsible for over 93% of these losses. Fluctuation in the refueling outages accounts for the fluctuation visible in the NSSS losses. Steam generator problems accounted for another 4.6% of the NSSS losses. The BOP losses have been small, averaging 0.5% per year or 1.4% of the total losses. The figure shows that the BOP losses have decreased since 1975. This reduction is due to decreased losses over time in the turbines and the CW, SW, and CCW systems.

The PWR losses are plotted as a function of age in Figure 2.26. The NSSS losses appear to be independent of reactor age while the BOP losses exhibit a decline in losses with age. The decline in the BOP losses was caused by improvements in turbine performance with age.

NSSS and BOP losses for the Japanese BWR's are plotted over time in Figure 2.27. The NSSS losses, which averaged 34.8% per year, represented 89.2% of the total losses.

Refueling losses are the largest fraction of the NSSS losses, contributing 95.1%. Fuel losses account for another 3.7% of the NSSS losses, partially as a result of the PreConditioning Interim Operating Management Recommendations (PCIOMR) used in the Japanese BWR's. From 1978 to 1984 the NSSS losses show a substantial improvement dropping from 45.4% to 27.2% as a result of a similar reduction in refueling losses. The BOP losses for BWR's have been very small, averaging 0.6% per year and representing only 1.5% of the total losses. The BOP losses are independent of time.

The Japanese BWR losses are shown as a function of age in Figure 2.28. Neither the NSSS or the BOP losses exhibit a trend with age.

Table 2.11
Japanese PWR Capacity Losses
By Year

CAPACITY LOSSES 1975 - 1979 — JAPAN ALL PWR'S

03/25/86

| | | | DATA:( 4) | ( 5) | ( 6) | ( 6) | ( 8) |
|---|---|---|---|---|---|---|---|
| | | | 1975 | 1976 | 1977 | 1978 | 1979 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.013 | 0.000 |
| | | SG | 0.006 | 0.054 | 0.007 | 0.009 | 0.027 |
| | | REFUEL | | | | | |
| | | OTHER | 0.001 | 0.002 | 0.000 | 0.000 | 0.020 |
| | | | 0.006 | 0.056 | 0.007 | 0.022 | 0.048 |
| | BOP | TURBINE | 0.024 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.025 | 0.005 | 0.004 | 0.001 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.049 | 0.006 | 0.004 | 0.001 | 0.001 |
| | ECONOMIC | | | | | | |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.025 | 0.009 | 0.000 | 0.003 | 0.002 |
| | TOTAL | | 0.080 | 0.072 | 0.012 | 0.026 | 0.050 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | 0.433 | 0.209 | 0.413 | 0.354 | 0.572 |
| | | OTHER | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | | 0.433 | 0.212 | 0.413 | 0.354 | 0.572 |
| | BOP | TURBINE | 0.001 | 0.003 | 0.006 | 0.009 | 0.002 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.001 | 0.003 | 0.006 | 0.009 | 0.002 |
| | ECONOMIC | | 0.000 | 0.009 | 0.000 | 0.001 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.004 | 0.057 | 0.020 | 0.004 | 0.030 |
| | TOTAL | | 0.438 | 0.281 | 0.439 | 0.367 | 0.604 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.008 | 0.026 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.525 | 0.379 | 0.451 | 0.393 | 0.655 |
| ** CAPACITY FACTOR ** | | | 0.475 | 0.621 | 0.549 | 0.607 | 0.345 |

## Table 2.11 - (Continued)

CAPACITY LOSSES
1980 - 1984

JAPAN
ALL PWR'S

03/25/86

| | | | DATA: ( 8) | ( 9) | (10) | (10) | (11) |
|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.006 | 0.000 | 0.000 | 0.000 | 0.002 |
| | | SG | 0.013 | 0.032 | 0.005 | 0.018 | 0.000 |
| | | REFUEL | | | | | |
| | | OTHER | 0.004 | 0.000 | 0.000 | 0.001 | 0.000 |
| | | | 0.023 | 0.033 | 0.005 | 0.019 | 0.002 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.002 | 0.000 | 0.001 | 0.001 | 0.000 |
| | ECONOMIC | | | | | | |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.000 | 0.001 | 0.000 | 0.002 | 0.000 |
| | TOTAL | | 0.026 | 0.034 | 0.006 | 0.022 | 0.002 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | 0.348 | 0.311 | 0.260 | 0.232 | 0.269 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.348 | 0.311 | 0.260 | 0.232 | 0.269 |
| | BOP | TURBINE | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 |
| | ECONOMIC | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.000 | 0.011 | 0.006 | 0.009 | 0.000 |
| | TOTAL | | 0.351 | 0.323 | 0.266 | 0.241 | 0.269 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.376 | 0.357 | 0.272 | 0.264 | 0.271 |
| ** CAPACITY FACTOR ** | | | 0.624 | 0.643 | 0.728 | 0.736 | 0.729 |

Table 2.11 - (Continued)

CAPACITY LOSSES 1975 - 1984 — JAPAN, ALL PWR'S

03/25/86 — DATA: 11 PLANTS — 77 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 |
| | | RCS | 0.002 |
| | | SG | 0.016 |
| | | REFUEL | |
| | | OTHER | 0.003 |
| | | | 0.021 |
| | BOP | TURBINE | 0.001 |
| | | GEN | 0.000 |
| | | COND | |
| | | CW/SW/CCW | 0.002 |
| | | OTHER | 0.000 |
| | | | 0.003 |
| | ECONOMIC | | |
| | HUMAN | | 0.000 |
| | OTHER | | 0.002 |
| | TOTAL | | 0.026 |
| SCHEDULED | NSSS | FUEL | 0.000 |
| | | RCS | 0.000 |
| | | SG | 0.000 |
| | | REFUEL | 0.325 |
| | | OTHER | 0.000 |
| | | | 0.325 |
| | BOP | TURBINE | 0.002 |
| | | GEN | 0.000 |
| | | COND | |
| | | CW/SW/CCW | 0.000 |
| | | OTHER | 0.000 |
| | | | 0.002 |
| | ECONOMIC | | 0.001 |
| | HUMAN | | |
| | OTHER | | 0.011 |
| | TOTAL | | 0.340 |
| REGULATORY | | | 0.000 |
| UNKNOWN | | | 0.002 |

** TOTAL CAPACITY LOSS ** 0.367

** CAPACITY FACTOR ** 0.633

## Table 2.12
## Japanese PWR Capacity Losses By Reactor Age

CAPACITY LOSSES BY REACTOR AGE — JAPAN
1975 - 1984 — ALL PWR'S

03/23/86

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | DATA: | ( 9) | ( 9) | (10) | ( 9) | ( 8) |
| | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.009 | 0.005 | 0.000 | 0.000 | 0.003 |
| | | SG | 0.000 | 0.000 | 0.037 | 0.031 | 0.000 |
| | | REFUEL | | | | | |
| | | OTHER | 0.001 | 0.004 | 0.000 | 0.015 | 0.001 |
| | | | 0.010 | 0.009 | 0.037 | 0.046 | 0.004 |
| | BOP | TURBINE | 0.007 | 0.001 | 0.000 | 0.001 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.010 | 0.001 | 0.001 | 0.001 | 0.001 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.017 | 0.002 | 0.001 | 0.002 | 0.001 |
| | ECONOMIC | | | | | | |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.013 | 0.000 | 0.002 | 0.001 | 0.000 |
| | TOTAL | | 0.039 | 0.011 | 0.040 | 0.049 | 0.006 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | 0.207 | 0.347 | 0.440 | 0.331 | 0.338 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.207 | 0.347 | 0.440 | 0.333 | 0.338 |
| | BOP | TURBINE | 0.002 | 0.004 | 0.003 | 0.002 | 0.001 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.002 | 0.004 | 0.003 | 0.002 | 0.001 |
| | ECONOMIC | | 0.001 | 0.000 | 0.000 | 0.003 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.033 | 0.019 | 0.003 | 0.018 | 0.000 |
| | TOTAL | | 0.243 | 0.370 | 0.446 | 0.357 | 0.340 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.015 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.297 | 0.381 | 0.486 | 0.406 | 0.345 |
| ** CAPACITY FACTOR ** | | | 0.703 | 0.619 | 0.514 | 0.594 | 0.655 |

## Table 2.12 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — JAPAN
1976 - 1984 — ALL PWR'S

03/23/86

| | | | DATA: | ( 7) | ( 6) | ( 5) | ( 4) | ( 2) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | 0.000 | 0.031 | 0.022 | 0.000 | 0.000 |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 |
| | | | | 0.000 | 0.032 | 0.022 | 0.001 | 0.000 |
| | BOP | TURBINE | | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | ECONOMIC | | | | | | | |
| | HUMAN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 |
| | TOTAL | | | 0.001 | 0.032 | 0.027 | 0.002 | 0.000 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | REFUEL | | 0.312 | 0.358 | 0.282 | 0.293 | 0.469 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.312 | 0.358 | 0.282 | 0.293 | 0.469 |
| | BOP | TURBINE | | 0.002 | 0.001 | 0.002 | 0.000 | 0.000 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.002 | 0.001 | 0.002 | 0.000 | 0.000 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.003 | 0.008 | 0.000 | 0.000 | 0.007 |
| | TOTAL | | | 0.317 | 0.367 | 0.284 | 0.294 | 0.477 |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.318 | 0.399 | 0.311 | 0.296 | 0.477 |
| ** CAPACITY FACTOR ** | | | | 0.682 | 0.601 | 0.689 | 0.704 | 0.523 |

## Table 2.12 - (Continued)

CAPACITY LOSSES BY REACTOR AGE 1975 - 1984

JAPAN ALL PWR'S

03/23/86

| | | | DATA:( 1) | ( 1) | ( 0) | ( 0) | ( 0) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 11 | 12 | 13 | 14 | 15 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | | | |
| | | RCS | 0.000 | 0.000 | | | |
| | | SG | 0.180 | 0.000 | | | |
| | | REFUEL | | | | | |
| | | OTHER | 0.000 | 0.000 | | | |
| | | | 0.180 | 0.000 | | | |
| | BOP | TURBINE | 0.000 | 0.000 | | | |
| | | GEN | 0.000 | 0.000 | | | |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | | | |
| | | OTHER | 0.000 | 0.000 | | | |
| | | | 0.000 | 0.000 | | | |
| | ECONOMIC | | | | | | |
| | HUMAN | | 0.000 | 0.000 | | | |
| | OTHER | | 0.000 | 0.000 | | | |
| | TOTAL | | 0.180 | 0.000 | | | |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | | | |
| | | RCS | 0.000 | 0.000 | | | |
| | | SG | 0.000 | 0.000 | | | |
| | | REFUEL | 0.398 | 0.050 | | | |
| | | OTHER | 0.000 | 0.000 | | | |
| | | | 0.398 | 0.050 | | | |
| | BOP | TURBINE | 0.000 | 0.001 | | | |
| | | GEN | 0.000 | 0.000 | | | |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | | | |
| | | OTHER | 0.000 | 0.000 | | | |
| | | | 0.000 | 0.001 | | | |
| | ECONOMIC | | 0.000 | 0.000 | | | |
| | HUMAN | | | | | | |
| | OTHER | | 0.077 | 0.000 | | | |
| | TOTAL | | 0.475 | 0.051 | | | |
| REGULATORY | | | 0.000 | 0.000 | | | |
| UNKNOWN | | | 0.000 | 0.000 | | | |

** TOTAL CAPACITY LOSS ** 0.655 0.051

** CAPACITY FACTOR ** 0.345 0.949

## Table 2.13
## Japanese BWR Capacity Losses
## By Year

CAPACITY LOSSES 1975 - 1979 — JAPAN ALL BWR'S

03/27/86

| | | | DATA: ( 3) | ( 5) | ( 5) | ( 9) | (10) |
|---|---|---|---|---|---|---|---|
| | | | 1975 | 1976 | 1977 | 1978 | 1979 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.010 | 0.025 | 0.001 | 0.000 | 0.004 |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | 0.020 | 0.001 | 0.000 | 0.000 | 0.001 |
| | | | 0.030 | 0.025 | 0.001 | 0.000 | 0.005 |
| | BOP | TURBINE | 0.000 | 0.008 | 0.000 | 0.000 | 0.004 |
| | | GEN | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.002 | 0.000 | 0.000 | 0.004 |
| | | OTHER | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 |
| | | | 0.001 | 0.012 | 0.000 | 0.000 | 0.009 |
| | ECONOMIC | | | | | | |
| | HUMAN | | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 |
| | OTHER | | 0.018 | 0.005 | 0.000 | 0.004 | 0.001 |
| | TOTAL | | 0.049 | 0.042 | 0.002 | 0.005 | 0.015 |
| SCHEDULED | NSSS | FUEL | 0.005 | 0.012 | 0.003 | 0.032 | 0.023 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.652 | 0.204 | 0.696 | 0.423 | 0.286 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.657 | 0.216 | 0.699 | 0.454 | 0.309 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ECONOMIC | | 0.000 | 0.003 | 0.006 | 0.009 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.014 | 0.119 | 0.035 | 0.035 | 0.051 |
| | TOTAL | | 0.670 | 0.339 | 0.740 | 0.498 | 0.360 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.719 | 0.381 | 0.742 | 0.503 | 0.375 |
| ** CAPACITY FACTOR ** | | | 0.281 | 0.619 | 0.258 | 0.497 | 0.625 |

## Table 2.13 - (Continued)

CAPACITY LOSSES JAPAN
1980 - 1984 ALL BWR'S

03/27/86

| | | | DATA: | (10) | (10) | (11) | (11) | (13) |
|---|---|---|---|---|---|---|---|---|
| | | | | 1980 | 1981 | 1982 | 1983 | 1984 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.000 | 0.004 | 0.003 | 0.000 |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.003 | 0.001 | 0.000 | 0.001 | 0.000 |
| | | | | 0.003 | 0.002 | 0.004 | 0.004 | 0.000 |
| | BOP | TURBINE | | 0.005 | 0.003 | 0.003 | 0.002 | 0.000 |
| | | GEN | | 0.001 | 0.000 | 0.000 | 0.005 | 0.001 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.003 | 0.005 | 0.001 | 0.000 | 0.001 |
| | | OTHER | | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.011 | 0.008 | 0.004 | 0.007 | 0.002 |
| | ECONOMIC | | | | | | | |
| | HUMAN | | | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.004 | 0.004 | 0.003 | 0.004 | 0.000 |
| | TOTAL | | | 0.018 | 0.015 | 0.011 | 0.015 | 0.002 |
| SCHEDULED | NSSS | FUEL | | 0.015 | 0.014 | 0.010 | 0.009 | 0.004 |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | | | | | |
| | | REFUEL | | 0.314 | 0.329 | 0.255 | 0.280 | 0.267 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.329 | 0.343 | 0.265 | 0.289 | 0.272 |
| | BOP | TURBINE | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ECONOMIC | | | 0.001 | 0.002 | 0.001 | 0.002 | 0.001 |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.034 | 0.026 | 0.021 | 0.012 | 0.004 |
| | TOTAL | | | 0.366 | 0.371 | 0.288 | 0.303 | 0.277 |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.383 | 0.386 | 0.298 | 0.318 | 0.279 |
| ** CAPACITY FACTOR ** | | | | 0.617 | 0.614 | 0.702 | 0.682 | 0.721 |

Table 2.13 - (Continued)

CAPACITY LOSSES
1975 - 1984

JAPAN
ALL BWR'S

03/27/86 DATA: 13 PLANTS 87 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 |
| | | RCS | 0.003 |
| | | SG | |
| | | REFUEL | |
| | | OTHER | 0.002 |
| | | | 0.005 |
| | BOP | TURBINE | 0.002 |
| | | GEN | 0.001 |
| | | COND | |
| | | CW/SW/CCW | 0.002 |
| | | OTHER | 0.000 |
| | | | 0.006 |
| | ECONOMIC | | |
| | HUMAN | | 0.000 |
| | OTHER | | 0.003 |
| | TOTAL | | 0.014 |
| SCHEDULED | NSSS | FUEL | 0.013 |
| | | RCS | 0.000 |
| | | SG | |
| | | REFUEL | 0.331 |
| | | OTHER | 0.000 |
| | | | 0.344 |
| | BOP | TURBINE | 0.000 |
| | | GEN | 0.000 |
| | | COND | |
| | | CW/SW/CCW | 0.000 |
| | | OTHER | 0.000 |
| | | | 0.000 |
| | ECONOMIC | | 0.002 |
| | HUMAN | | |
| | OTHER | | 0.030 |
| | TOTAL | | 0.376 |
| REGULATORY | | | 0.000 |
| UNKNOWN | | | 0.000 |

** TOTAL CAPACITY LOSS ** 0.390

** CAPACITY FACTOR ** 0.610

## Table 2.14
## Japanese BWR Capacity Losses By Reactor Age

CAPACITY LOSSES BY REACTOR AGE — JAPAN
1975 - 1984 — ALL BWR'S

03/23/86

| | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| | | DATA: | (11) | (10) | (10) | ( 9) | (10) |
| | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.010 | 0.005 | 0.003 | 0.001 | 0.001 |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | 0.007 | 0.003 | 0.001 | 0.000 | 0.000 |
| | | | 0.017 | 0.008 | 0.004 | 0.001 | 0.001 |
| | BOP | TURBINE | 0.003 | 0.002 | 0.005 | 0.001 | 0.001 |
| | | GEN | 0.000 | 0.001 | 0.001 | 0.002 | 0.003 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.002 | 0.003 | 0.002 | 0.005 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.003 | 0.005 | 0.009 | 0.005 | 0.009 |
| | ECONOMIC | | | | | | |
| | HUMAN | | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 |
| | OTHER | | 0.006 | 0.004 | 0.000 | 0.003 | 0.003 |
| | TOTAL | | 0.026 | 0.019 | 0.014 | 0.009 | 0.015 |
| SCHEDULED | NSSS | FUEL | 0.018 | 0.012 | 0.012 | 0.018 | 0.010 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.259 | 0.266 | 0.423 | 0.261 | 0.349 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.277 | 0.278 | 0.435 | 0.279 | 0.359 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| | | | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| | ECONOMIC | | 0.000 | 0.005 | 0.001 | 0.002 | 0.002 |
| | HUMAN | | | | | | |
| | OTHER | | 0.044 | 0.060 | 0.017 | 0.038 | 0.021 |
| | TOTAL | | 0.321 | 0.345 | 0.453 | 0.320 | 0.382 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.347 | 0.364 | 0.467 | 0.329 | 0.397 |
| ** CAPACITY FACTOR ** | | | 0.653 | 0.636 | 0.533 | 0.671 | 0.603 |

## Table 2.14 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — JAPAN
1975 - 1984 — ALL BWR'S

03/23/86

| | | | DATA: ( 9) | ( 5) | ( 5) | ( 5) | ( 3) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.006 | 0.000 | 0.000 | 0.003 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.006 | 0.000 | 0.000 | 0.003 | 0.000 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.003 | 0.007 |
| | | GEN | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.001 | 0.000 | 0.002 | 0.000 | 0.000 |
| | | OTHER | 0.002 | 0.000 | 0.000 | 0.002 | 0.000 |
| | | | 0.004 | 0.000 | 0.002 | 0.005 | 0.007 |
| | ECONOMIC | | | | | | |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.002 | 0.007 | 0.004 | 0.000 | 0.000 |
| | TOTAL | | 0.012 | 0.008 | 0.006 | 0.009 | 0.007 |
| SCHEDULED | NSSS | FUEL | 0.008 | 0.011 | 0.008 | 0.008 | 0.008 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.340 | 0.478 | 0.329 | 0.365 | 0.441 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.348 | 0.489 | 0.337 | 0.373 | 0.449 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ECONOMIC | | 0.000 | 0.001 | 0.007 | 0.001 | 0.000 |
| | HUMAN | | | | | | |
| | OTHER | | 0.021 | 0.021 | 0.031 | 0.018 | 0.015 |
| | TOTAL | | 0.369 | 0.511 | 0.376 | 0.392 | 0.463 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.381 | 0.519 | 0.381 | 0.401 | 0.470 |
| ** CAPACITY FACTOR ** | | | 0.619 | 0.481 | 0.619 | 0.599 | 0.530 |

## Table 2.14 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — JAPAN
1975 - 1984 — ALL BWR'S

03/23/86

| | | | DATA: | ( 2) | ( 1) | ( 1) | ( 1) | ( 0) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 11 | 12 | 13 | 14 | 15 |
| FORCED | NSSS | FUEL | | 0.000 | 0.001 | 0.000 | 0.000 | |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.000 | 0.000 | 0.009 | 0.000 | |
| | | | | 0.000 | 0.001 | 0.009 | 0.000 | |
| | BOP | TURBINE | | 0.000 | 0.016 | 0.018 | 0.000 | |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.001 | 0.000 | 0.000 | |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | | | 0.000 | 0.017 | 0.018 | 0.000 | |
| | ECONOMIC | | | | | | | |
| | HUMAN | | | 0.005 | 0.000 | 0.000 | 0.000 | |
| | OTHER | | | 0.000 | 0.026 | 0.000 | 0.000 | |
| | TOTAL | | | 0.005 | 0.044 | 0.027 | 0.000 | |
| SCHEDULED | NSSS | FUEL | | 0.009 | 0.009 | 0.004 | 0.002 | |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | SG | | | | | | |
| | | REFUEL | | 0.443 | 0.306 | 0.147 | 0.306 | |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | | | 0.452 | 0.315 | 0.151 | 0.308 | |
| | BOP | TURBINE | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | | | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | |
| | HUMAN | | | | | | | |
| | OTHER | | | 0.009 | 0.023 | 0.029 | 0.000 | |
| | TOTAL | | | 0.461 | 0.338 | 0.180 | 0.308 | |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | |

| | | | | | |
|---|---|---|---|---|---|
| ** TOTAL CAPACITY LOSS ** | 0.466 | 0.382 | 0.207 | 0.308 | |
| ** CAPACITY FACTOR ** | 0.534 | 0.618 | 0.793 | 0.692 | |

## Table 2.15 - Japanese Capacity Factor Distributions

| By Year | PWR Mean | PWR σ | PWR # Data | BWR Mean | BWR σ | BWR # Data |
|---|---|---|---|---|---|---|
| 75 | 0.475 | 0.363 | 4 | 0.281 | 0.330 | 3 |
| 76 | 0.621 | 0.125 | 5 | 0.619 | 0.136 | 5 |
| 77 | 0.549 | 0.283 | 6 | 0.258 | 0.215 | 5 |
| 78 | 0.607 | 0.103 | 6 | 0.497 | 0.267 | 9 |
| 79 | 0.345 | 0.157 | 8 | 0.625 | 0.096 | 10 |
| 80 | 0.624 | 0.154 | 8 | 0.617 | 0.123 | 10 |
| 81 | 0.643 | 0.179 | 9 | 0.614 | 0.136 | 10 |
| 82 | 0.728 | 0.132 | 10 | 0.702 | 0.145 | 11 |
| 83 | 0.736 | 0.173 | 10 | 0.682 | 0.081 | 11 |
| 84 | 0.729 | 0.129 | 11 | 0.721 | 0.138 | 13 |

| By Age | PWR Mean | PWR σ | PWR # Data | BWR Mean | BWR σ | BWR # Data |
|---|---|---|---|---|---|---|
| 1 | 0.703 | 0.166 | 9 | 0.653 | 0.249 | 11 |
| 2 | 0.619 | 0.145 | 9 | 0.636 | 0.134 | 10 |
| 3 | 0.514 | 0.299 | 10 | 0.533 | 0.275 | 10 |
| 4 | 0.593 | 0.187 | 9 | 0.671 | 0.127 | 9 |
| 5 | 0.655 | 0.212 | 8 | 0.603 | 0.219 | 10 |
| 6 | 0.682 | 0.168 | 7 | 0.620 | 0.149 | 9 |
| 7 | 0.601 | 0.189 | 6 | 0.481 | 0.258 | 5 |
| 8 | 0.689 | 0.127 | 5 | 0.618 | 0.133 | 5 |
| 9 | 0.705 | 0.071 | 4 | 0.599 | 0.064 | 5 |
| 10 | 0.524 | 0.013 | 2 | 0.529 | 0.155 | 3 |
| 11 | 0.345 | 0.000 | 1 | 0.533 | 0.244 | 2 |
| 12 | 0.949 | 0.000 | 1 | 0.618 | 0.000 | 1 |
| 13 | | | | 0.793 | 0.000 | 1 |
| 14 | | | | 0.692 | 0.000 | 1 |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |

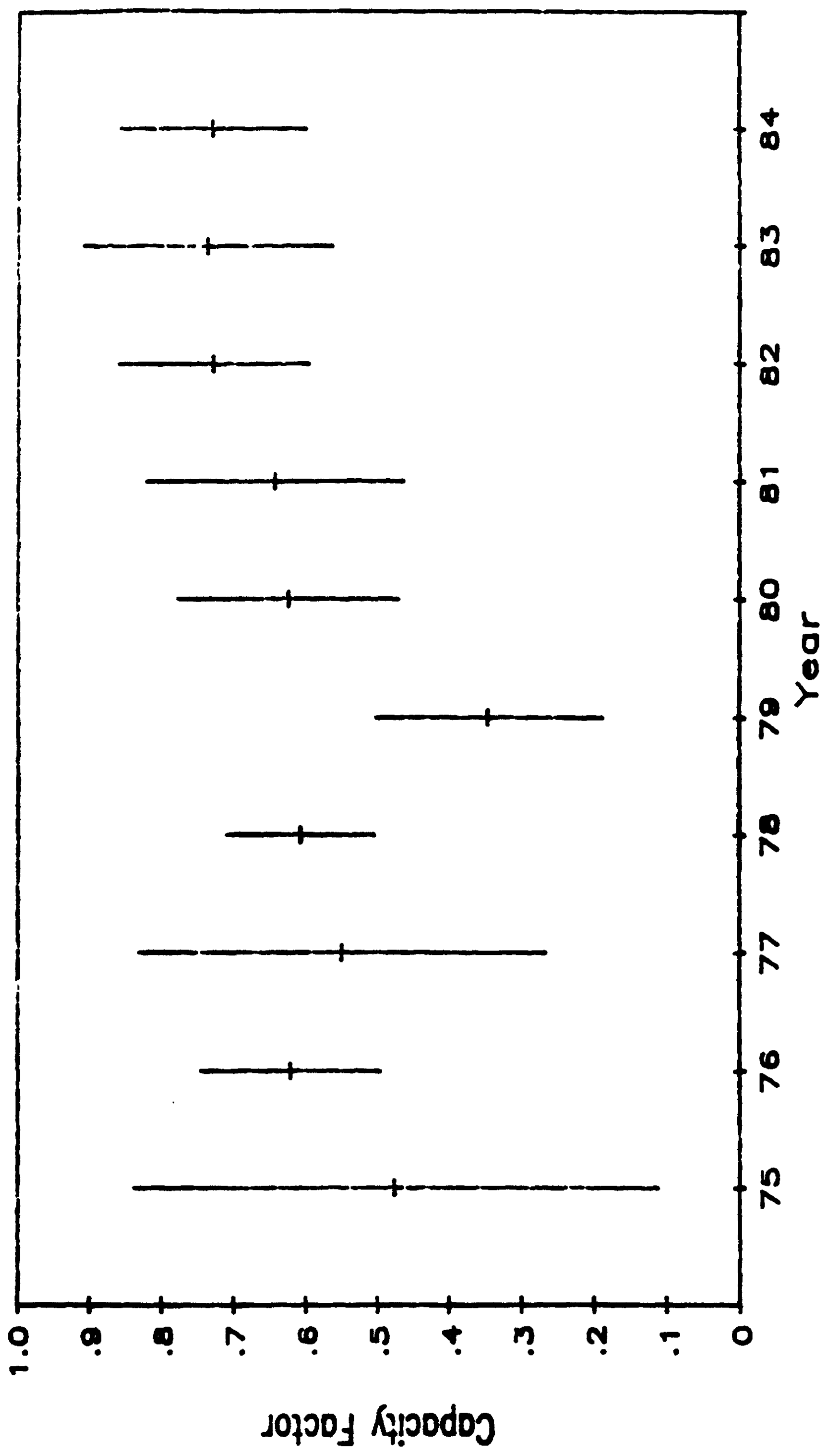
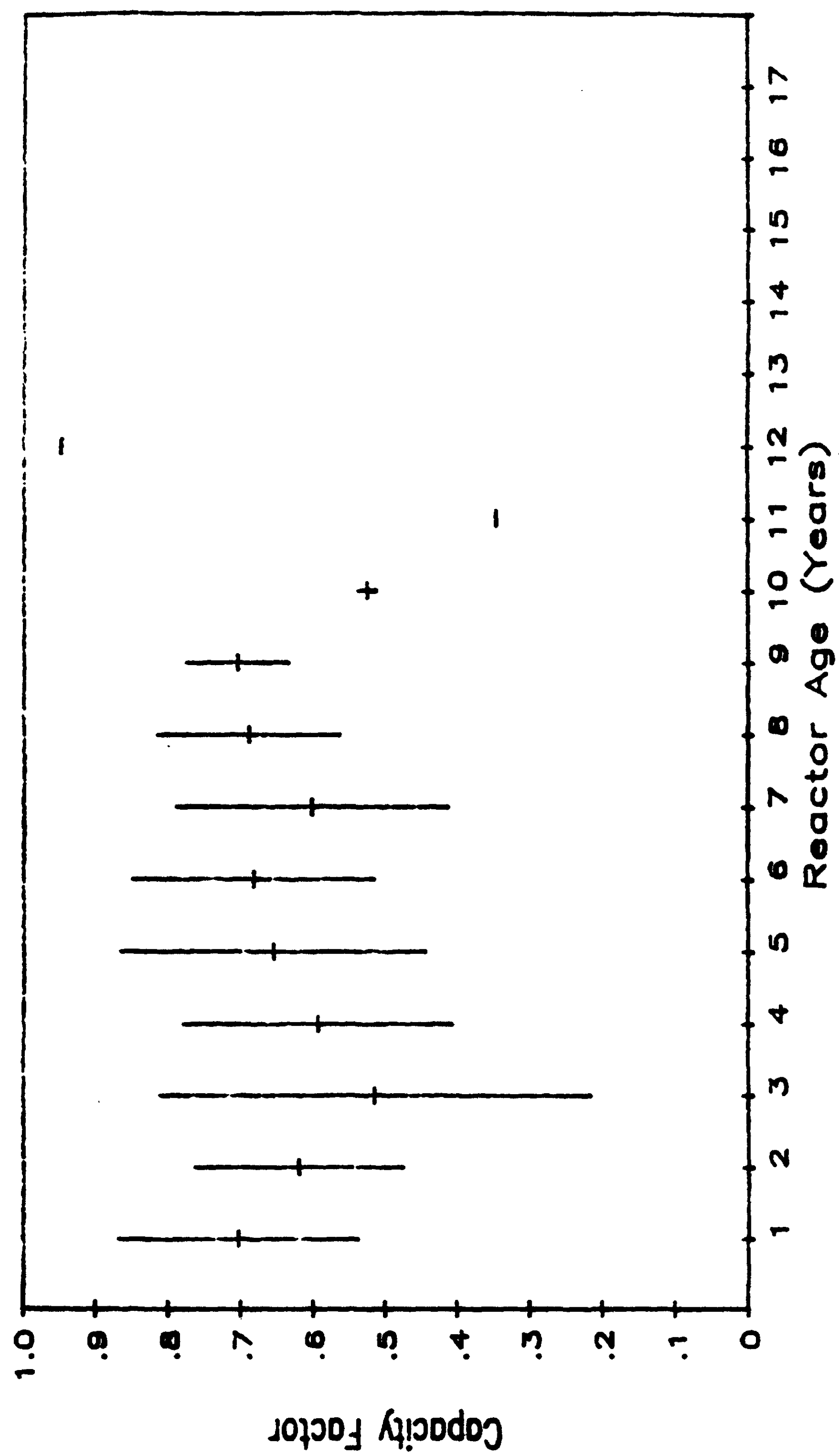



Figure 2.17
Japanese PWR Capacity Factor Distribution
By Year

Figure 2.18
Japanese PWR Capacity Factor Distribution
By Reactor Age



## Figure 2.19
Japanese BWR Capacity Factor Distribution By Year

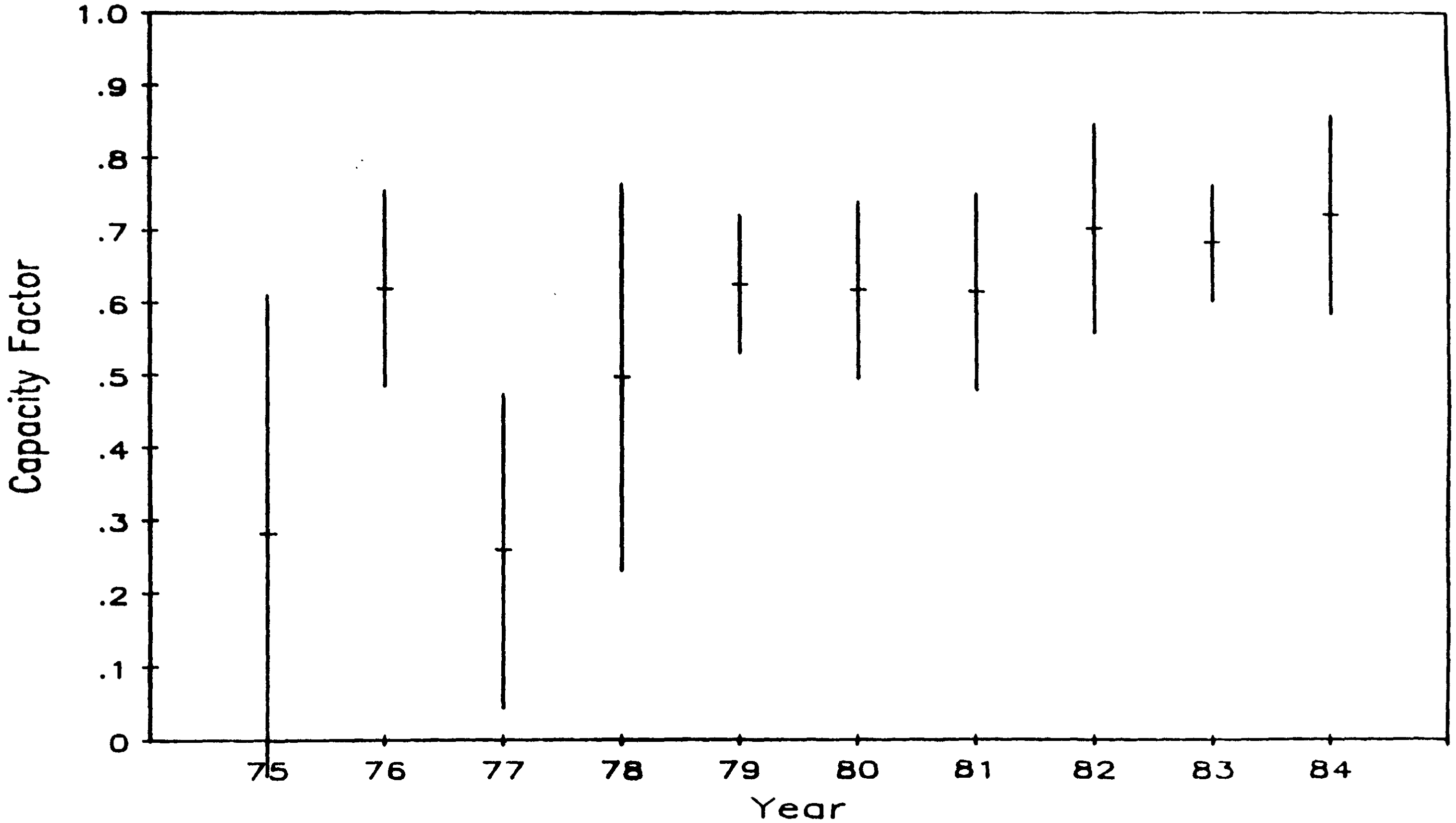


Figure 2.20
Japanese BWR Capacity Factor Distribution
By Reactor Age

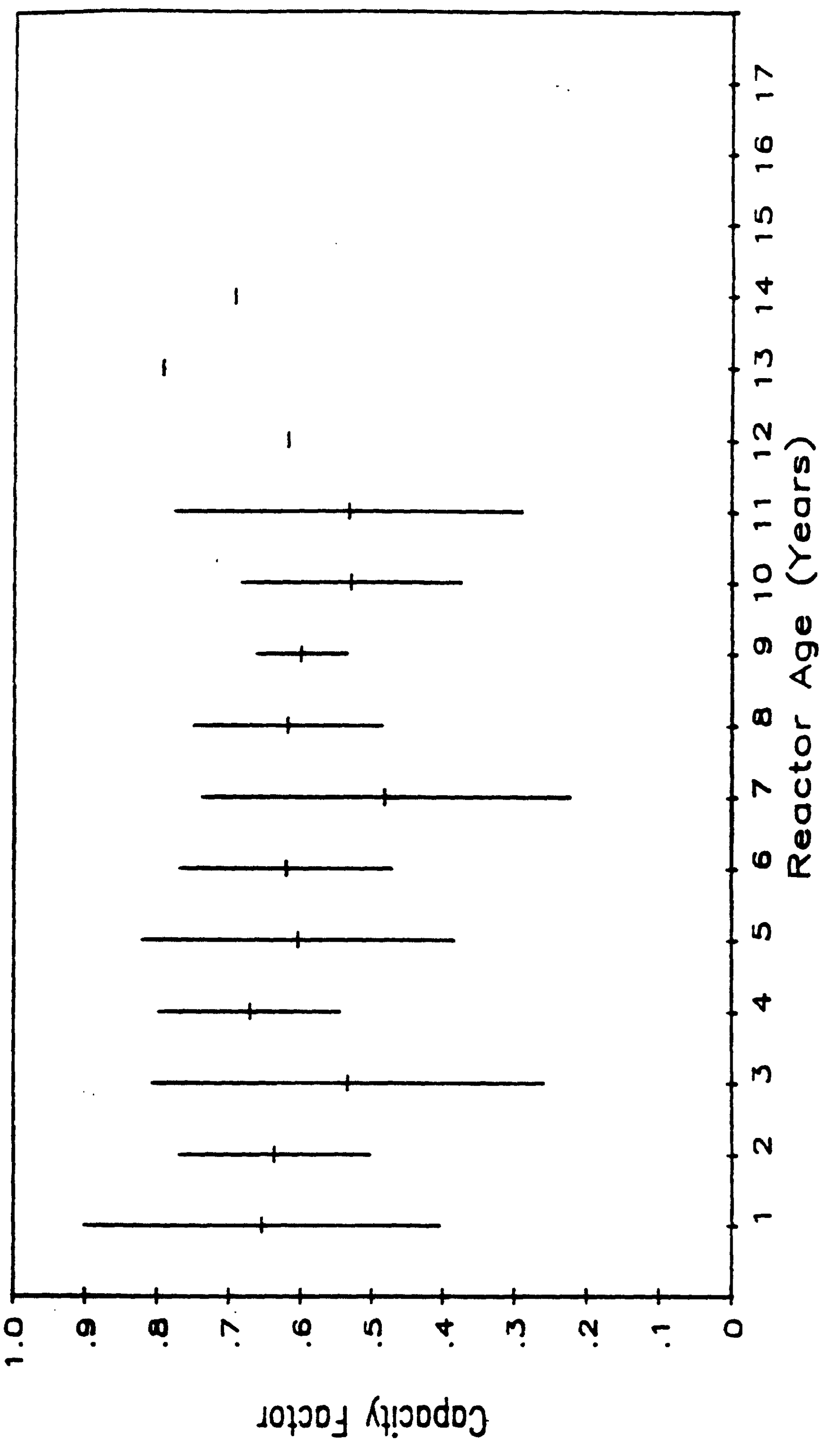
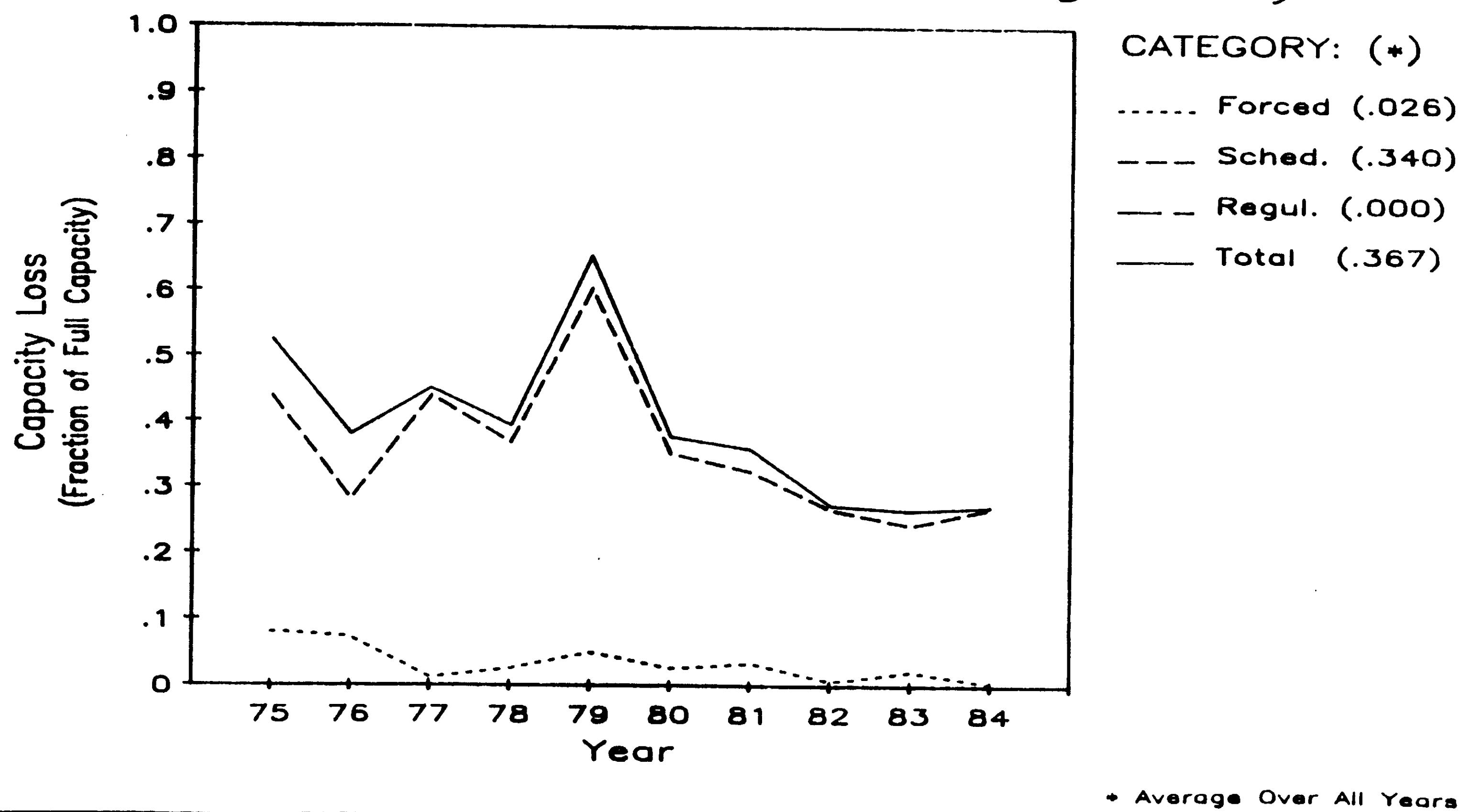
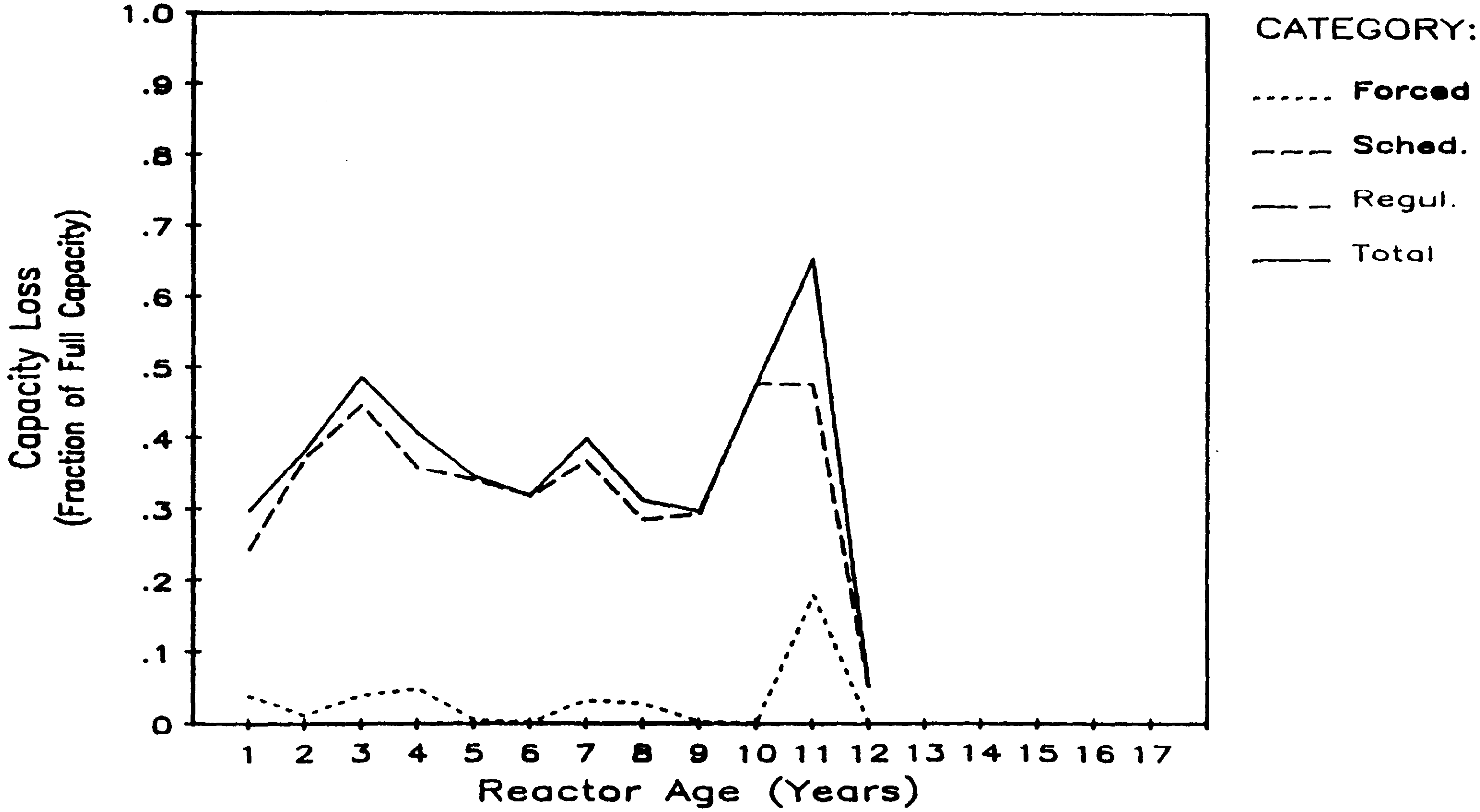


Figure 2.21
Japanese PWR Capacity Losses By Year
Forced, Scheduled, and Regulatory



## Figure 2.22
## Japanese PWR Capacity Losses By Rx Age Forced, Scheduled, and Regulatory



## Figure 2.23
Japanese BWR Capacity Losses By Year
Forced, Scheduled, and Regulatory

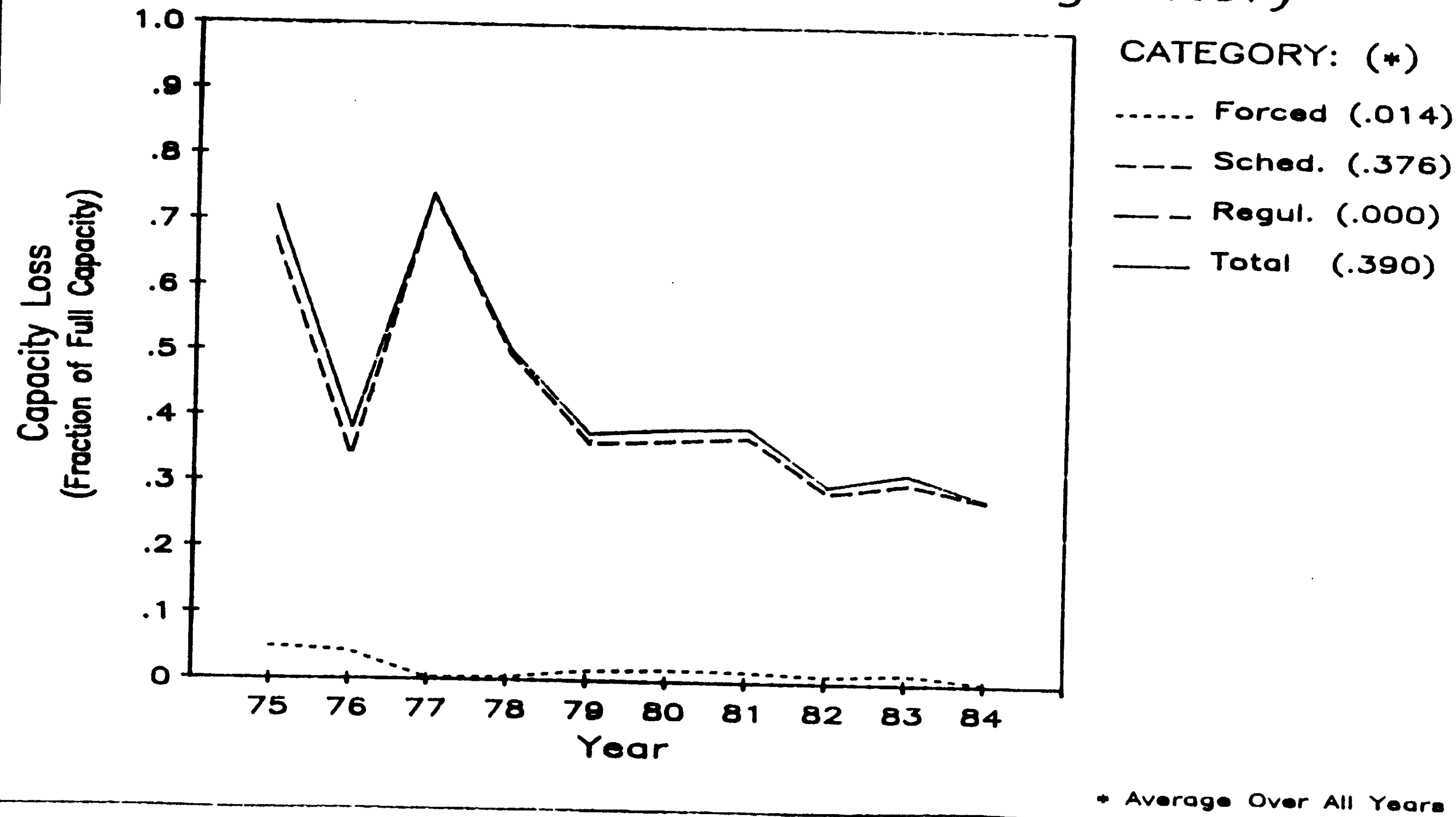
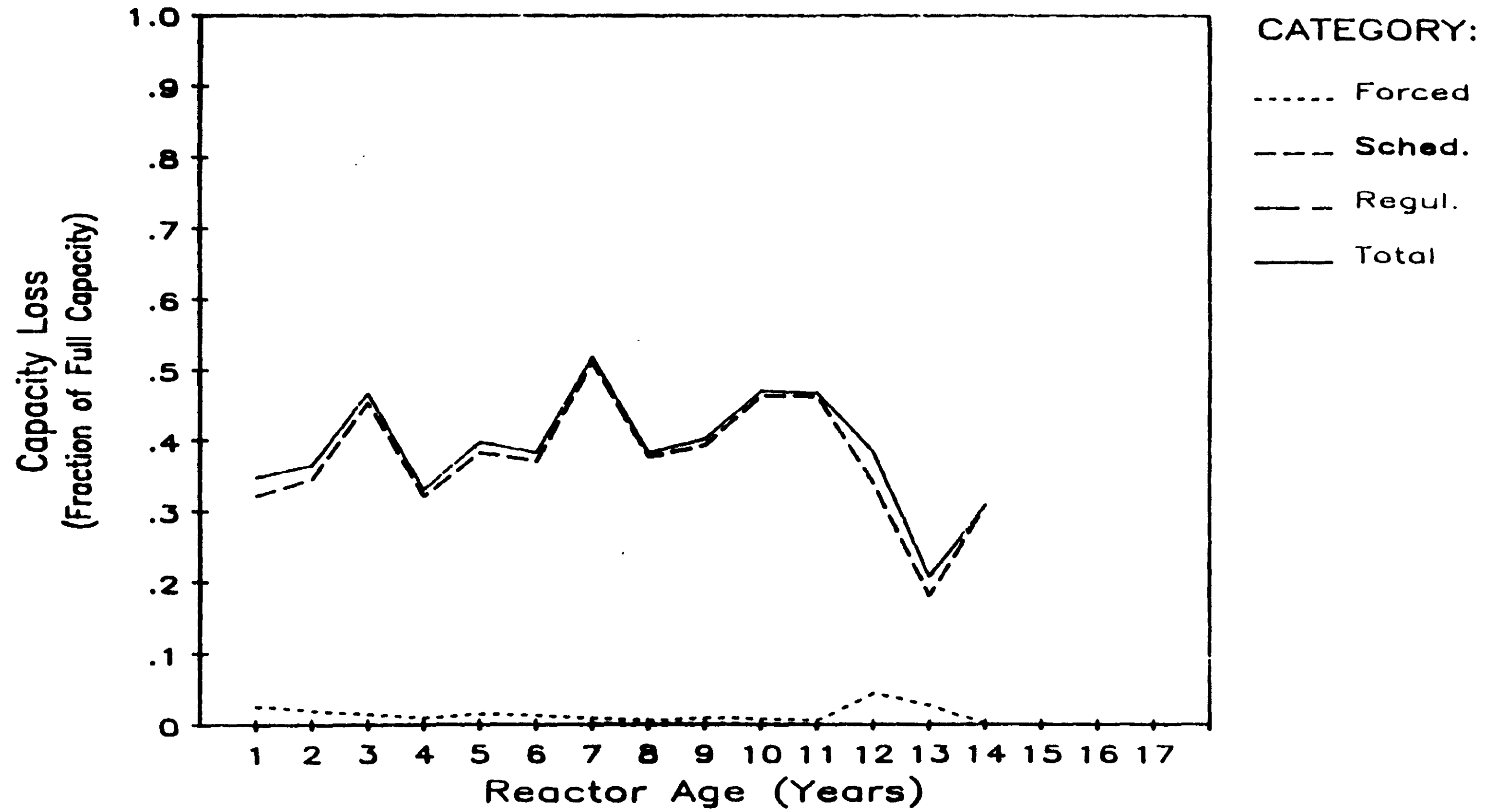
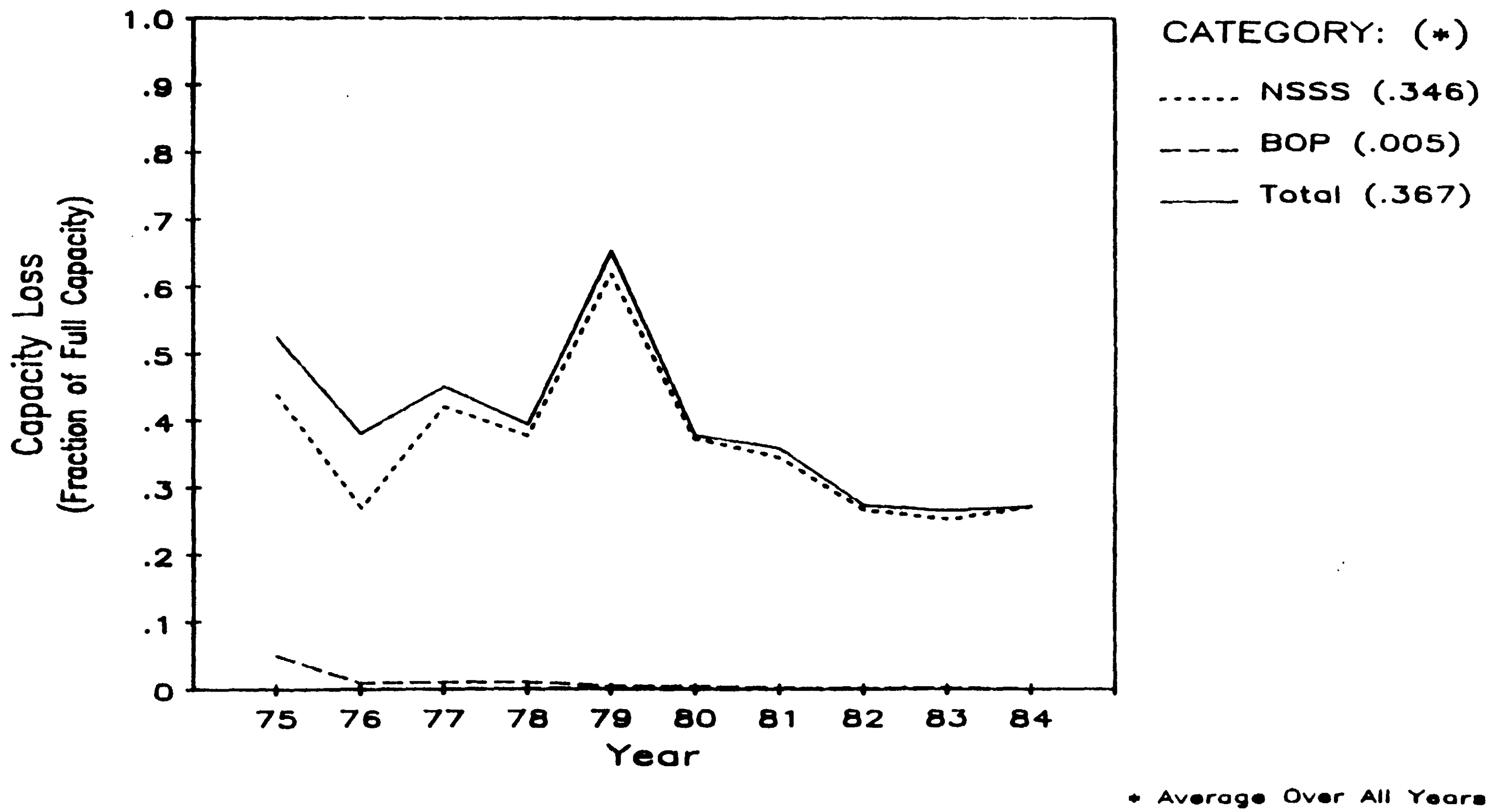


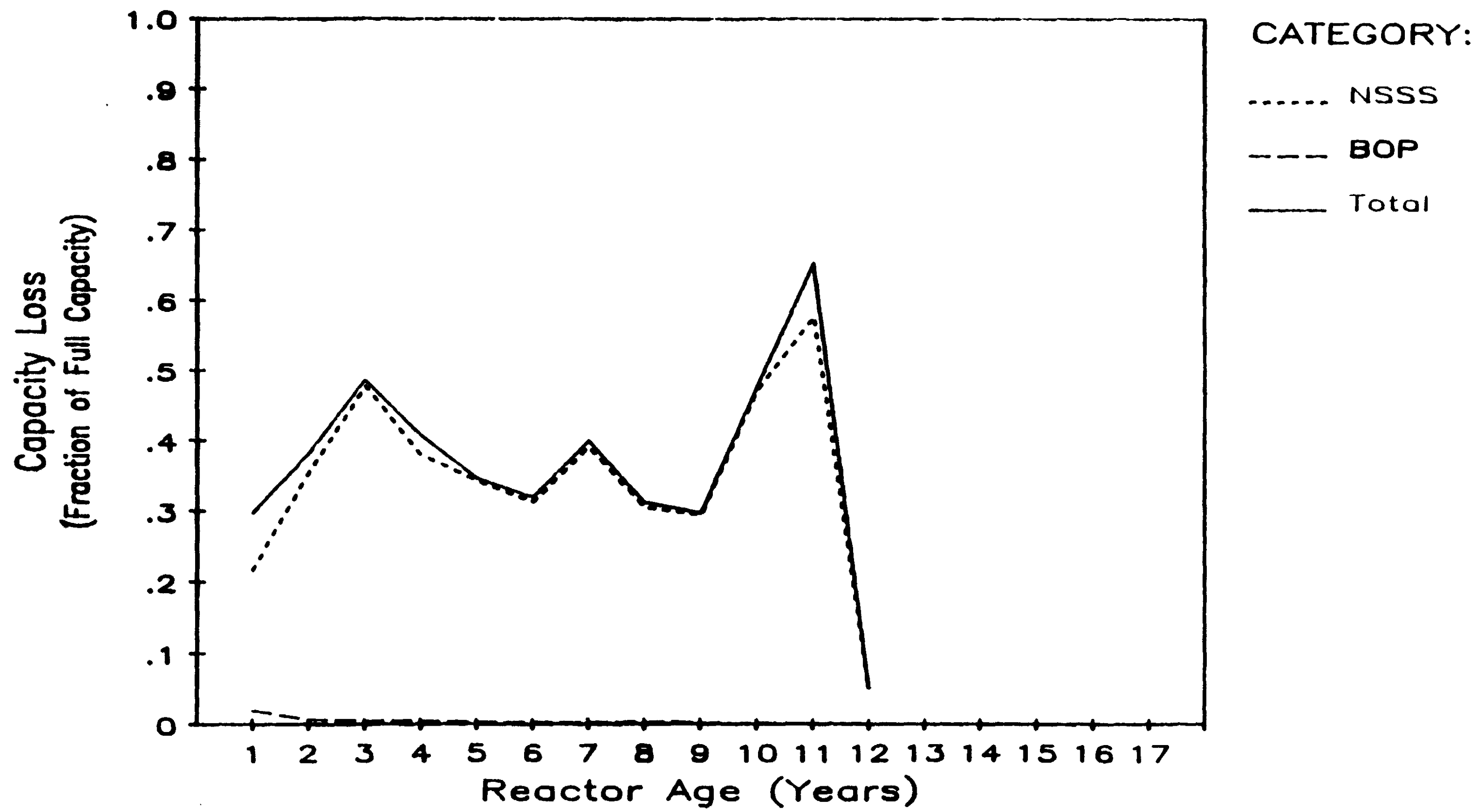
Figure 2.24
Japanese BWR Capacity Losses By Rx Age
Forced, Scheduled, and Regulatory



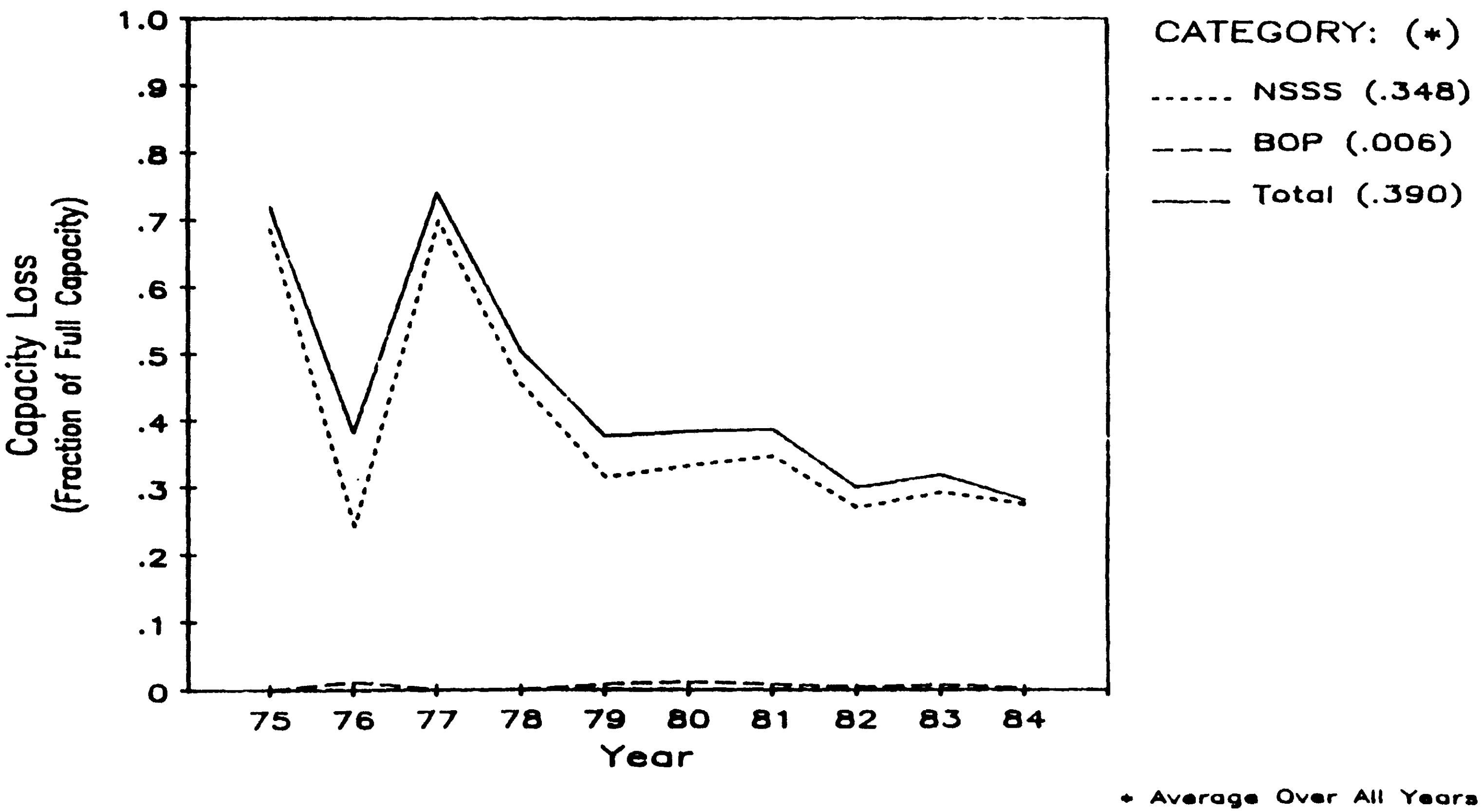
## Figure 2.25
Japanese PWR Capacity Losses By Year
NSSS and BOP



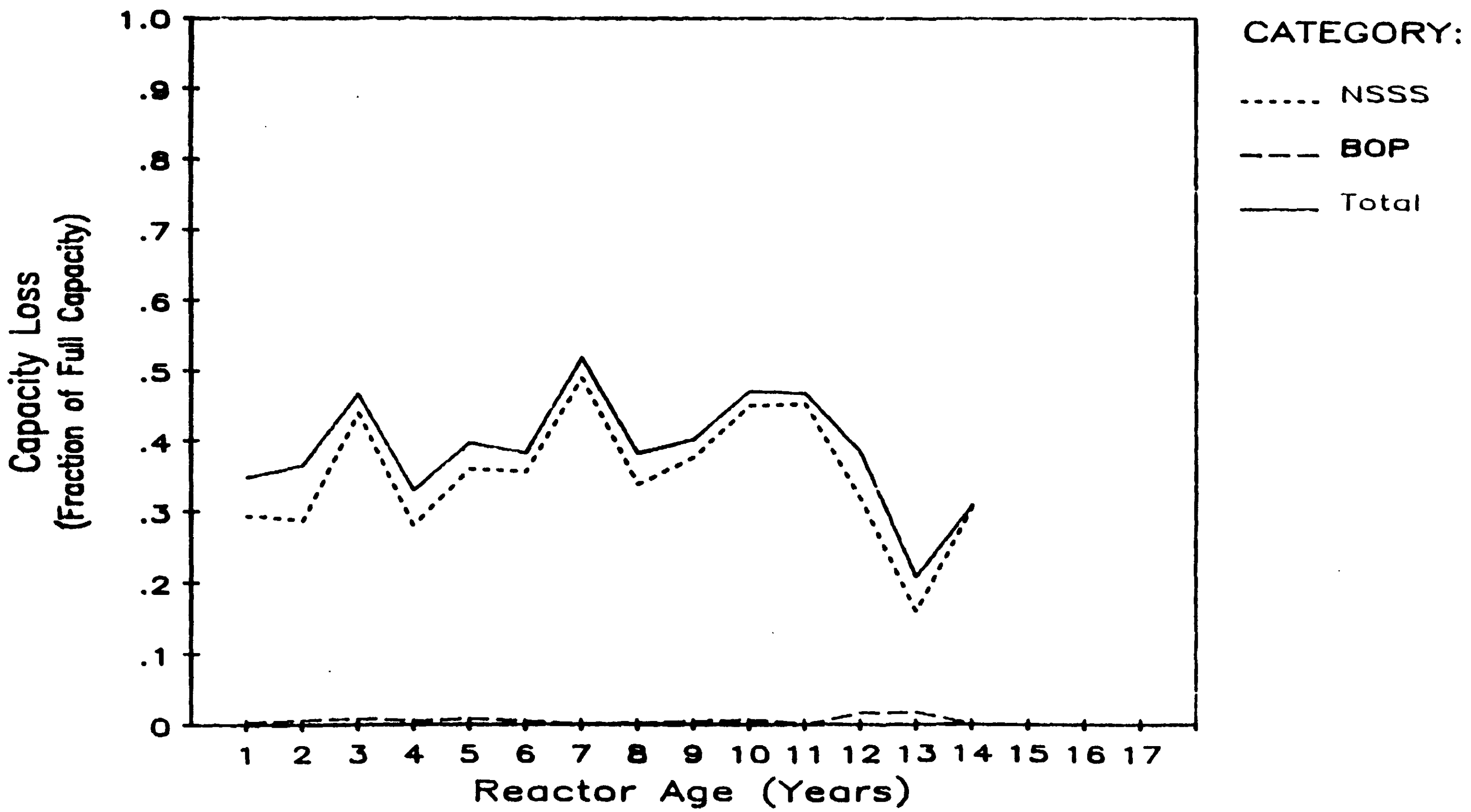
## Figure 2.26
Japanese PWR Capacity Losses By Rx Age
NSSS and BOP



## Figure 2.27
## Japanese BWR Capacity Losses By Year
## NSSS and BOP



## Figure 2.28
## Japanese BWR Capacity Losses By Rx Age
## NSSS and BOP



## 2.4 Sweden

In this section the performance losses for the Swedish nuclear power plants are presented and briefly examined. Capacity was the performance index used in compiling the Swedish data.

### 2.4.1 Aggregated Data

The Swedish PWR capacity losses are tabulated by calendar year and reactor age in Table 2.16 and Table 2.17 respectively. BWR capacity losses are given by year in Table 2.18 and by reactor age in Table 2.19. The mean and standard deviation of the capacity factor are tabulated by year and by age in Table 2.20. Scheduled losses were only available in aggregate form with the exception of economic losses.

### 2.4.2 Capacity Factor Distribution

Capacity factors for Swedish PWR's are plotted over time in Figure 2.29. The Swedish PWR performance has been the poorest of the six countries examined with a 10 year average of 54.4%. From 1975 to 1980 the capacity factor was from just one plant. Between 1980 and 1984, two more PWR's came online. The average capacity factor shows a drop in 1982 which is from several large steam generator and regulatory losses. The specific issue causing the regulatory shutdowns is unknown; it is plausible that they are related to the steam generators. Neither the capacity factors nor the standard deviations show any time dependency.

Plotted as a function of age in Figure 2.30, the performance of the Swedish PWR's shows a slight increasing age dependency. However, the number of plants for each age is small so that the trend is insignificant. This is confirmed by the large standard deviations through age 3.

Swedish BWR capacity factors are shown graphically in Figure 2.31. The figure indicates that Swedish BWR performance has been improving over time. Capacity factors increased an average of 10 percentage points from 1975 to 1984. The cause for the improvement was a reduction in forced balance of plant losses. The standard deviations, with an average of .081, do not show as large a variation as some of the other figures. This indicates that the Swedish BWR's have consistently performed well.

The BWR capacity factors are plotted by reactor age in Figure 2.32. In addition to the time dependency identified in the previous figure, the Swedish BWR's also exhibit an age dependence, with performance improving with age. This improvement was also caused by reductions in forced BOP losses. The magnitude of the standard deviations fluctuates with age and does not show an age dependence.

### 2.4.3 Losses by Outage Type

In this subsection, forced, scheduled, and regulatory losses for the Swedish nuclear plants are displayed and examined as functions of time and age.

Forced, scheduled and regulatory losses for the Swedish PWR's are plotted by year in Figure 2.33. From 1975 through 1980 the data shown is from one PWR. A second plant came online in 1981 and a third in 1983. The major contributor to the total losses over the 10 years was forced outages, representing 52.4% of the total loss. A considerable amount of variation is shown from year to year from several different systems. Scheduled losses were generally less than the forced losses with an average of 17.4% per year. As with the forced losses, there is fluctuation in the year to year data that cannot be identified. The regulatory losses prior to 1982 were generally small. In 1982 and 1983 unknown regulatory losses at two plants were primarily responsible for a drop in the average performance of approximately 20% of full capacity. None of the outage categories shows dependence on time.

The same Swedish PWR losses are also shown as a function of reactor age in Figure 2.34. The total losses exhibit a decreasing tendency with age that probably is not significant due to the small number of plants in the Swedish data. The forced losses also tend to follow this curve but do not display as much age dependence. Scheduled losses fluctuate about a constant value with no trend visible. As with the previous figure, the regulatory losses were small except over a two year period.

Forced, scheduled and regulatory losses are plotted by year for the Swedish BWR's in Figure 2.35. Compared to the PWR's, the BWR's exhibit much less fluctuation in forced and scheduled losses over the 10 years. Forced and scheduled losses have contributed nearly equally to the total losses each year, with almost negligible regulatory losses. Additionally, the forced, scheduled and total losses have been slowly decreasing over time. In the forced outage category, the reduced losses are due to fewer losses in the balance of plant. Individual categories within the scheduled outage category were not distinguishable.

The BWR outage category losses are plotted as a function of age in Figure 2.36. Here also, the forced and scheduled loss categories show a general dependence upon plant age, each decreasing with increased age. The age dependent decrease in the forced losses was due to reductions in many areas, while the aggregate scheduled losses data would not permit the identification of the responsible system(s).

### 2.4.4 NSSS and BOP Losses

The losses in the Nuclear Steam Supply System (NSSS) and the Balance of Plant (BOP) cannot be examined for the Swedish nuclear power plants because the data was unobtainable in completely disaggregated form.

## Table 2.16
Swedish PWR Capacity Losses
By Year

CAPACITY LOSSES — SWEDEN
1975 - 1979 — ALL PWR'S

03/25/86

| | | | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| | | DATA: | ( 1) | ( 1) | ( 1) | ( 1) | ( 1) |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 |
| | | SG | 0.000 | 0.003 | 0.031 | 0.000 | 0.082 |
| | | REFUEL | | | | | |
| | | OTHER | 0.000 | 0.108 | 0.002 | 0.048 | 0.051 |
| | | | 0.000 | 0.111 | 0.036 | 0.048 | 0.140 |
| | BOP | TURBINE | 0.001 | 0.003 | 0.008 | 0.000 | 0.044 |
| | | GEN | 0.049 | 0.024 | 0.001 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.017 | 0.148 | 0.033 | 0.002 | 0.000 |
| | | OTHER | 0.080 | 0.034 | 0.021 | 0.177 | 0.121 |
| | | | 0.147 | 0.209 | 0.063 | 0.179 | 0.165 |
| | ECONOMIC | | 0.019 | 0.061 | 0.032 | 0.009 | 0.030 |
| | HUMAN | | 0.004 | 0.002 | 0.000 | 0.000 | 0.007 |
| | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | 0.170 | 0.383 | 0.131 | 0.236 | 0.342 |
| SCHEDULED | NSSS | FUEL | | | | | |
| | | RCS | | | | | |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | | | | | |
| | BOP | TURBINE | | | | | |
| | | GEN | | | | | |
| | | COND | | | | | |
| | | CW/SW/CCW | | | | | |
| | | OTHER | | | | | |
| | ECONOMIC | | 0.000 | 0.000 | 0.069 | 0.000 | 0.002 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.266 | 0.030 | 0.292 | 0.169 | 0.136 |
| REGULATORY | | | 0.112 | 0.003 | 0.004 | 0.011 | 0.006 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.548 | 0.416 | 0.427 | 0.416 | 0.484 |
| ** CAPACITY FACTOR ** | | | 0.452 | 0.584 | 0.573 | 0.584 | 0.516 |

Table 2.16 - (Continued)

CAPACITY LOSSES — SWEDEN
1980 - 1984 — ALL PWR'S

03/25/86

| | | | DATA:( 1) | ( 2) | ( 2) | ( 3) | ( 3) |
|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | 0.062 | 0.245 | 0.280 | 0.034 | 0.018 |
| | | REFUEL | | | | | |
| | | OTHER | 0.042 | 0.025 | 0.008 | 0.008 | 0.042 |
| | | | 0.104 | 0.270 | 0.287 | 0.045 | 0.061 |
| | BOP | TURBINE | 0.001 | 0.001 | 0.000 | 0.001 | 0.004 |
| | | GEN | 0.010 | 0.002 | 0.001 | 0.016 | 0.015 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.023 | 0.068 | 0.007 | 0.026 | 0.010 |
| | | OTHER | 0.043 | 0.018 | 0.008 | 0.007 | 0.020 |
| | | | 0.077 | 0.089 | 0.014 | 0.049 | 0.049 |
| | ECONOMIC | | 0.016 | 0.037 | 0.011 | 0.073 | 0.041 |
| | HUMAN | | 0.002 | 0.002 | 0.000 | 0.000 | 0.002 |
| | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | 0.199 | 0.398 | 0.312 | 0.168 | 0.153 |
| SCHEDULED | NSSS | FUEL | | | | | |
| | | RCS | | | | | |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | | | | | |
| | | | | | | | |
| | BOP | TURBINE | | | | | |
| | | GEN | | | | | |
| | | COND | | | | | |
| | | CW/SW/CCW | | | | | |
| | | OTHER | | | | | |
| | | | | | | | |
| | ECONOMIC | | 0.000 | 0.002 | 0.001 | 0.004 | 0.013 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.187 | 0.103 | 0.164 | 0.223 | 0.173 |
| REGULATORY | | | 0.001 | 0.000 | 0.120 | 0.124 | 0.004 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.387 | 0.502 | 0.597 | 0.515 | 0.330 |
| ** CAPACITY FACTOR ** | | | 0.613 | 0.498 | 0.403 | 0.485 | 0.670 |

## Table 2.16 - (Continued)

CAPACITY LOSSES — SWEDEN
1975 - 1984 — ALL PWR'S

03/25/86 — DATA: 3 PLANTS — 16 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.001 |
| | | RCS | 0.000 |
| | | SG | 0.084 |
| | | REFUEL | |
| | | OTHER | 0.031 |
| | | | 0.117 |
| | BOP | TURBINE | 0.005 |
| | | GEN | 0.011 |
| | | COND | |
| | | CW/SW/CCW | 0.029 |
| | | OTHER | 0.040 |
| | | | 0.084 |
| | ECONOMIC | | 0.036 |
| | HUMAN | | 0.002 |
| | OTHER | | 0.000 |
| | TOTAL | | 0.239 |
| SCHEDULED | NSSS | FUEL | |
| | | RCS | |
| | | SG | |
| | | REFUEL | |
| | | OTHER | |
| | | | ------ |
| | BOP | TURBINE | |
| | | GEN | |
| | | COND | |
| | | CW/SW/CCW | |
| | | OTHER | |
| | | | ------ |
| | ECONOMIC | | 0.009 |
| | HUMAN | | |
| | OTHER | | |
| | TOTAL | | 0.174 |
| REGULATORY | | | 0.044 |
| UNKNOWN | | | 0.000 |

** TOTAL CAPACITY LOSS ** 0.456

** CAPACITY FACTOR ** 0.544

## Table 2.17
## Swedish PWR Capacity Losses
## By Reactor Age

CAPACITY LOSSES BY REACTOR AGE — SWEDEN
1975 - 1984 — ALL PWR'S

03/23/86

| | | | DATA: | ( 3) | ( 2) | ( 2) | ( 2) | ( 1) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 |
| | | SG | | 0.098 | 0.203 | 0.015 | 0.000 | 0.082 |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.013 | 0.057 | 0.005 | 0.074 | 0.051 |
| | | | | 0.111 | 0.260 | 0.025 | 0.074 | 0.140 |
| | BOP | TURBINE | | 0.000 | 0.002 | 0.004 | 0.002 | 0.044 |
| | | GEN | | 0.038 | 0.012 | 0.001 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.023 | 0.079 | 0.035 | 0.010 | 0.000 |
| | | OTHER | | 0.034 | 0.018 | 0.013 | 0.098 | 0.121 |
| | | | | 0.095 | 0.111 | 0.053 | 0.110 | 0.165 |
| | ECONOMIC | | | 0.028 | 0.036 | 0.045 | 0.016 | 0.030 |
| | HUMAN | | | 0.002 | 0.001 | 0.001 | 0.000 | 0.007 |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.237 | 0.406 | 0.123 | 0.198 | 0.342 |
| SCHEDULED | NSSS | FUEL | | | | | | |
| | | RCS | | | | | | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | | | | | |
| | BOP | TURBINE | | | | | | |
| | | GEN | | | | | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | | | | | |
| | | OTHER | | | | | | |
| | ECONOMIC | | | 0.001 | 0.000 | 0.035 | 0.016 | 0.002 |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.155 | 0.101 | 0.284 | 0.171 | 0.136 |
| REGULATORY | | | | 0.043 | 0.122 | 0.126 | 0.005 | 0.006 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.435 | 0.629 | 0.533 | 0.375 | 0.484 |
| ** CAPACITY FACTOR ** | | | | 0.565 | 0.371 | 0.467 | 0.625 | 0.516 |

## Table 2.17 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — SWEDEN
1975 - 1984 — ALL PWR'S

03/23/86

| | | | DATA: | ( 1) | ( 1) | ( 1) | ( 1) | ( 1) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | 0.062 | 0.130 | 0.156 | 0.074 | 0.055 |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.042 | 0.010 | 0.010 | 0.009 | 0.024 |
| | | | | 0.104 | 0.140 | 0.166 | 0.083 | 0.079 |
| | BOP | TURBINE | | 0.001 | 0.001 | 0.000 | 0.002 | 0.009 |
| | | GEN | | 0.010 | 0.003 | 0.001 | 0.005 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.023 | 0.069 | 0.004 | 0.020 | 0.001 |
| | | OTHER | | 0.043 | 0.024 | 0.014 | 0.008 | 0.026 |
| | | | | 0.077 | 0.097 | 0.019 | 0.035 | 0.036 |
| | ECONOMIC | | | 0.016 | 0.038 | 0.011 | 0.096 | 0.070 |
| | HUMAN | | | 0.002 | 0.003 | 0.000 | 0.000 | 0.005 |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.198 | 0.278 | 0.196 | 0.214 | 0.190 |
| SCHEDULED | NSSS | FUEL | | | | | | |
| | | RCS | | | | | | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | | | | | |
| | BOP | TURBINE | | | | | | |
| | | GEN | | | | | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | | | | | |
| | | OTHER | | | | | | |
| | ECONOMIC | | | 0.000 | 0.003 | 0.002 | 0.008 | 0.004 |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.187 | 0.138 | 0.155 | 0.209 | 0.214 |
| REGULATORY | | | | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.387 | 0.416 | 0.351 | 0.423 | 0.405 |
| ** CAPACITY FACTOR ** | | | | 0.613 | 0.584 | 0.649 | 0.577 | 0.595 |

# Table 2.18
## Swedish BWR Capacity Losses By Year

CAPACITY LOSSES
1975 - 1979

SWEDEN
ALL BWR'S

03/25/86

| | | | DATA: | ( 2) | ( 4) | ( 4) | ( 5) | ( 5) |
|---|---|---|---|---|---|---|---|---|
| | | | | 1975 | 1976 | 1977 | 1978 | 1979 |
| FORCED | NSSS | FUEL | | 0.000 | 0.001 | 0.000 | 0.009 | 0.000 |
| | | RCS | | 0.000 | 0.002 | 0.002 | 0.001 | 0.004 |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.014 | 0.038 | 0.008 | 0.014 | 0.016 |
| | | | | 0.014 | 0.041 | 0.010 | 0.024 | 0.020 |
| | BOP | TURBINE | | 0.061 | 0.025 | 0.026 | 0.002 | 0.023 |
| | | GEN | | 0.004 | 0.001 | 0.030 | 0.020 | 0.087 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.071 | 0.023 | 0.007 | 0.041 | 0.041 |
| | | OTHER | | 0.052 | 0.135 | 0.086 | 0.026 | 0.034 |
| | | | | 0.188 | 0.185 | 0.149 | 0.089 | 0.184 |
| | ECONOMIC | | | 0.003 | 0.019 | 0.008 | 0.001 | 0.002 |
| | HUMAN | | | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.204 | 0.245 | 0.168 | 0.115 | 0.207 |
| SCHEDULED | NSSS | FUEL | | | | | | |
| | | RCS | | | | | | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | | | | | |
| | | | | ------ | ------ | ------ | ------ | ------ |
| | BOP | TURBINE | | | | | | |
| | | GEN | | | | | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | | | | | |
| | | OTHER | | | | | | |
| | | | | ------ | ------ | ------ | ------ | ------ |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.147 | 0.192 | 0.217 | 0.134 | 0.130 |
| REGULATORY | | | | 0.002 | 0.034 | 0.003 | 0.004 | 0.002 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.354 | 0.470 | 0.389 | 0.252 | 0.340 |
| ** CAPACITY FACTOR ** | | | | 0.646 | 0.530 | 0.612 | 0.748 | 0.660 |

Table 2.18 - (Continued)

CAPACITY LOSSES 1980 - 1984 — SWEDEN, ALL BWR'S

03/25/86

| | | | DATA:( 5) | ( 7) | ( 7) | ( 7) | ( 7) |
|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
| FORCED | NSSS | FUEL | 0.000 | 0.002 | 0.002 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.001 | 0.002 | 0.004 | 0.001 |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | 0.009 | 0.013 | 0.057 | 0.008 | 0.008 |
| | | | 0.009 | 0.015 | 0.060 | 0.012 | 0.009 |
| | BOP | TURBINE | 0.009 | 0.010 | 0.003 | 0.004 | 0.000 |
| | | GEN | 0.010 | 0.001 | 0.003 | 0.004 | 0.001 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.035 | 0.013 | 0.014 | 0.014 | 0.003 |
| | | OTHER | 0.036 | 0.019 | 0.022 | 0.023 | 0.026 |
| | | | 0.090 | 0.043 | 0.043 | 0.045 | 0.030 |
| | ECONOMIC | | 0.010 | 0.025 | 0.012 | 0.053 | 0.029 |
| | HUMAN | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | 0.108 | 0.084 | 0.116 | 0.109 | 0.068 |
| SCHEDULED | NSSS | FUEL | | | | | |
| | | RCS | | | | | |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | | | | | |
| | | | | | | | |
| | BOP | TURBINE | | | | | |
| | | GEN | | | | | |
| | | COND | | | | | |
| | | CW/SW/CCW | | | | | |
| | | OTHER | | | | | |
| | | | | | | | |
| | ECONOMIC | | 0.004 | 0.014 | 0.019 | 0.028 | 0.022 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.150 | 0.156 | 0.100 | 0.155 | 0.120 |
| REGULATORY | | | 0.006 | 0.009 | 0.007 | 0.005 | 0.003 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.264 | 0.250 | 0.223 | 0.269 | 0.191 |
| ** CAPACITY FACTOR ** | | | 0.736 | 0.750 | 0.777 | 0.731 | 0.809 |

## Table 2.18 - (Continued)

CAPACITY LOSSES
1975 - 1984

SWEDEN
ALL BWR'S

03/25/86 DATA: 7 PLANTS 53 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.001 |
| | | RCS | 0.002 |
| | | SG | |
| | | REFUEL | |
| | | OTHER | 0.019 |
| | | | 0.022 |
| | BOP | TURBINE | 0.011 |
| | | GEN | 0.015 |
| | | COND | |
| | | CW/SW/CCW | 0.022 |
| | | OTHER | 0.039 |
| | | | 0.088 |
| | ECONOMIC | | 0.019 |
| | HUMAN | | 0.000 |
| | OTHER | | 0.000 |
| | TOTAL | | 0.129 |
| SCHEDULED | NSSS | FUEL | |
| | | RCS | |
| | | SG | |
| | | REFUEL | |
| | | OTHER | |
| | | | |
| | BOP | TURBINE | |
| | | GEN | |
| | | COND | |
| | | CW/SW/CCW | |
| | | OTHER | |
| | | | |
| | ECONOMIC | | 0.012 |
| | HUMAN | | |
| | OTHER | | |
| | TOTAL | | 0.145 |
| REGULATORY | | | 0.007 |
| UNKNOWN | | | 0.000 |

** TOTAL CAPACITY LOSS ** 0.281

** CAPACITY FACTOR ** 0.719

## Table 2.19
## Swedish BWR Capacity Losses
## By Reactor Age

CAPACITY LOSSES BY REACTOR AGE — SWEDEN
1975 - 1984 — ALL BWR'S

03/23/86

| | | | DATA: | ( 5) | ( 6) | ( 6) | ( 6) | ( 5) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | | 0.001 | 0.000 | 0.007 | 0.000 | 0.000 |
| | | RCS | | 0.001 | 0.002 | 0.000 | 0.002 | 0.000 |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.061 | 0.037 | 0.009 | 0.012 | 0.005 |
| | | | | 0.063 | 0.039 | 0.016 | 0.014 | 0.005 |
| | BOP | TURBINE | | 0.042 | 0.020 | 0.002 | 0.009 | 0.011 |
| | | GEN | | 0.004 | 0.003 | 0.021 | 0.016 | 0.085 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.023 | 0.014 | 0.011 | 0.041 | 0.032 |
| | | OTHER | | 0.033 | 0.086 | 0.062 | 0.026 | 0.049 |
| | | | | 0.102 | 0.123 | 0.096 | 0.092 | 0.177 |
| | ECONOMIC | | | 0.009 | 0.029 | 0.019 | 0.014 | 0.014 |
| | HUMAN | | | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.176 | 0.191 | 0.131 | 0.121 | 0.198 |
| SCHEDULED | NSSS | FUEL | | | | | | |
| | | RCS | | | | | | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | | | | | |
| | BOP | TURBINE | | | | | | |
| | | GEN | | | | | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | | | | | |
| | | OTHER | | | | | | |
| | ECONOMIC | | | 0.000 | 0.016 | 0.010 | 0.014 | 0.005 |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.165 | 0.152 | 0.191 | 0.142 | 0.104 |
| REGULATORY | | | | 0.031 | 0.003 | 0.006 | 0.004 | 0.007 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.372 | 0.346 | 0.327 | 0.267 | 0.309 |
| ** CAPACITY FACTOR ** | | | | 0.628 | 0.654 | 0.673 | 0.733 | 0.691 |

## Table 2.19 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — SWEDEN
1975 - 1984 — ALL BWR'S

03/23/86

| | | | DATA: ( 5) | ( 5) | ( 4) | ( 4) | ( 3) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | 0.002 | 0.000 | 0.004 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.004 | 0.006 | 0.004 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | 0.008 | 0.013 | 0.017 | 0.027 | 0.013 |
| | | | 0.010 | 0.017 | 0.027 | 0.031 | 0.013 |
| | BOP | TURBINE | 0.008 | 0.013 | 0.002 | 0.002 | 0.000 |
| | | GEN | 0.008 | 0.001 | 0.010 | 0.001 | 0.001 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.008 | 0.028 | 0.030 | 0.021 | 0.011 |
| | | OTHER | 0.046 | 0.017 | 0.021 | 0.010 | 0.023 |
| | | | 0.070 | 0.059 | 0.063 | 0.034 | 0.035 |
| | ECONOMIC | | 0.019 | 0.009 | 0.029 | 0.024 | 0.018 |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | 0.100 | 0.084 | 0.118 | 0.090 | 0.066 |
| SCHEDULED | NSSS | FUEL | | | | | |
| | | RCS | | | | | |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | | | | | |
| | BOP | TURBINE | | | | | |
| | | GEN | | | | | |
| | | COND | | | | | |
| | | CW/SW/CCW | | | | | |
| | | OTHER | | | | | |
| | ECONOMIC | | 0.015 | 0.017 | 0.008 | 0.013 | 0.010 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.171 | 0.122 | 0.163 | 0.121 | 0.102 |
| REGULATORY | | | 0.007 | 0.006 | 0.005 | 0.004 | 0.001 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.278 | 0.212 | 0.286 | 0.215 | 0.169 |
| ** CAPACITY FACTOR ** | | | 0.722 | 0.788 | 0.714 | 0.785 | 0.831 |

Table 2.19 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — SWEDEN
1975 - 1984 — ALL BWR'S

03/23/86

| | | | DATA: | ( 1) | ( 1) | ( 1) | ( 0) | ( 0) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 11 | 12 | 13 | 14 | 15 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | | |
| | | RCS | | 0.000 | 0.000 | 0.000 | | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.009 | 0.000 | 0.000 | | |
| | | | | 0.009 | 0.000 | 0.000 | | |
| | BOP | TURBINE | | 0.018 | 0.000 | 0.000 | | |
| | | GEN | | 0.000 | 0.000 | 0.000 | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.044 | 0.000 | 0.000 | | |
| | | OTHER | | 0.021 | 0.031 | 0.072 | | |
| | | | | 0.083 | 0.031 | 0.072 | | |
| | ECONOMIC | | | 0.011 | 0.024 | 0.002 | | |
| | HUMAN | | | 0.000 | 0.000 | 0.000 | | |
| | OTHER | | | 0.000 | 0.000 | 0.000 | | |
| | TOTAL | | | 0.103 | 0.055 | 0.074 | | |
| SCHEDULED | NSSS | FUEL | | | | | | |
| | | RCS | | | | | | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | | | | | |
| | BOP | TURBINE | | | | | | |
| | | GEN | | | | | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | | | | | |
| | | OTHER | | | | | | |
| | ECONOMIC | | | 0.000 | 0.025 | 0.044 | | |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.133 | 0.128 | 0.154 | | |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | | |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | | |

| | | | | | |
|---|---|---|---|---|---|
| ** TOTAL CAPACITY LOSS ** | 0.236 | 0.183 | 0.228 | | |
| ** CAPACITY FACTOR ** | 0.764 | 0.817 | 0.772 | | |

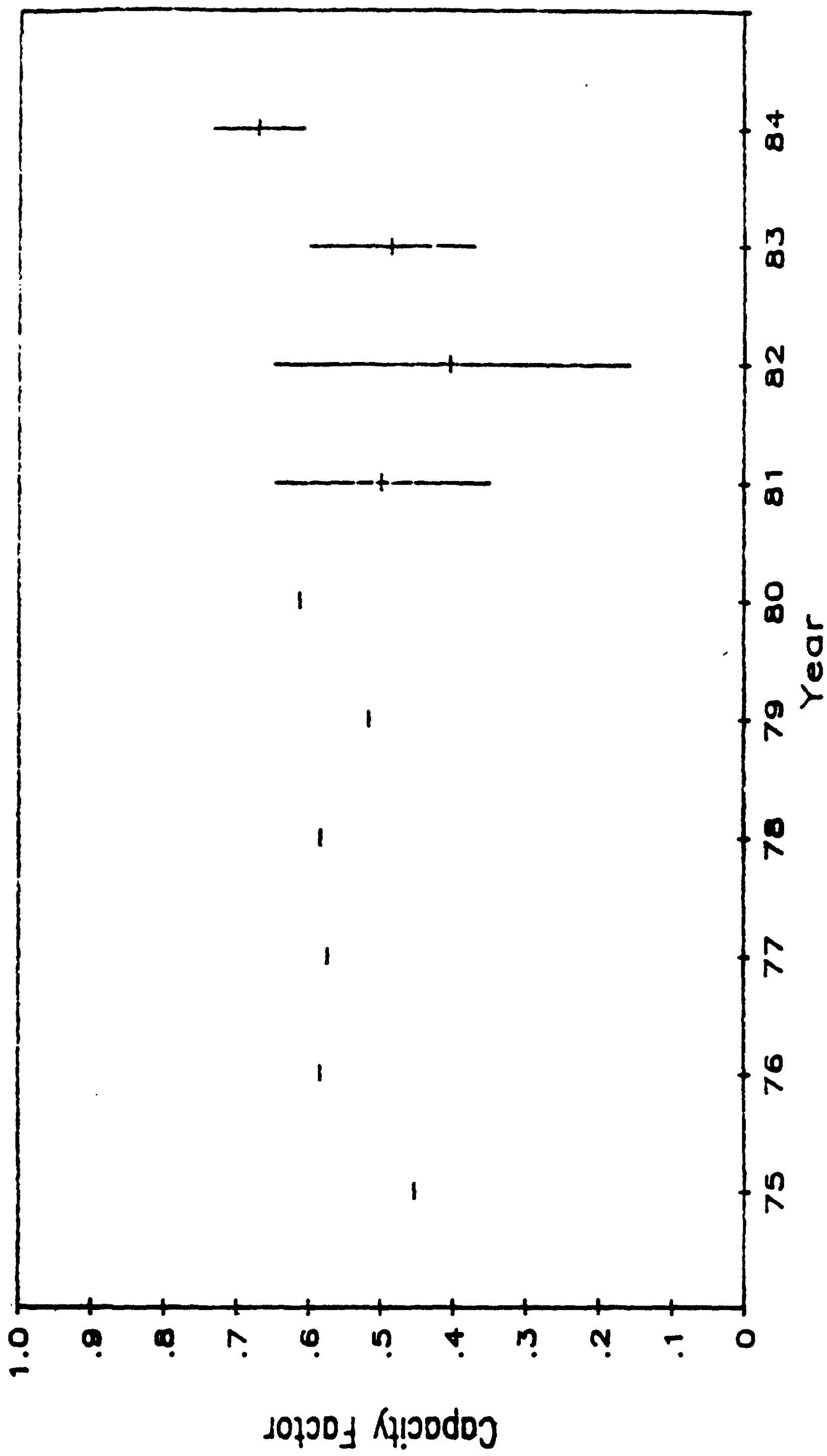
Table 2.20 - Swedish Capacity Factor Distributions

| By Year | PWR Mean | PWR σ | PWR # Data | BWR Mean | BWR σ | BWR # Data |
|---|---|---|---|---|---|---|
| 75 | 0.452 | 0.000 | 1 | 0.647 | 0.049 | 2 |
| 76 | 0.584 | 0.000 | 1 | 0.530 | 0.129 | 4 |
| 77 | 0.573 | 0.000 | 1 | 0.612 | 0.074 | 4 |
| 78 | 0.584 | 0.000 | 1 | 0.748 | 0.062 | 5 |
| 79 | 0.516 | 0.000 | 1 | 0.660 | 0.126 | 5 |
| 80 | 0.613 | 0.000 | 1 | 0.736 | 0.063 | 5 |
| 81 | 0.498 | 0.149 | 2 | 0.750 | 0.063 | 7 |
| 82 | 0.403 | 0.246 | 2 | 0.777 | 0.085 | 7 |
| 83 | 0.485 | 0.115 | 3 | 0.731 | 0.103 | 7 |
| 84 | 0.670 | 0.063 | 3 | 0.809 | 0.051 | 7 |

| By Age | PWR Mean | PWR σ | PWR # Data | BWR Mean | BWR σ | BWR # Data |
|---|---|---|---|---|---|---|
| 1 | 0.565 | 0.197 | 3 | 0.628 | 0.166 | 5 |
| 2 | 0.370 | 0.214 | 2 | 0.654 | 0.091 | 6 |
| 3 | 0.468 | 0.105 | 2 | 0.673 | 0.071 | 6 |
| 4 | 0.625 | 0.040 | 2 | 0.733 | 0.076 | 6 |
| 5 | 0.516 | 0.000 | 1 | 0.692 | 0.157 | 5 |
| 6 | 0.613 | 0.000 | 1 | 0.723 | 0.073 | 5 |
| 7 | 0.584 | 0.000 | 1 | 0.788 | 0.041 | 5 |
| 8 | 0.649 | 0.000 | 1 | 0.714 | 0.138 | 4 |
| 9 | 0.577 | 0.000 | 1 | 0.785 | 0.017 | 4 |
| 10 | 0.595 | 0.000 | 1 | 0.832 | 0.066 | 3 |
| 11 | | | | 0.764 | 0.000 | 1 |
| 12 | | | | 0.817 | 0.000 | 1 |
| 13 | | | | 0.772 | 0.000 | 1 |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |

Figure 2.29

Swedish PWR Capacity Factor Distribution By Year



## Figure 2.30
Swedish PWR Capacity Factor Distribution
By Reactor Age

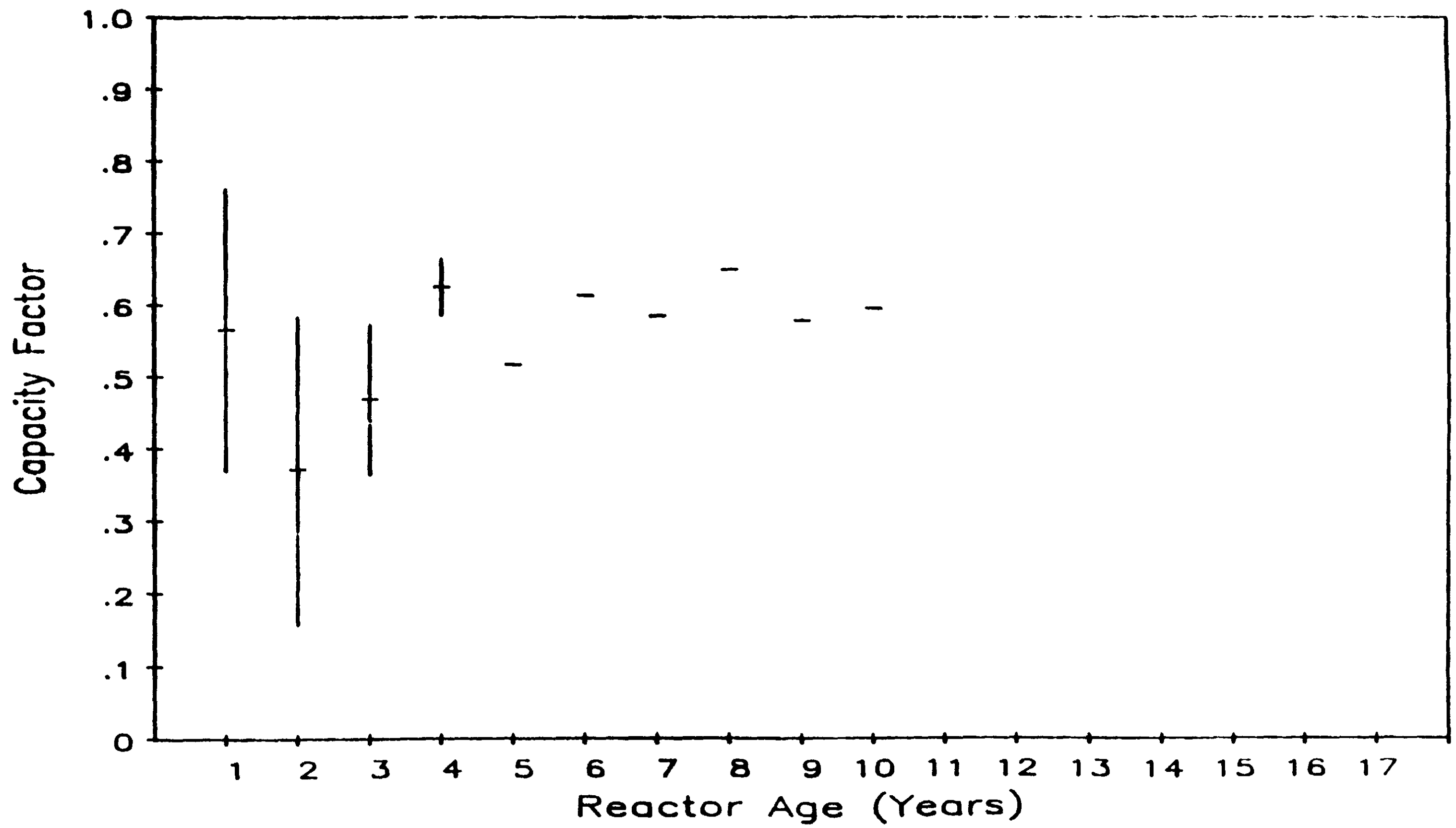
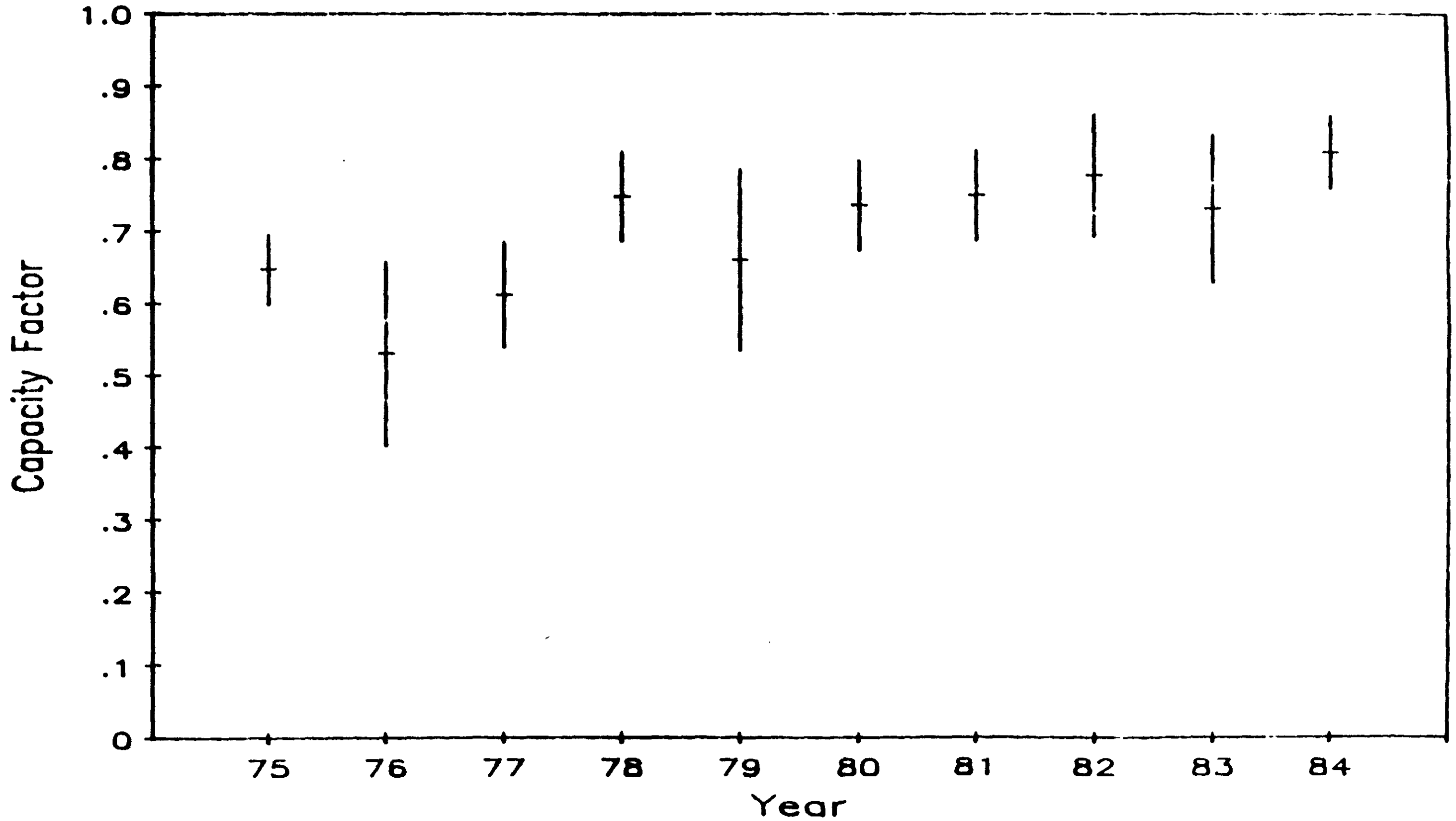


Figure 2.31
Swedish BWR Capacity Factor Distribution
By Year



## Figure 2.32

Swedish BWR Capacity Factor Distribution
By Reactor Age

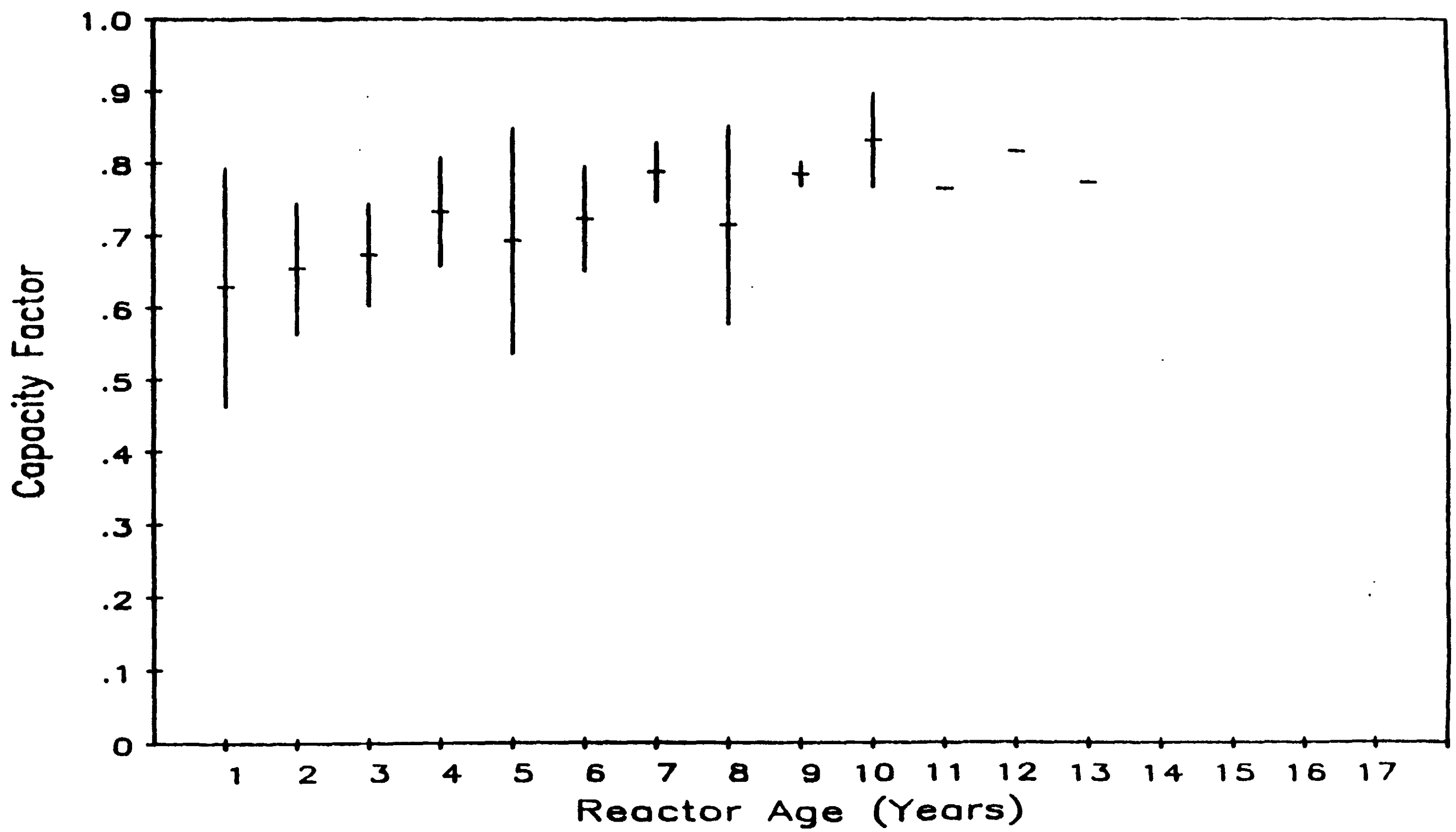
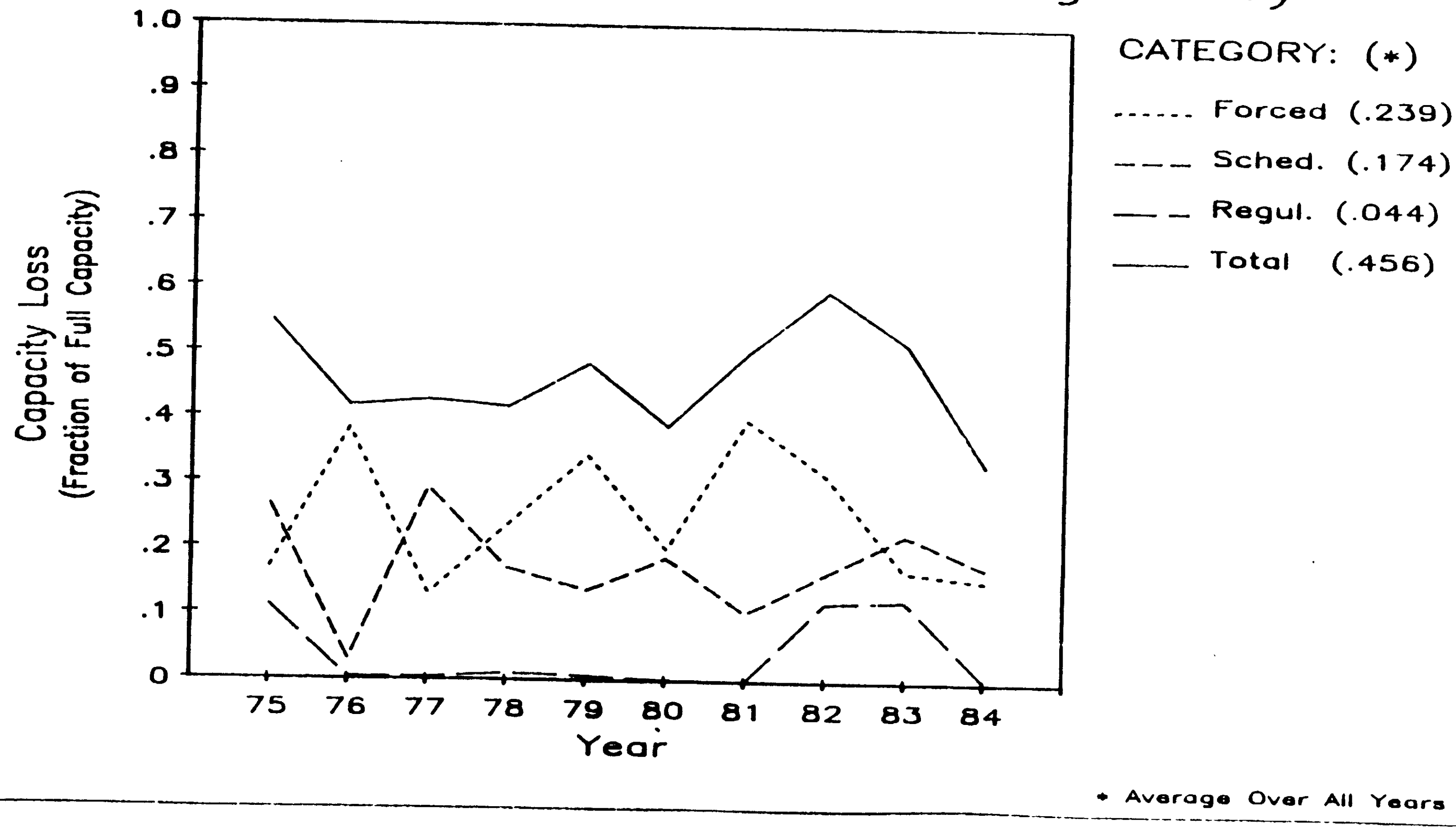
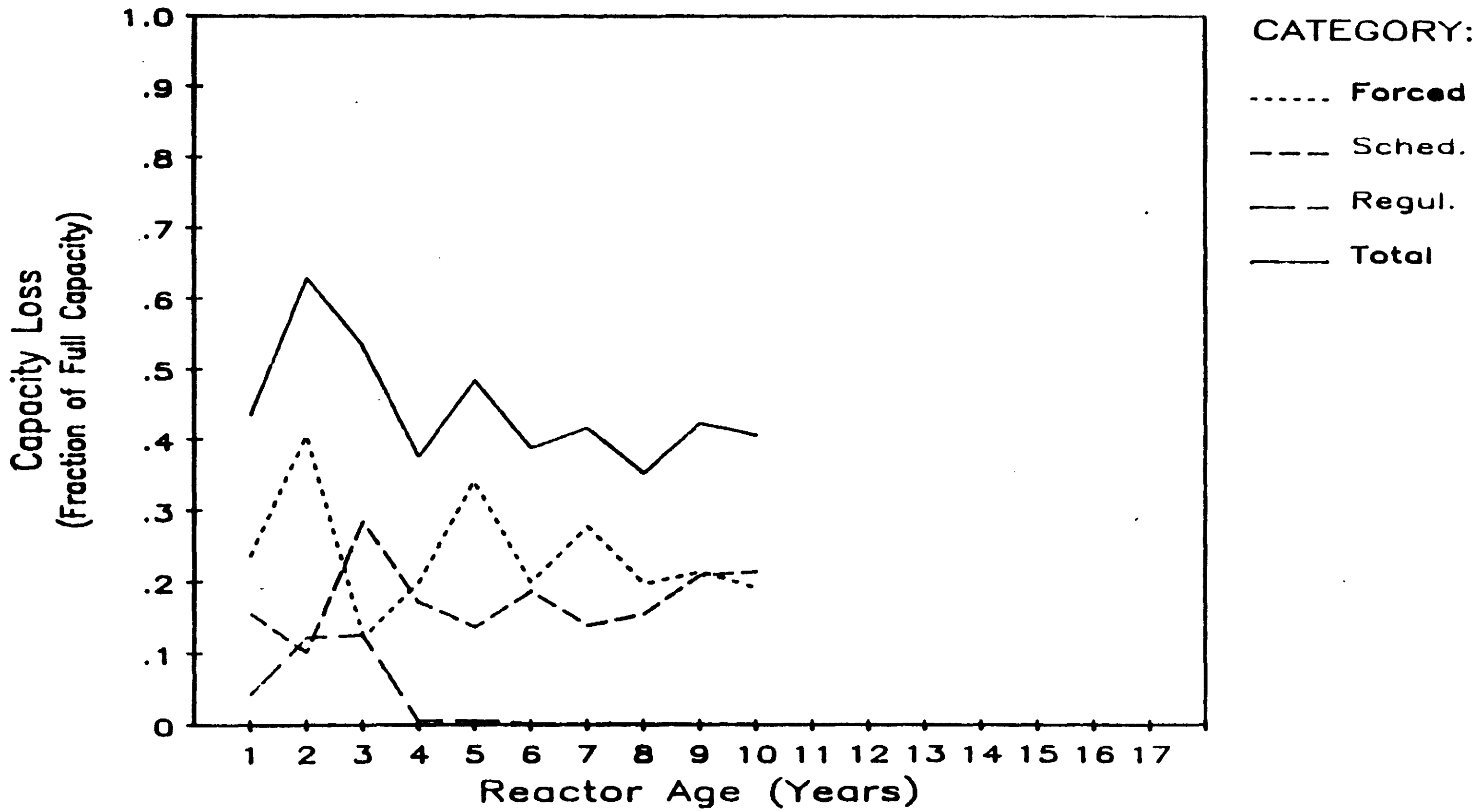


Figure 2.33
Swedish PWR Capacity Losses By Year
Forced, Scheduled, and Regulatory

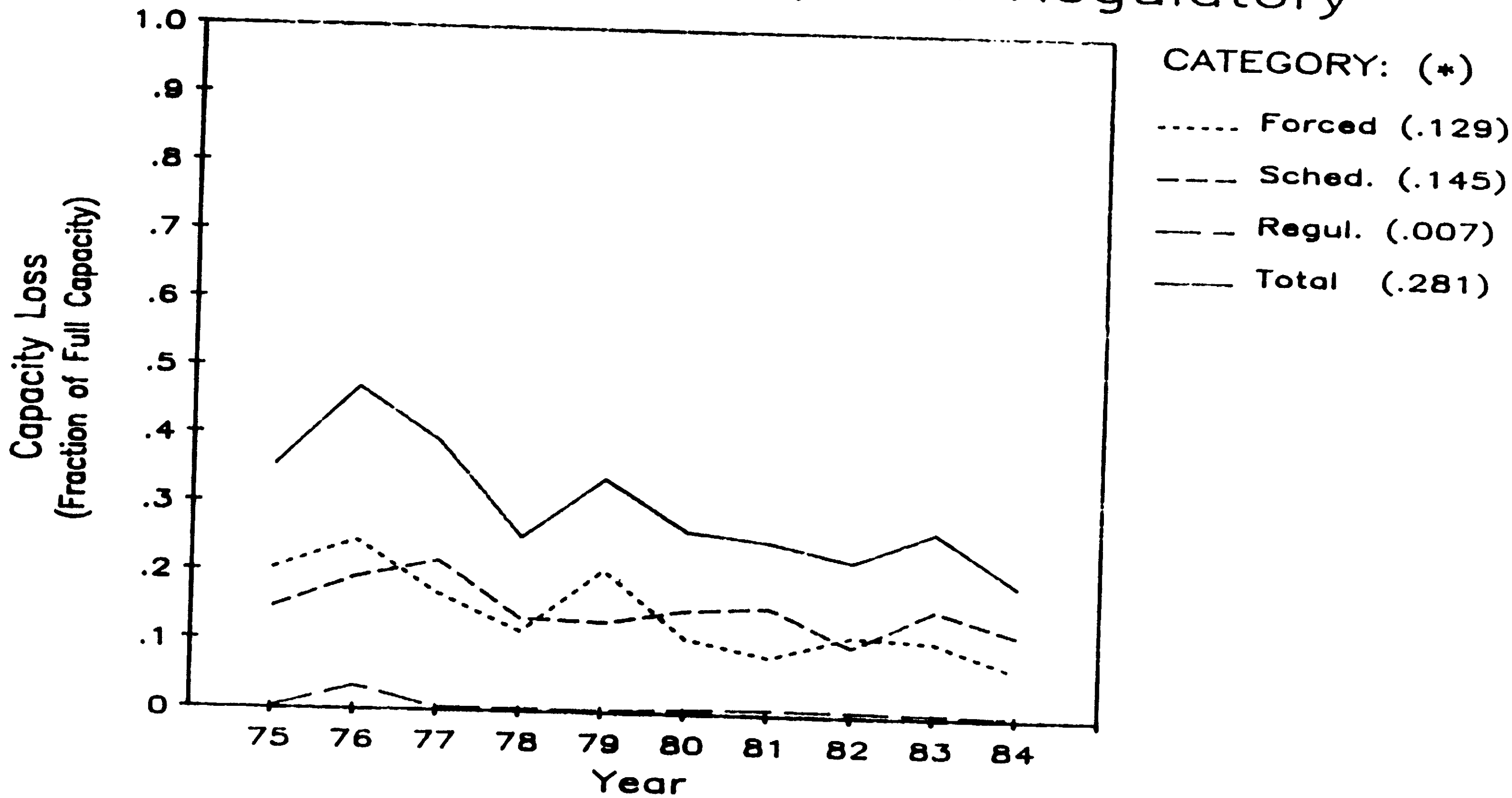


## Figure 2.34

Swedish PWR Capacity Losses By Rx Age
Forced, Scheduled, and Regulatory

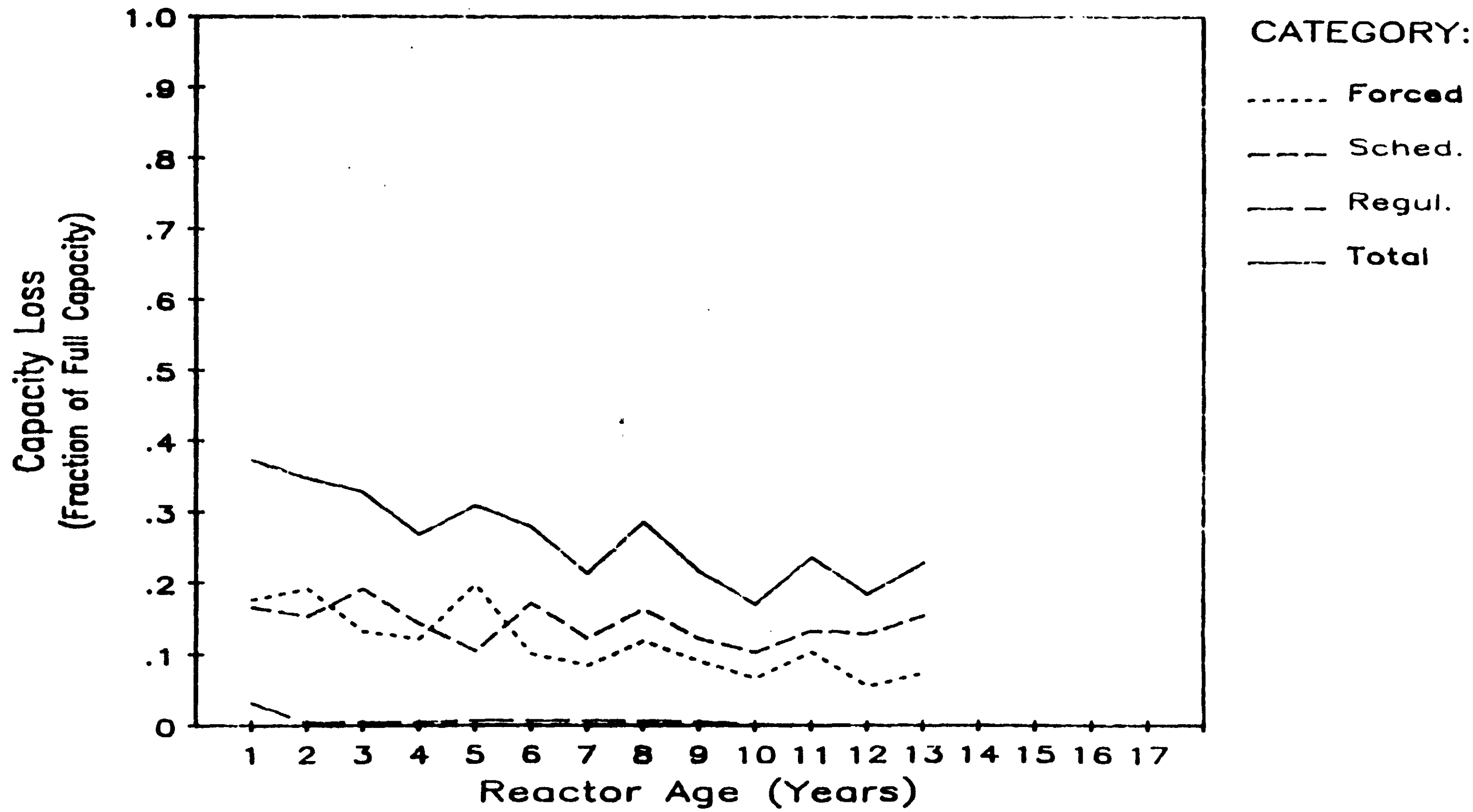


## Figure 2.35
Swedish BWR Capacity Losses By Year
Forced, Scheduled, and Regulatory




* Average Over All Years

## Figure 2.36
Swedish BWR Capacity Losses By Rx Age
Forced, Scheduled, and Regulatory



## 2.5 Switzerland

In this section the performance losses for the Swiss nuclear power plants are presented and briefly examined. Capacity was the performance index used to compile the Swiss nuclear plant performance data.

### 2.5.1 Aggregated Data

Swiss PWR capacity losses are tabulated by calendar year in Table 2.21 and by reactor age in Table 2.22. The BWR capacity losses are tabulated by year and by reactor age in Table 2.23 and Table 2.24 respectively. The mean and standard deviation for the capacity factors are tabulated in Table 2.25 by year and by reactor age.

### 2.5.2 Capacity Factor Distribution

The Swiss PWR capacity factors are shown graphically in Figure 2.37. Performance of the Swiss PWR's has been excellent, with a ten year average of 85.8%. Two periods of improvement are visible in this figure. The first is from 1975 to 1978 with small standard deviations associated with the mean capacity factors. The second period of improvement is from 1980 to 1984 with larger standard deviations than during 1975 to 1978. A drop in performance occurred between these two periods in 1980 as a third plant came online and did not perform as well as the others. The increased standard deviations after this plant came online result not only from the new plant's lower performance but also from more variation in the performance of the other two PWR's.

The PWR capacity factors are plotted by age in Figure 2.38. Performance shows improvement over the first five years and finally levels off after age 6 as the plants get older. As with the previous plot, the lower performance during the first five years is the result of the third PWR coming online in 1980 and not operating as well as the other two reactors. The standard deviations are generally small and exhibit no age dependence.

There is only one Swiss BWR. The performance of this plant can be found plotted by year and by age in Figures 3.1 and 3.2 respectively.

### 2.5.3 Losses by Outage Type

In this subsection, forced, scheduled, and regulatory losses for the Swiss nuclear plants are displayed and examined as functions of time and age.

Forced, scheduled, and regulatory losses of Swiss PWR's are plotted by year in Figure 2.39. The total losses of the

Swiss PWR's have been the lowest of the six countries investigated, with a 10 year average of 14.2%. The figure shows that the total losses display two periods of improvement. Scheduled losses are the largest contributor to the total losses responsible for 83.1%. The scheduled losses have been generally constant with a small amount of fluctuation from year to year. The forced outages have been very small, averaging only 2.1% per year. In addition, the forced losses also account for the two periods of improvement seen in the curve of the total losses. The first of these periods was from 1975 to 1979 when losses decreased as a result of improvements in steam generator, turbine, and CW/SW/CCW performance. In 1980, a new PWR came online which did not perform as well as the two already operating, causing an increase in losses. From 1980 to 1984 losses again decreased but this time from a combination of different improvements from all three of the PWR's. There were no regulatory losses reported for the Swiss PWR's.

The Swiss PWR losses are plotted by reactor age in Figure 2.40. In this figure it can be seen that all the losses have generally decreased each year up to age 5, after which they have remained essentially constant. The peak at age 14 is due to increased reactor coolant system problems at the only plant with that age.

The forced, scheduled and regulatory losses for the only Swiss BWR are plotted by year in Figure 2.41. As illustrated, the losses in all categories have decreased slightly with time. The scheduled losses, with a ten year average of 10.7%, make up the largest fraction of the total losses, representing 89.2% of the total. Forced losses are small, averaging only 1.3% per year over the 10 year period. There were no reported regulatory losses for the Swiss BWR's. The magnitude of the decrease in losses was approximately 2.5 percentage points and is too small to allow the identification of the specific systems responsible.

As there is only one Swiss BWR, a plot of the forced, scheduled and regulatory losses as a function age would be identical to Figure 2.41. Therefore, such a figure is not presented.

### 2.5.4 NSSS and BOP Losses

In this subsection the losses in the Nuclear Steam Supply System (NSSS) and the Balance of Plant (BOP) are displayed and examined as functions of time and reactor age for the Swiss nuclear power plants.

The Swiss PWR NSSS and BOP losses are plotted over time in Figure 2.42. The NSSS losses have averaged 11.0% per year and represent 77.5% of the total losses. Refueling losses were the largest contributor, representing 42.7% of the NSSS losses. The contribution of refueling losses should actually be larger because of the inconsistent reporting of maintenance performed during refueling. In addition to refueling losses, reactor coolant system problems contributed 30.9% and steam generator problems contributed 24.5%. The curve displays two periods of declining losses from 1975 to 1978 and from 1980 to 1984. No specific system was responsible for these two trends. The peak in 1980 was caused by increased losses in several systems, partially as a result of a new plant coming online. The Swiss PWR BOP losses have averaged 2.2% per year, or 15.5% of the total losses. The largest contributor to the BOP losses was the turbines, representing 81.8%. The drop that occurs in 1981 was the result of the inconsistent reporting of maintenance performed during refueling. The new PWR going online in 1980 reported this maintenance as refueling losses and not in the specific systems categories as did the other two plants. As a result, the new plant reported no BOP losses. However, the BOP losses from the other two PWR's were averaged over an additional plant each year, resulting in the drop observed.

The Swiss PWR losses are displayed as a function of reactor age in Figure 2.43. NSSS losses exhibit an improvement from age 1 to age 5. However, the losses shown for ages 1 through 3 were from the PWR reporting maintenance performed during refueling as a refueling loss. Therefore, NSSS losses in these years were higher. Neglecting this inconsistency, NSSS losses in the Swiss PWR's have remained relatively constant over age. The BOP losses decline with age from ages 6 though 13 as a result of reduced turbine losses each year. The low losses prior to age 6 were primarily the result of the inconsistent reporting of losses mentioned above.

The NSSS and BOP losses are plotted by year in Figure 2.44 for Switzerland's only BWR. The NSSS losses have averaged 9.4% per year, representing 78.3% of the average total losses. Refueling losses were the largest component of this, contributing 93.6%. NSSS losses have remained relatively constant over time. The BOP losses averaged 0.8% each year, and represented 6.7% of all losses. Turbine losses accounted for 75% of the BOP losses. As the figure illustrates, the BOP losses have decreased with time. This was caused by a decline in turbine losses from 1975 to 1984.

Since there is only one Swiss BWR, a plot of the NSSS and BOP losses as a function age would be identical to Figure 2.44. Therefore, no figure is presented.

<u>Table 2.21</u>
Swiss PWR Capacity Losses
By Year

CAPACITY LOSSES
1975 - 1979

SWITZERLAND
ALL PWR'S

03/25/86

| | | | DATA: | ( 2) | ( 2) | ( 2) | ( 2) | ( 2) |
|---|---|---|---|---|---|---|---|---|
| | | | | 1975 | 1976 | 1977 | 1978 | 1979 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.002 | 0.001 | 0.001 | 0.000 |
| | | SG | | 0.028 | 0.007 | 0.011 | 0.009 | 0.011 |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.028 | 0.009 | 0.011 | 0.010 | 0.011 |
| | BOP | TURBINE | | 0.009 | 0.002 | 0.000 | 0.001 | 0.001 |
| | | GEN | | 0.000 | 0.001 | 0.002 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.005 | 0.006 | 0.001 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.015 | 0.008 | 0.003 | 0.001 | 0.001 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.043 | 0.017 | 0.014 | 0.011 | 0.011 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.037 | 0.050 | 0.034 | 0.028 | 0.038 |
| | | SG | | 0.024 | 0.016 | 0.015 | 0.008 | 0.024 |
| | | REFUEL | | 0.039 | 0.036 | 0.043 | 0.027 | 0.019 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.100 | 0.102 | 0.092 | 0.062 | 0.081 |
| | BOP | TURBINE | | 0.025 | 0.027 | 0.025 | 0.021 | 0.027 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.025 | 0.027 | 0.025 | 0.021 | 0.027 |
| | ECONOMIC | | | 0.009 | 0.006 | 0.004 | 0.004 | 0.004 |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.133 | 0.135 | 0.121 | 0.087 | 0.112 |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.176 | 0.151 | 0.135 | 0.098 | 0.123 |
| ** CAPACITY FACTOR ** | | | | 0.825 | 0.849 | 0.865 | 0.902 | 0.877 |

## Table 2.21 - (Continued)

CAPACITY LOSSES — SWITZERLAND
1980 - 1984 — ALL PWR'S

03/25/86

| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| DATA: | | | ( 3) | ( 3) | ( 3) | ( 3) | ( 3) |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.011 | 0.010 | 0.006 | 0.001 | 0.001 |
| | | SG | 0.017 | 0.005 | 0.007 | 0.000 | 0.000 |
| | | REFUEL | | | | | |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.028 | 0.015 | 0.013 | 0.001 | 0.001 |
| | BOP | TURBINE | 0.002 | 0.002 | 0.000 | 0.002 | 0.001 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.016 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.005 | 0.000 | 0.000 | 0.002 | 0.000 |
| | | | 0.023 | 0.002 | 0.001 | 0.004 | 0.001 |
| | ECONOMIC | | 0.004 | 0.003 | 0.009 | 0.003 | 0.003 |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | 0.055 | 0.021 | 0.024 | 0.008 | 0.005 |
| SCHEDULED | NSSS | FUEL | 0.001 | 0.003 | 0.005 | 0.002 | 0.000 |
| | | RCS | 0.037 | 0.017 | 0.027 | 0.032 | 0.018 |
| | | SG | 0.010 | 0.023 | 0.022 | 0.018 | 0.023 |
| | | REFUEL | 0.065 | 0.063 | 0.059 | 0.050 | 0.044 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.112 | 0.105 | 0.114 | 0.102 | 0.085 |
| | BOP | TURBINE | 0.012 | 0.010 | 0.010 | 0.012 | 0.010 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.012 | 0.010 | 0.010 | 0.012 | 0.010 |
| | ECONOMIC | | 0.001 | 0.002 | 0.005 | 0.005 | 0.007 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.126 | 0.118 | 0.130 | 0.118 | 0.102 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.008 | 0.008 | 0.000 | 0.004 | 0.004 |
| ** TOTAL CAPACITY LOSS ** | | | 0.189 | 0.147 | 0.153 | 0.129 | 0.110 |
| ** CAPACITY FACTOR ** | | | 0.811 | 0.853 | 0.847 | 0.871 | 0.890 |

Table 2.21 - (Continued)

CAPACITY LOSSES
1975 - 1984

SWITZERLAND
ALL PWR'S

03/25/86 DATA: 3 PLANTS 25 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 |
| | | RCS | 0.004 |
| | | SG | 0.009 |
| | | REFUEL | |
| | | OTHER | 0.000 |
| | | | 0.012 |
| | BOP | TURBINE | 0.002 |
| | | GEN | 0.000 |
| | | COND | |
| | | CW/SW/CCW | 0.003 |
| | | OTHER | 0.001 |
| | | | 0.006 |
| | ECONOMIC | | 0.003 |
| | HUMAN | | 0.000 |
| | OTHER | | 0.000 |
| | TOTAL | | 0.021 |
| SCHEDULED | NSSS | FUEL | 0.001 |
| | | RCS | 0.031 |
| | | SG | 0.018 |
| | | REFUEL | 0.047 |
| | | OTHER | 0.000 |
| | | | 0.097 |
| | BOP | TURBINE | 0.016 |
| | | GEN | 0.000 |
| | | COND | |
| | | CW/SW/CCW | 0.000 |
| | | OTHER | 0.000 |
| | | | 0.016 |
| | ECONOMIC | | 0.004 |
| | HUMAN | | |
| | OTHER | | |
| | TOTAL | | 0.118 |
| REGULATORY | | | 0.000 |
| UNKNOWN | | | 0.003 |

** TOTAL CAPACITY LOSS ** 0.142

** CAPACITY FACTOR ** 0.858

## Table 2.22
## Swiss PWR Capacity Losses By Reactor Age

CAPACITY LOSSES BY REACTOR AGE — SWITZERLAND
1975 - 1984 — ALL PWR'S

03/23/86

| | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| | | DATA: | ( 1) | ( 1) | ( 1) | ( 2) | ( 2) |
| | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.014 | 0.000 | 0.001 |
| | | SG | 0.006 | 0.000 | 0.000 | 0.009 | 0.000 |
| | | REFUEL | | | | | |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.006 | 0.000 | 0.014 | 0.009 | 0.001 |
| | BOP | TURBINE | 0.000 | 0.005 | 0.000 | 0.000 | 0.001 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.048 | 0.000 | 0.000 | 0.004 | 0.000 |
| | | OTHER | 0.015 | 0.000 | 0.001 | 0.002 | 0.000 |
| | | | 0.063 | 0.005 | 0.001 | 0.006 | 0.001 |
| | ECONOMIC | | 0.011 | 0.010 | 0.027 | 0.005 | 0.004 |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | 0.080 | 0.018 | 0.043 | 0.020 | 0.006 |
| SCHEDULED | NSSS | FUEL | 0.004 | 0.009 | 0.016 | 0.003 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.019 | 0.025 |
| | | SG | 0.000 | 0.000 | 0.000 | 0.014 | 0.009 |
| | | REFUEL | 0.159 | 0.139 | 0.132 | 0.074 | 0.060 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.163 | 0.148 | 0.148 | 0.110 | 0.094 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.014 | 0.013 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.000 | 0.000 | 0.000 | 0.014 | 0.013 |
| | ECONOMIC | | 0.000 | 0.000 | 0.002 | 0.003 | 0.003 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.163 | 0.148 | 0.151 | 0.127 | 0.112 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.024 | 0.024 | 0.000 | 0.005 | 0.005 |
| ** TOTAL CAPACITY LOSS ** | | | 0.267 | 0.190 | 0.194 | 0.152 | 0.123 |
| ** CAPACITY FACTOR ** | | | 0.733 | 0.810 | 0.806 | 0.848 | 0.877 |

## Table 2.22 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — 1975 - 1984 — SWITZERLAND, ALL PWR'S

03/23/86

| | | | DATA: | ( 2) | ( 2) | ( 2) | ( 2) | ( 2) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.002 | 0.001 | 0.012 | 0.001 |
| | | SG | | 0.018 | 0.017 | 0.022 | 0.009 | 0.000 |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.018 | 0.019 | 0.023 | 0.021 | 0.001 |
| | BOP | TURBINE | | 0.009 | 0.002 | 0.001 | 0.003 | 0.000 |
| | | GEN | | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.002 | 0.006 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.013 | 0.009 | 0.001 | 0.003 | 0.000 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.032 | 0.027 | 0.022 | 0.024 | 0.001 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.024 | 0.033 | 0.037 | 0.051 | 0.038 |
| | | SG | | 0.025 | 0.014 | 0.014 | 0.010 | 0.026 |
| | | REFUEL | | 0.044 | 0.033 | 0.029 | 0.025 | 0.022 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.093 | 0.080 | 0.080 | 0.086 | 0.086 |
| | BOP | TURBINE | | 0.022 | 0.025 | 0.026 | 0.018 | 0.022 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.023 | 0.025 | 0.026 | 0.018 | 0.022 |
| | ECONOMIC | | | 0.006 | 0.003 | 0.005 | 0.003 | 0.003 |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.120 | 0.107 | 0.111 | 0.108 | 0.111 |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.152 | 0.134 | 0.133 | 0.132 | 0.112 |
| ** CAPACITY FACTOR ** | | | | 0.848 | 0.866 | 0.867 | 0.868 | 0.888 |

## Table 2.22 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — SWITZERLAND
1975 - 1984 — ALL PWR'S

03/23/86

| | | | DATA: | ( 2) | ( 2) | ( 2) | ( 1) | ( 1) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 11 | 12 | 13 | 14 | 15 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.005 | 0.015 | 0.002 | 0.000 | 0.000 |
| | | SG | | 0.014 | 0.008 | 0.011 | 0.000 | 0.000 |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.019 | 0.023 | 0.013 | 0.000 | 0.000 |
| | BOP | TURBINE | | 0.001 | 0.002 | 0.000 | 0.005 | 0.002 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.001 | 0.003 | 0.000 | 0.005 | 0.003 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | 0.021 | 0.026 | 0.014 | 0.005 | 0.003 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.049 | 0.025 | 0.029 | 0.075 | 0.029 |
| | | SG | | 0.015 | 0.030 | 0.042 | 0.028 | 0.030 |
| | | REFUEL | | 0.016 | 0.022 | 0.024 | 0.022 | 0.021 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.080 | 0.077 | 0.095 | 0.125 | 0.080 |
| | BOP | TURBINE | | 0.018 | 0.015 | 0.015 | 0.020 | 0.014 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.018 | 0.015 | 0.015 | 0.020 | 0.014 |
| | ECONOMIC | | | 0.003 | 0.004 | 0.010 | 0.014 | 0.010 |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.101 | 0.097 | 0.121 | 0.159 | 0.104 |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.122 | 0.122 | 0.135 | 0.164 | 0.107 |
| ** CAPACITY FACTOR ** | | | | 0.878 | 0.878 | 0.865 | 0.836 | 0.893 |

<u>Table 2.23</u>
Swiss BWR Capacity Losses
By Year

CAPACITY LOSSES 1975 - 1979 — SWITZERLAND ALL BWR'S

03/25/86 DATA: ( 1) ( 1) ( 1) ( 1) ( 1)

| | | | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.009 | 0.003 | 0.017 | 0.003 | 0.001 |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 |
| | | | 0.009 | 0.003 | 0.019 | 0.003 | 0.002 |
| | BOP | TURBINE | 0.011 | 0.010 | 0.006 | 0.007 | 0.004 |
| | | GEN | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.003 | 0.000 | 0.000 | 0.002 |
| | | OTHER | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 |
| | | | 0.011 | 0.014 | 0.008 | 0.008 | 0.007 |
| | ECONOMIC | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 |
| | TOTAL | | 0.020 | 0.017 | 0.026 | 0.012 | 0.008 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.084 | 0.096 | 0.079 | 0.096 | 0.093 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.085 | 0.096 | 0.079 | 0.096 | 0.093 |
| | BOP | TURBINE | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ECONOMIC | | 0.023 | 0.028 | 0.031 | 0.019 | 0.018 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.111 | 0.124 | 0.111 | 0.115 | 0.111 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.131 | 0.141 | 0.137 | 0.127 | 0.120 |
| ** CAPACITY FACTOR ** | | | 0.869 | 0.859 | 0.863 | 0.873 | 0.880 |

## Table 2.23 - (Continued)

CAPACITY LOSSES 1980 - 1984

SWITZERLAND ALL BWR'S

03/25/86

| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| | | DATA: | ( 1) | ( 1) | ( 1) | ( 1) | ( 1) |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.004 | 0.001 | 0.004 | 0.000 | 0.010 |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.004 | 0.001 | 0.004 | 0.001 | 0.010 |
| | BOP | TURBINE | 0.007 | 0.004 | 0.003 | 0.004 | 0.003 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 |
| | | | 0.007 | 0.005 | 0.005 | 0.005 | 0.004 |
| | ECONOMIC | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 |
| | TOTAL | | 0.012 | 0.008 | 0.009 | 0.006 | 0.014 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | 0.096 | 0.085 | 0.085 | 0.082 | 0.087 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.096 | 0.085 | 0.085 | 0.082 | 0.087 |
| | BOP | TURBINE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ECONOMIC | | 0.012 | 0.012 | 0.012 | 0.011 | 0.015 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | 0.108 | 0.097 | 0.097 | 0.093 | 0.102 |
| REGULATORY | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | 0.121 | 0.105 | 0.106 | 0.099 | 0.115 |
| ** CAPACITY FACTOR ** | | | 0.879 | 0.895 | 0.894 | 0.901 | 0.885 |

## Table 2.23 - (Continued)

CAPACITY LOSSES
1975 - 1984

SWITZERLAND
ALL BWR'S

03/25/86 DATA: 1 PLANTS 10 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 |
| | | RCS | 0.005 |
| | | SG | |
| | | REFUEL | |
| | | OTHER | 0.000 |
| | | | 0.006 |
| | BOP | TURBINE | 0.006 |
| | | GEN | 0.000 |
| | | COND | |
| | | CW/SW/CCW | 0.001 |
| | | OTHER | 0.001 |
| | | | 0.007 |
| | ECONOMIC | | 0.000 |
| | HUMAN | | 0.000 |
| | OTHER | | 0.000 |
| | TOTAL | | 0.013 |
| SCHEDULED | NSSS | FUEL | 0.000 |
| | | RCS | 0.000 |
| | | SG | |
| | | REFUEL | 0.088 |
| | | OTHER | 0.000 |
| | | | 0.089 |
| | BOP | TURBINE | 0.000 |
| | | GEN | 0.000 |
| | | COND | |
| | | CW/SW/CCW | 0.000 |
| | | OTHER | 0.000 |
| | | | 0.000 |
| | ECONOMIC | | 0.018 |
| | HUMAN | | |
| | OTHER | | |
| | TOTAL | | 0.107 |
| REGULATORY | | | 0.000 |
| UNKNOWN | | | 0.000 |

** TOTAL CAPACITY LOSS ** 0.120

** CAPACITY FACTOR ** 0.880

## Table 2.24
Swiss BWR Capacity Losses
By Reactor Age

CAPACITY LOSSES BY REACTOR AGE — SWITZERLAND
1975 - 1984 — ALL BWR'S

03/23/86

| | | | DATA: ( 0) | ( 0) | ( 1) | ( 1) | ( 1) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | | | 0.000 | 0.000 | 0.000 |
| | | RCS | | | 0.009 | 0.003 | 0.017 |
| | | SG | | | | | |
| | | REFUEL | | | | | |
| | | OTHER | | | 0.000 | 0.000 | 0.001 |
| | | | | | 0.009 | 0.003 | 0.018 |
| | BOP | TURBINE | | | 0.011 | 0.010 | 0.006 |
| | | GEN | | | 0.000 | 0.000 | 0.001 |
| | | COND | | | | | |
| | | CW/SW/CCW | | | 0.000 | 0.003 | 0.000 |
| | | OTHER | | | 0.000 | 0.001 | 0.001 |
| | | | | | 0.011 | 0.014 | 0.008 |
| | ECONOMIC | | | | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | | 0.000 | 0.000 | 0.000 |
| | OTHER | | | | 0.000 | 0.000 | 0.000 |
| | TOTAL | | | | 0.020 | 0.017 | 0.026 |
| SCHEDULED | NSSS | FUEL | | | 0.000 | 0.000 | 0.000 |
| | | RCS | | | 0.001 | 0.000 | 0.000 |
| | | SG | | | | | |
| | | REFUEL | | | 0.084 | 0.096 | 0.079 |
| | | OTHER | | | 0.000 | 0.000 | 0.000 |
| | | | | | 0.085 | 0.096 | 0.079 |
| | BOP | TURBINE | | | 0.002 | 0.000 | 0.000 |
| | | GEN | | | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | |
| | | CW/SW/CCW | | | 0.000 | 0.000 | 0.000 |
| | | OTHER | | | 0.000 | 0.000 | 0.000 |
| | | | | | 0.002 | 0.000 | 0.000 |
| | ECONOMIC | | | | 0.023 | 0.028 | 0.031 |
| | HUMAN | | | | | | |
| | OTHER | | | | | | |
| | TOTAL | | | | 0.111 | 0.124 | 0.111 |
| REGULATORY | | | | | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | | 0.131 | 0.141 | 0.137 |
| ** CAPACITY FACTOR ** | | | | | 0.869 | 0.859 | 0.863 |

## Table 2.24 - (Continued)

CAPACITY LOSSES BY REACTOR AGE — SWITZERLAND
1975 - 1984 — ALL BWR'S

03/23/86

| | | | DATA: | ( 1) | ( 1) | ( 1) | ( 1) | ( 1) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.003 | 0.001 | 0.004 | 0.001 | 0.004 |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | | | 0.003 | 0.002 | 0.004 | 0.001 | 0.004 |
| | BOP | TURBINE | | 0.007 | 0.004 | 0.007 | 0.004 | 0.003 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.002 | 0.000 | 0.000 | 0.001 |
| | | OTHER | | 0.001 | 0.001 | 0.000 | 0.001 | 0.001 |
| | | | | 0.008 | 0.007 | 0.007 | 0.005 | 0.005 |
| | ECONOMIC | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | HUMAN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.002 | 0.000 | 0.001 | 0.001 | 0.001 |
| | TOTAL | | | 0.012 | 0.008 | 0.012 | 0.008 | 0.009 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | SG | | | | | | |
| | | REFUEL | | 0.096 | 0.093 | 0.096 | 0.085 | 0.085 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.096 | 0.093 | 0.096 | 0.085 | 0.085 |
| | BOP | TURBINE | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | GEN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ECONOMIC | | | 0.019 | 0.018 | 0.012 | 0.012 | 0.012 |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.115 | 0.111 | 0.108 | 0.097 | 0.097 |
| REGULATORY | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| UNKNOWN | | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ** TOTAL CAPACITY LOSS ** | | | | 0.127 | 0.119 | 0.120 | 0.105 | 0.106 |
| ** CAPACITY FACTOR ** | | | | 0.873 | 0.881 | 0.880 | 0.895 | 0.894 |

Table 2.24 - (Continued)

CAPACITY LOSSES BY REACTOR AGE 1975 - 1984

SWITZERLAND ALL BWR'S

03/23/86

| | | | DATA: | ( 1) | ( 1) | ( 0) | ( 0) | ( 0) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 11 | 12 | 13 | 14 | 15 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | | | |
| | | RCS | | 0.000 | 0.010 | | | |
| | | SG | | | | | | |
| | | REFUEL | | | | | | |
| | | OTHER | | 0.000 | 0.000 | | | |
| | | | | 0.000 | 0.010 | | | |
| | BOP | TURBINE | | 0.004 | 0.003 | | | |
| | | GEN | | 0.000 | 0.000 | | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | | | |
| | | OTHER | | 0.001 | 0.001 | | | |
| | | | | 0.005 | 0.004 | | | |
| | ECONOMIC | | | 0.000 | 0.000 | | | |
| | HUMAN | | | 0.000 | 0.000 | | | |
| | OTHER | | | 0.001 | 0.000 | | | |
| | TOTAL | | | 0.006 | 0.014 | | | |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | | | |
| | | RCS | | 0.000 | 0.000 | | | |
| | | SG | | | | | | |
| | | REFUEL | | 0.082 | 0.087 | | | |
| | | OTHER | | 0.000 | 0.000 | | | |
| | | | | 0.082 | 0.087 | | | |
| | BOP | TURBINE | | 0.000 | 0.000 | | | |
| | | GEN | | 0.000 | 0.000 | | | |
| | | COND | | | | | | |
| | | CW/SW/CCW | | 0.000 | 0.000 | | | |
| | | OTHER | | 0.000 | 0.000 | | | |
| | | | | 0.000 | 0.000 | | | |
| | ECONOMIC | | | 0.011 | 0.015 | | | |
| | HUMAN | | | | | | | |
| | OTHER | | | | | | | |
| | TOTAL | | | 0.093 | 0.102 | | | |
| REGULATORY | | | | 0.000 | 0.000 | | | |
| UNKNOWN | | | | 0.000 | 0.000 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| ** TOTAL CAPACITY LOSS ** | 0.099 | 0.116 | | | | |
| ** CAPACITY FACTOR ** | 0.901 | 0.884 | | | | |

Table 2.25 - Swiss Capacity Factor Distributions

| By | PWR | | | BWR | | |
|---|---|---|---|---|---|---|
| Year | Mean | σ | # Data | Mean | σ | # Data |
| 75 | 0.825 | 0.008 | 2 | 0.869 | 0.000 | 1 |
| 76 | 0.849 | 0.017 | 2 | 0.859 | 0.000 | 1 |
| 77 | 0.865 | 0.015 | 2 | 0.863 | 0.000 | 1 |
| 78 | 0.902 | 0.001 | 2 | 0.873 | 0.000 | 1 |
| 79 | 0.877 | 0.007 | 2 | 0.880 | 0.000 | 1 |
| 80 | 0.811 | 0.056 | 3 | 0.879 | 0.000 | 1 |
| 81 | 0.853 | 0.040 | 3 | 0.895 | 0.000 | 1 |
| 82 | 0.847 | 0.035 | 3 | 0.894 | 0.000 | 1 |
| 83 | 0.871 | 0.032 | 3 | 0.901 | 0.000 | 1 |
| 84 | 0.890 | 0.002 | 3 | 0.885 | 0.000 | 1 |

| By | PWR | | | BWR | | |
|---|---|---|---|---|---|---|
| Age | Mean | σ | # Data | Mean | σ | # Data |
| 1 | 0.734 | 0.000 | 1 | | | |
| 2 | 0.810 | 0.000 | 1 | | | |
| 3 | 0.807 | 0.000 | 1 | 0.869 | 0.000 | 1 |
| 4 | 0.847 | 0.014 | 2 | 0.859 | 0.000 | 1 |
| 5 | 0.877 | 0.012 | 2 | 0.863 | 0.000 | 1 |
| 6 | 0.848 | 0.032 | 2 | 0.873 | 0.000 | 1 |
| 7 | 0.867 | 0.035 | 2 | 0.880 | 0.000 | 1 |
| 8 | 0.867 | 0.017 | 2 | 0.879 | 0.000 | 1 |
| 9 | 0.869 | 0.034 | 2 | 0.895 | 0.000 | 1 |
| 10 | 0.889 | 0.019 | 2 | 0.894 | 0.000 | 1 |
| 11 | 0.879 | 0.014 | 2 | 0.901 | 0.000 | 1 |
| 12 | 0.878 | 0.036 | 2 | 0.885 | 0.000 | 1 |
| 13 | 0.865 | 0.023 | 2 | | | |
| 14 | 0.836 | 0.000 | 1 | | | |
| 15 | 0.893 | 0.000 | 1 | | | |
| 16 | | | | | | |
| 17 | | | | | | |

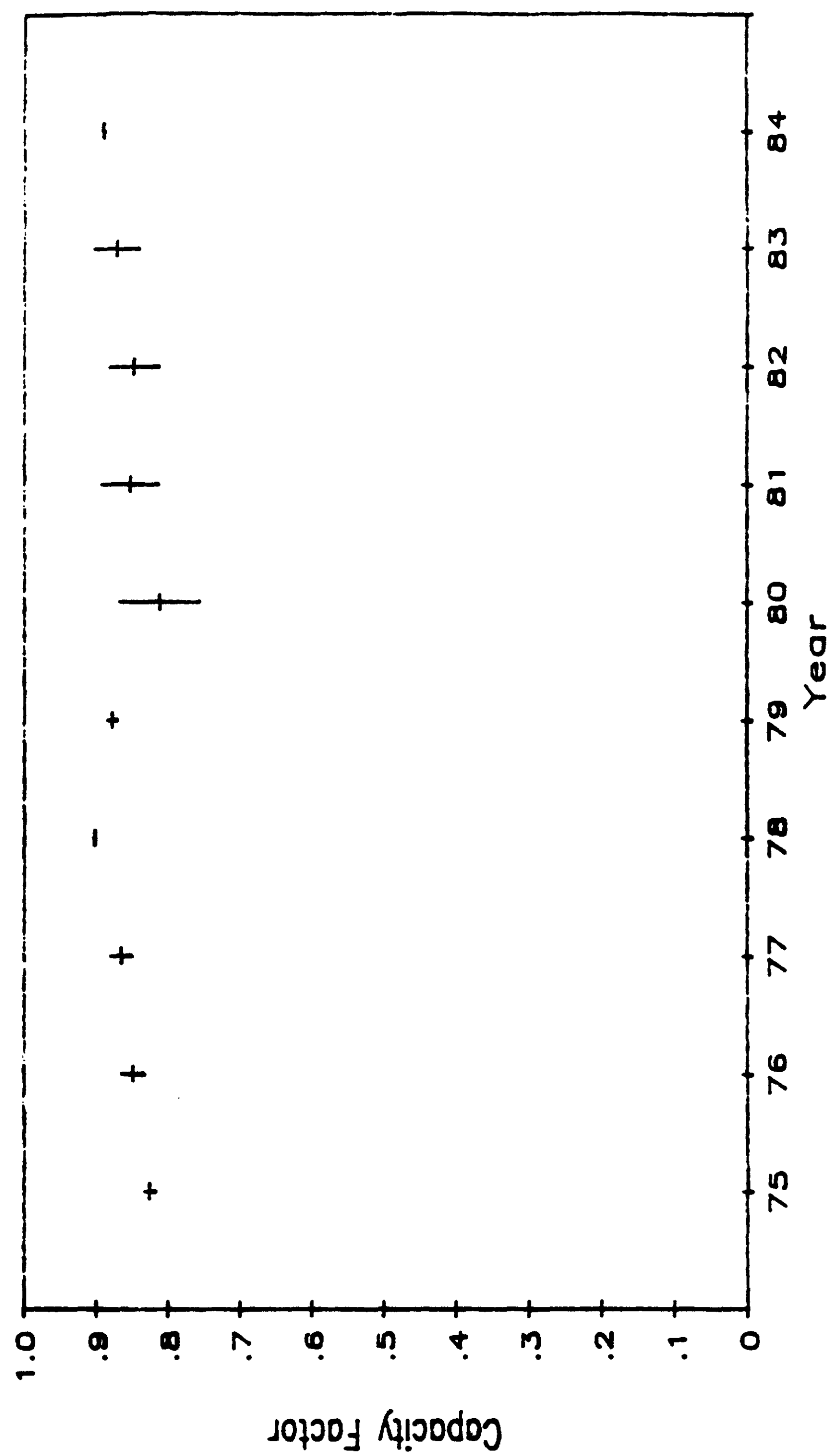
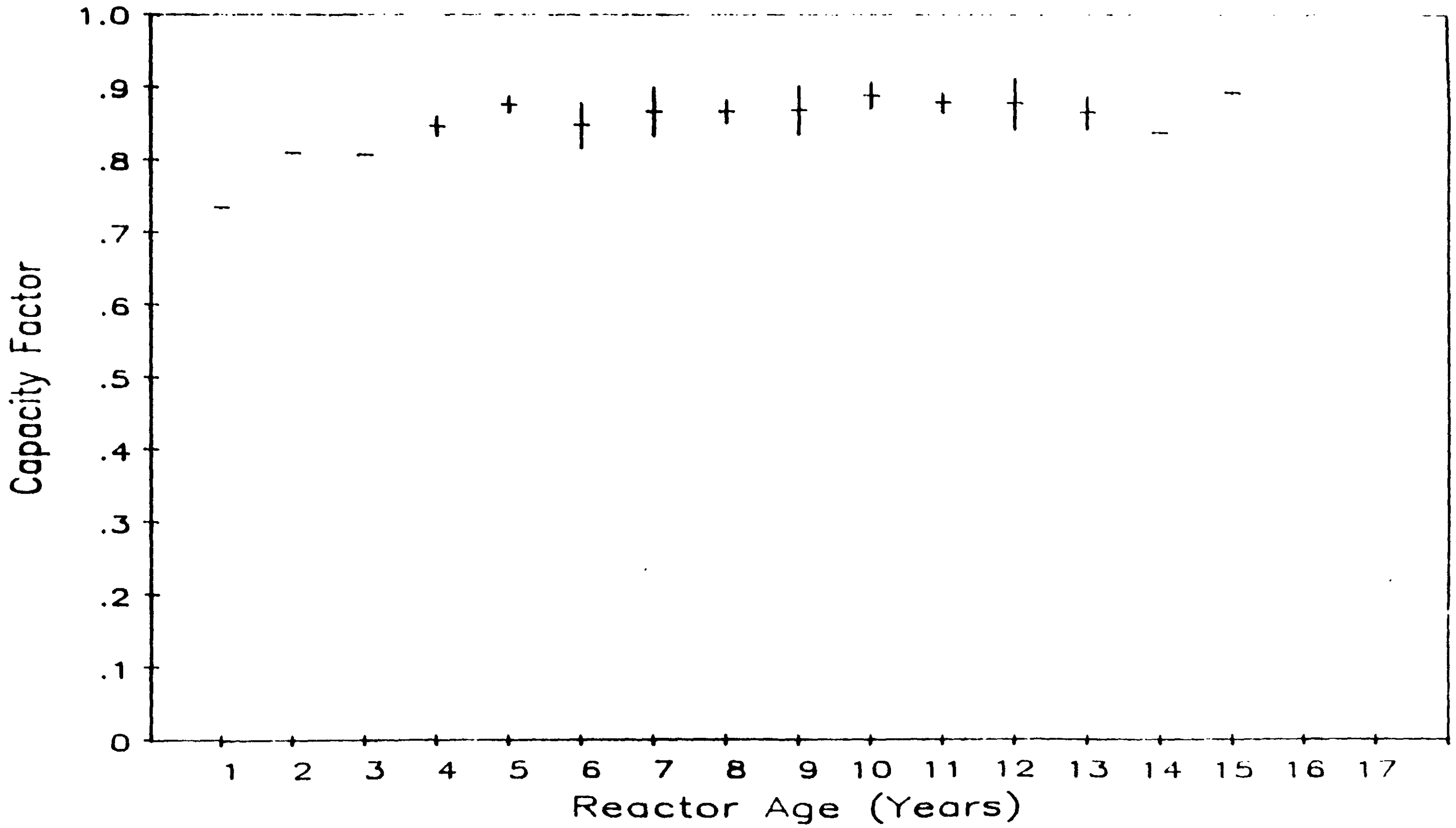



Figure 2.37
Swiss PWR Capacity Factor Distribution
By Year

## Figure 2.38
Swiss PWR Capacity Factor Distribution
By Reactor Age



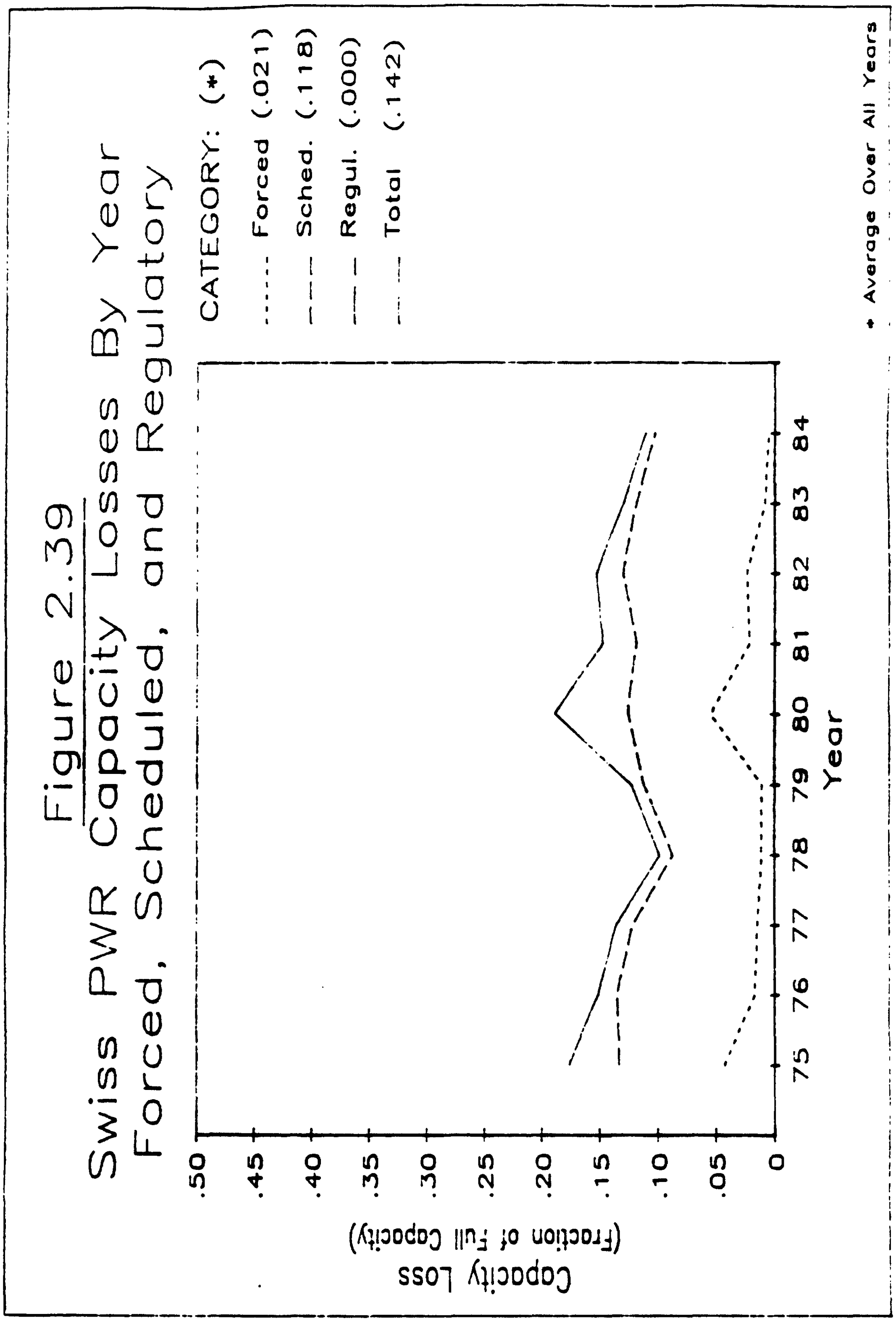


Figure 2.39
Swiss PWR Capacity Losses By Year
Forced, Scheduled, and Regulatory
CATEGORY: (*)
Forced (.021)
Sched. (.118)
Regul. (.000)
Total (.142)
* Average Over All Years
Capacity Loss
(Fraction of Full Capacity)
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0
75
76
77
78
79
80
81
82
83
84
Year

Figure 2.40

Swiss PWR Capacity Losses By Reactor Age
Forced, Scheduled, and Regulatory

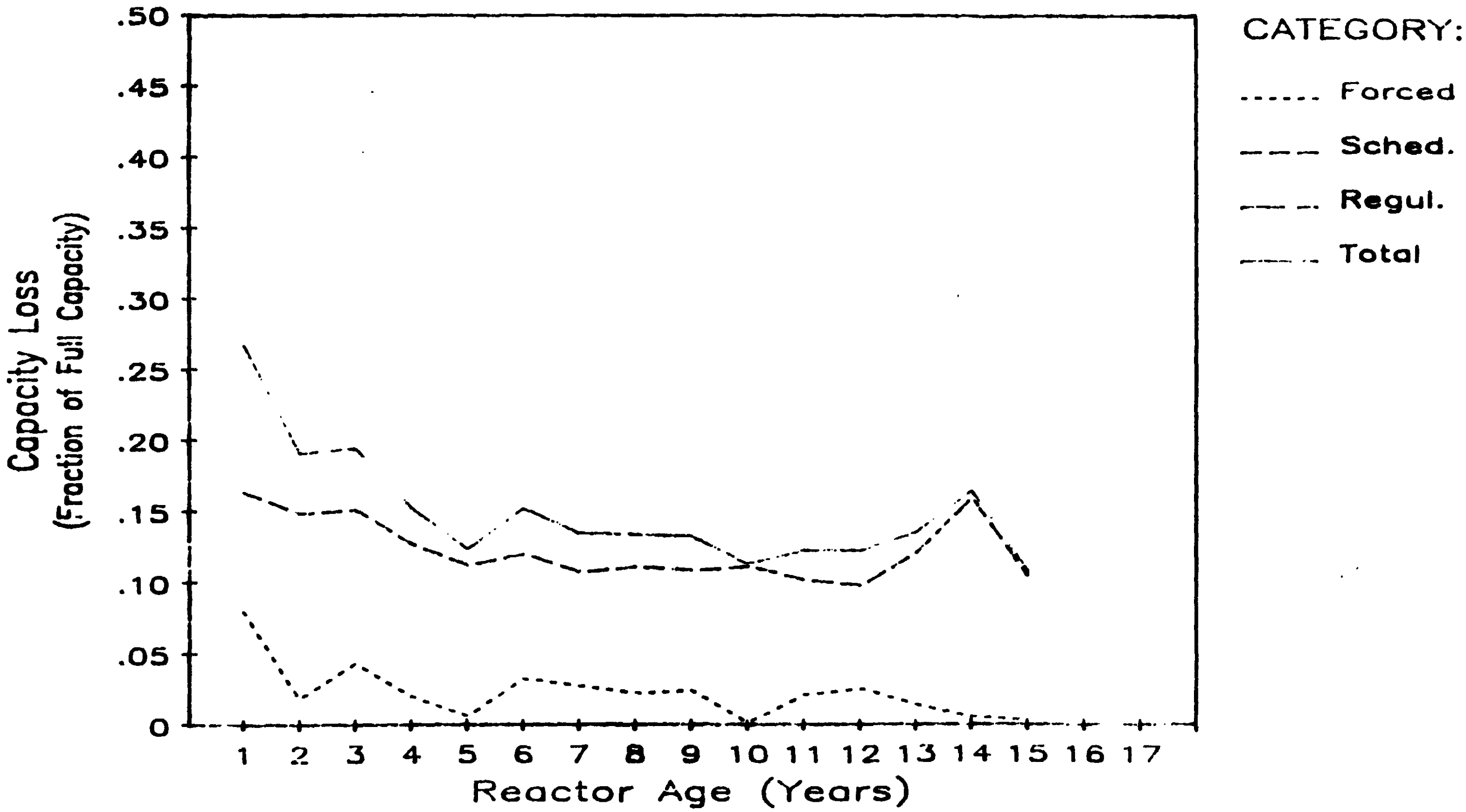
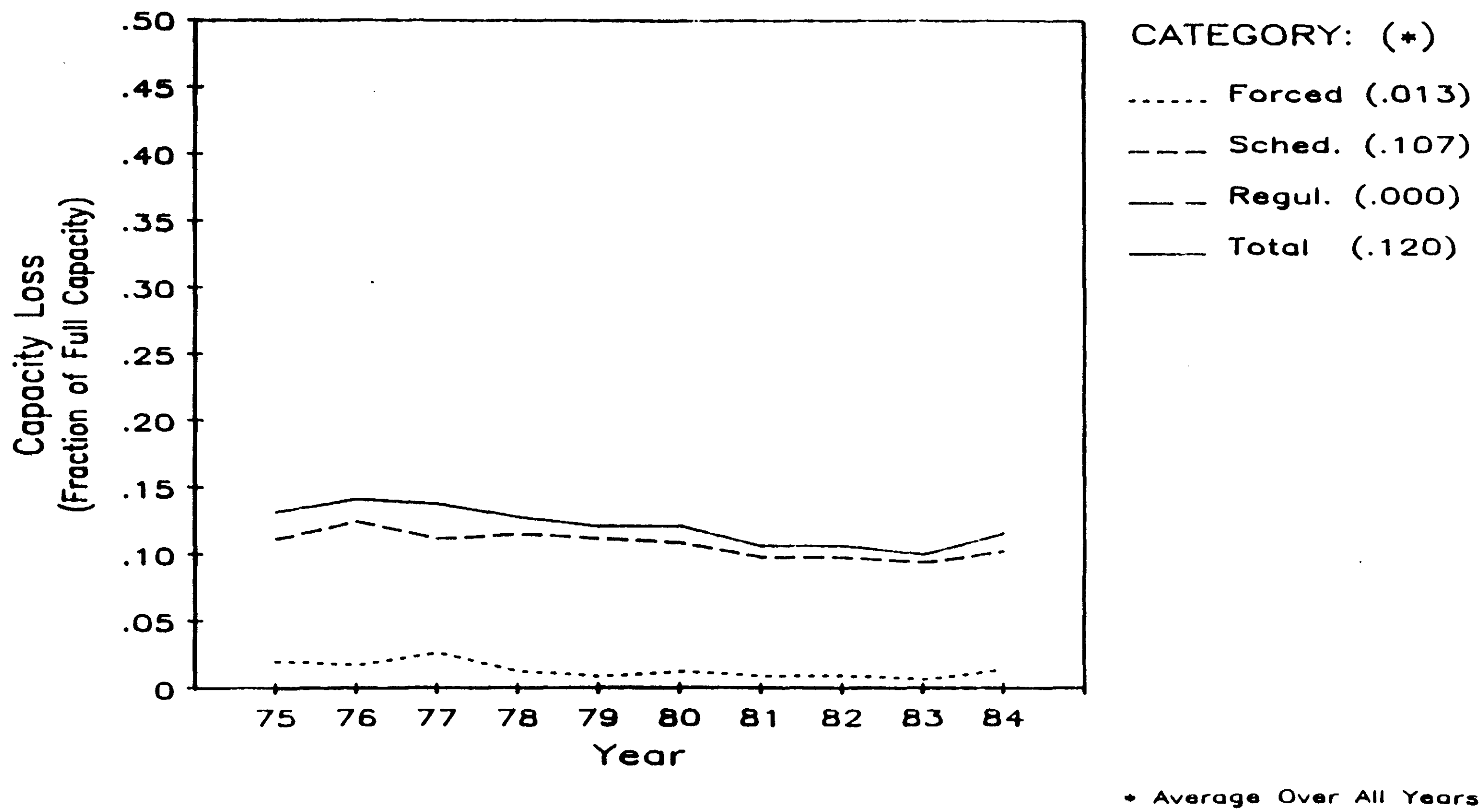


Figure 2.41
Swiss BWR Capacity Losses By Year
Forced, Scheduled, and Regulatory



## Figure 2.42
Swiss PWR Capacity Losses By Year
NSSS and BOP

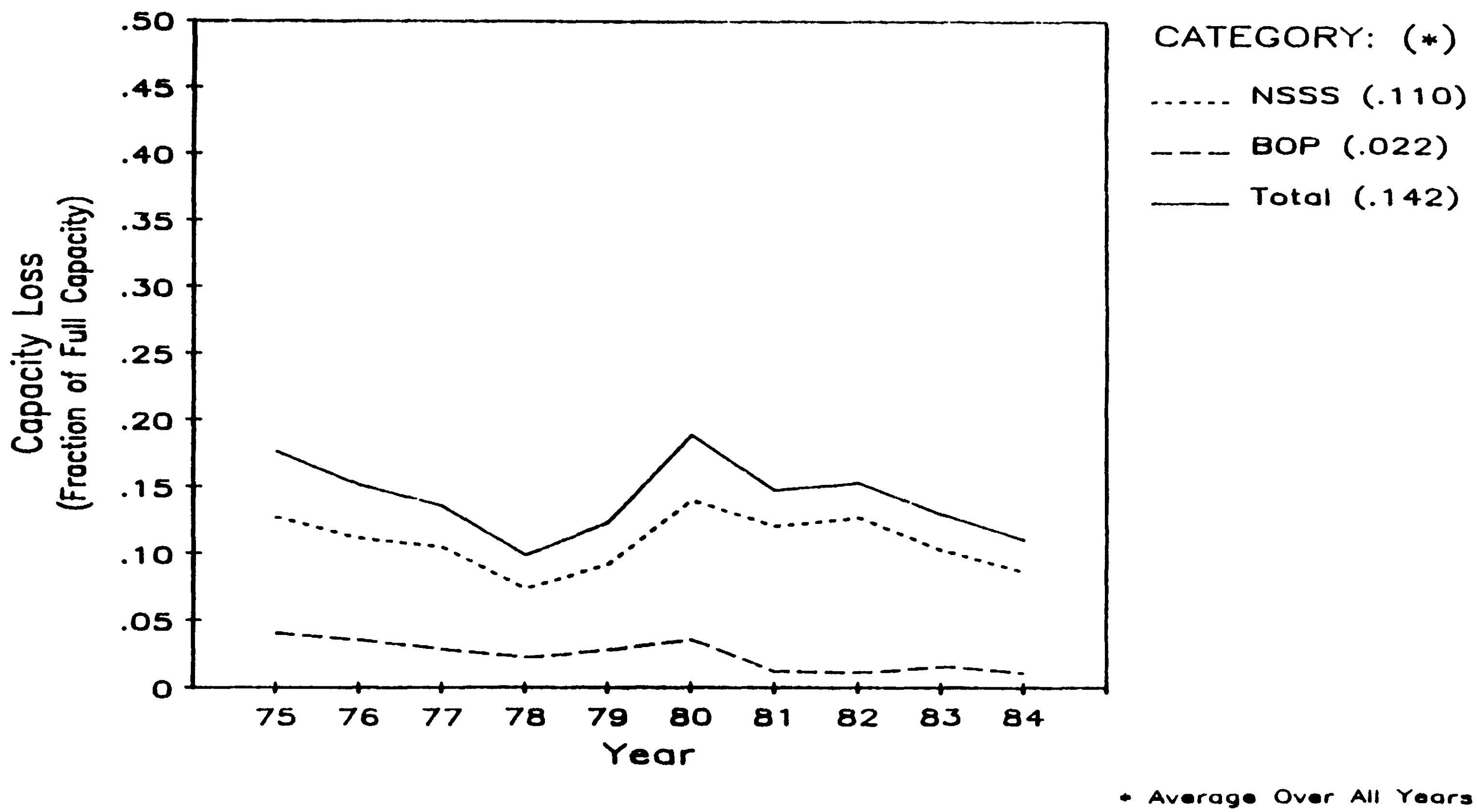


Figure 2.43
Swiss PWR Capacity Losses By Reactor Age
NSSS and BOP

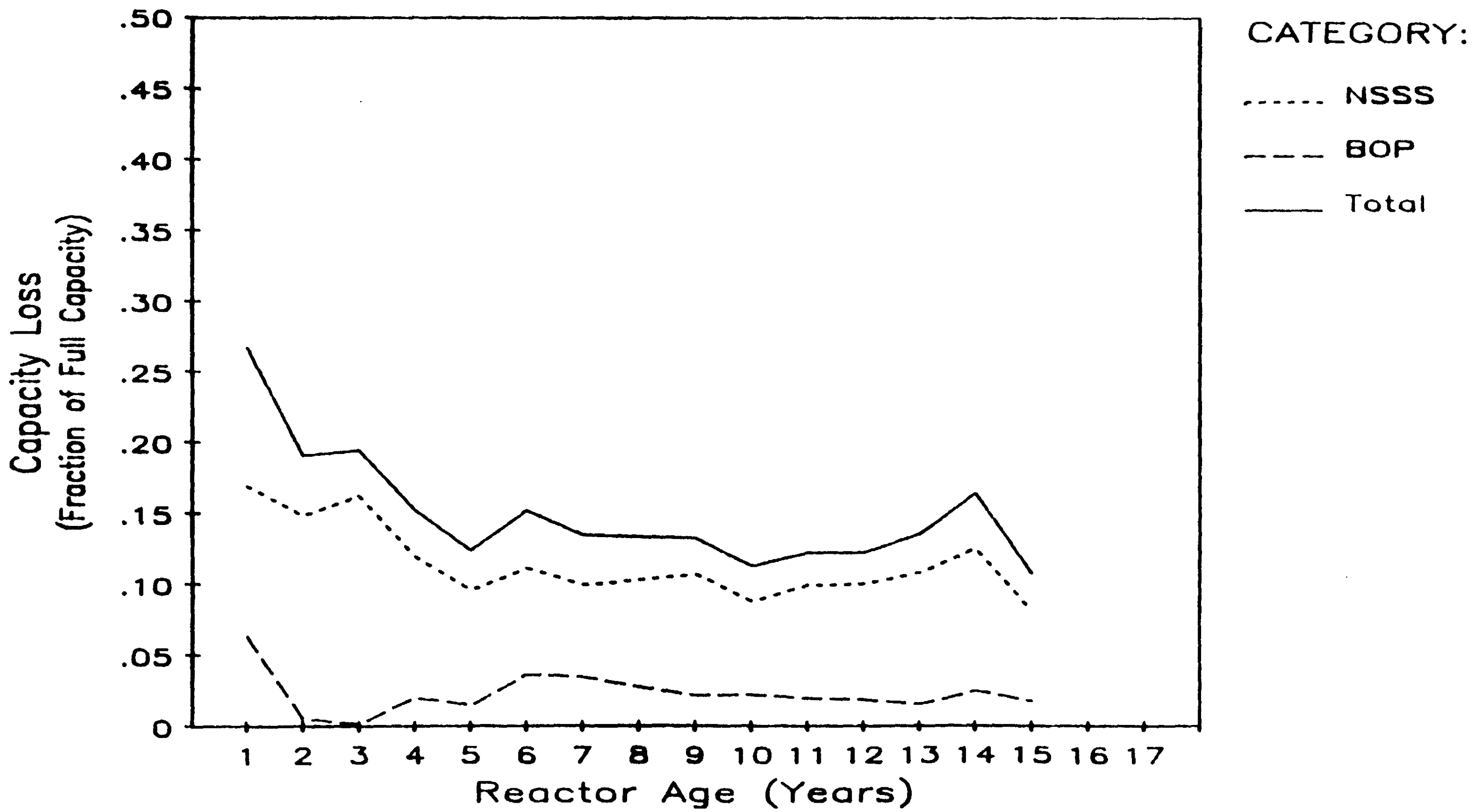
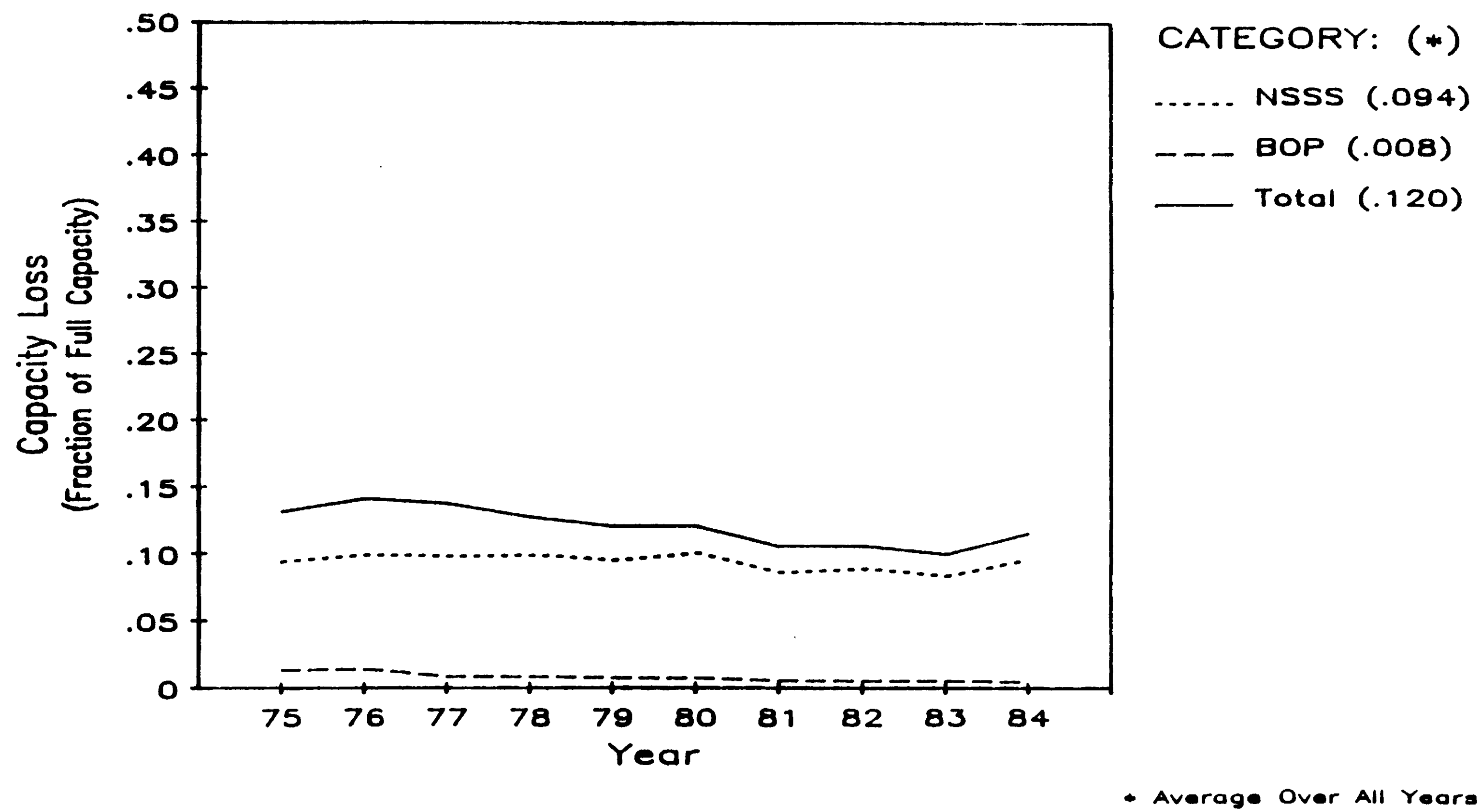


Figure 2.44

Swiss BWR Capacity Losses By Year
NSSS and BOP



## 2.6 United States

In this section the performance losses for the U.S. nuclear power plants are presented and briefly examined. U.S. performance data was compiled using energy availability as the performance index.

### 2.6.1 Aggregated Data

The U.S. PWR energy availability losses are tabulated by calendar year and by reactor age in Table 2.26 and Table 2.27 respectively. The BWR energy availability losses are tabulated by year in Table 2.28 and by reactor age in Table 2.29. The mean and standard deviations of the U.S. energy availability factors are tabulated in Table 2.30.

### 2.6.2 Capacity Factor Distribution

U.S. PWR energy availability factors are plotted by year in Figure 2.45. The performance of the PWR's averaged 60.2% over the 10 years with two distinct periods. From 1975 to 1978, the energy availability factor averaged 64.5% with a small amount of fluctuation. In 1979 the energy availability for U.S. PWR's dropped 10.7 percentage points as a result of the accident at Three Mile Island (TMI). Since the accident, performance has been slowly improving but has not yet reached its pre-TMI level. The magnitude of the standard deviation of the energy availability factors noticeably increases during this period. This indicates that there were large variations in the performance of the plants in each year, possibly as a result of the non-uniform impact of post-TMI safety regulation. From 3.5 to 5.0 percentage points of the U.S. PWR losses from 1979 to 1984 can be directly attributed to the two out of service TMI reactors.

The U.S. PWR energy availability factors as a function of reactor age are shown graphically in Figure 2.46. This figure shows that performance improved up to age 12 after which it started to decrease. The decrease is due to large regulatory losses in those plants. The standard deviations of the mean also significantly increase after age 12 indicating that the regulatory losses were not spread evenly over all the plants.

Energy availability factors for U.S. BWR's are plotted over time in Figure 2.47. The average energy availability factor over the 10 year period was 58.0%. The curve shown has a peak of 67% in 1978 and 1979 with the performance falling off to less than 50% on either side. The increase in performance prior to 1979 was due to reductions in balance of plant losses. The decrease in performance after 1979 was due to increased regulatory losses in the wake of the Three Mile Island accident. The standard deviation of the mean increases in magnitude after 1979 and gets larger every year. This is probably caused by the uneven impact of the increased regulation during those years.

The BWR energy availability factors are plotted as a function of reactor age in Figure 2.48. The figure shows a slight improvement in performance over the first five years and then levels out until age 13 where there is a large drop. This trend is very similar to that exhibited by the PWR's in Figure 2.46. The low performance and high standard deviations beyond age 12 were from large steam generator and regulatory losses at only a couple of plants.

### 2.6.3 Losses by Outage Type

In this subsection, forced, scheduled, and regulatory losses for the U.S. nuclear plants are displayed and examined as functions of time and age.

Forced, scheduled and regulatory losses are plotted by year in Figure 2.49. The total losses were high over the 10 year period, averaging 39.8% and increasing from 1975 to 1984. The scheduled losses were the largest component of the total losses with a 10 year average of 16.3%, or 41.0% of the total losses. No trend is exhibited by the scheduled losses as they are relatively constant across the entire period of interest. Forced losses were also a large fraction of the total, contributing 31.4%. The forced losses were also relatively constant from 1975 to 1984. Finally, the regulatory losses, averaging 10.9% and representing an average of 27.4% of the total losses each year, increased in magnitude from 1975 to 1984. In 1979 there was an increase in the regulatory losses of 10.7 percentage points to 16% as a result of the accident at Three Mile Island. Since the accident, it has subsided slightly and remained constant at approximately 13%.

The PWR outage category losses are plotted as a function of age in Figure 2.50. In this figure, the total losses exhibit a slight decrease from age 1 to age 12 after which it fluctuates and increases. The scheduled losses show some fluctuation but remain mostly constant to age 12. The forced losses exhibit a definite age dependency, with losses decreasing over the entire range of ages. The cause of this decrease is difficult to determine but it appears that it occurred as the result of a general reduction in many of the forced outage categories.

The forced, scheduled, and regulatory losses for the U.S. BWR's are shown by year in Figure 2.51. The curve of the total losses shows a decrease from 1975 to 1979 and then a rise again from 1980 to 1984. Scheduled outages were the largest component of the total losses, contributing 40.7%. The scheduled losses fluctuated from year to year but remained relatively constant over the 10 years. The forced losses represent 34.3% of the total losses and have decreased as a function of time. Reductions in the balance of plant OTHER losses over time were the main cause of the trend. The regulatory losses have increased since 1977 from 2.4% to 21.8% in 1984 and represent 27.4% of the total loss.

The same BWR outage categories are plotted as a function of reactor age in Figure 2.52. The U.S. BWR scheduled losses remained constant with some fluctuation and did not display an age dependency. The forced losses show a decline through age 10 after which there is a large amount of fluctuation. No specific category is responsible for the decline in forced losses. Regulatory losses exhibit a very gradual increase over all ages.

### 2.6.4 NSSS and BOP Losses

In this subsection the losses in the Nuclear Steam Supply System (NSSS) and the Balance of Plant (BOP) are displayed and examined as functions of time and reactor age for the U.S. nuclear power plants.

NSSS and BOP losses are displayed over time for the U.S. PWR's in Figure 2.53. NSSS losses remained essentially constant over the 10 year period averaging 18.0% and representing 45.2% of the total losses. Refueling losses made up almost 60% of the NSSS losses while the reactor coolant system and steam generator problems accounted for

18.3% and 13.9% respectively. BOP losses have also been essentially constant, averaging 5.9% and contributing 14.8% of the total losses. Turbine losses were the largest fraction of the BOP losses accounting for 33.9%. Condenser problems also contributed to 30.5% of the losses.

U.S. PWR NSSS and BOP losses are shown as a function of reactor age in Figure 2.54. Both NSSS and BOP losses show more variation by age than by year. The NSSS generally remain constant as a function of age while the BOP losses show a decrease with increasing age. The decrease in BOP losses was primarily the result of similar trends in the turbines and condensers.

NSSS and BOP losses are illustrated by year for the U.S. BWR's in Figure 2.55. NSSS losses have averaged 18.6% and have accounted for 44.3% of the total losses each year. The largest fraction (48.9%) of the NSSS losses was from refueling losses while reactor coolant system losses accounted for 24.2%. The BWR NSSS losses exhibit a slight decrease over time as a result of a decrease in fuel losses which is discussed in Section 3.2.2. The BOP losses for U.S. BWR's have averaged 7.3%, representing 17.4% of the average total losses. Approximately 80% of these losses were evenly attributed to turbine, condenser, and BOP OTHER losses. From 1975 to 1978 the BOP losses declined as a result of reductions in BOP OTHER losses. From 1978 to 1984 the BOP losses slowly grew as a result of increasing turbine losses.

The BWR's NSSS and BOP losses are plotted by reactor age in Figure 2.56. From age 3 to age 10 the U.S. NSSS losses have slowly improved as a result of decreased losses in several categories. The peak at ages 13 and 14 was from high reactor coolant system losses at several plants. The BOP losses show a steep drop from age 1 to age 4 which occurred as a result of decreases in BOP OTHER losses. After age 4 the BOP losses flatten out and fluctuate with age.

## Table 2.26
## U.S. PWR Energy Availability Losses By Year

ENERGY AVAIL. LOSSES | UNITED STATES
1975 - 1979 | ALL PWR'S

04/11/86

| | | | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| | | DATA: | (27) | (30) | (36) | (39) | (40) |
| FORCED | NSSS | FUEL | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 |
| | | RCS | 0.044 | 0.037 | 0.017 | 0.020 | 0.020 |
| | | SG | 0.005 | 0.014 | 0.015 | 0.001 | 0.002 |
| | | REFUEL | 0.000 | 0.002 | 0.000 | 0.001 | 0.001 |
| | | OTHER | 0.013 | 0.012 | 0.011 | 0.033 | 0.007 |
| | | | 0.064 | 0.065 | 0.044 | 0.055 | 0.030 |
| | BOP | TURBINE | 0.029 | 0.020 | 0.004 | 0.014 | 0.017 |
| | | GEN | 0.004 | 0.023 | 0.004 | 0.002 | 0.002 |
| | | COND | 0.022 | 0.012 | 0.012 | 0.015 | 0.015 |
| | | CW/SW/CCW | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | | OTHER | 0.001 | 0.002 | 0.003 | 0.017 | 0.002 |
| | | | 0.057 | 0.058 | 0.024 | 0.049 | 0.036 |
| | ECONOMIC | | 0.029 | 0.020 | 0.025 | 0.022 | 0.017 |
| | HUMAN | | 0.004 | 0.005 | 0.002 | 0.005 | 0.003 |
| | OTHER | | 0.007 | 0.006 | 0.006 | 0.004 | 0.023 |
| | TOTAL | | 0.161 | 0.156 | 0.101 | 0.135 | 0.109 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.018 | 0.026 | 0.006 | 0.006 | 0.004 |
| | | SG | 0.017 | 0.006 | 0.009 | 0.002 | 0.022 |
| | | REFUEL | 0.071 | 0.117 | 0.107 | 0.103 | 0.109 |
| | | OTHER | 0.008 | 0.004 | 0.006 | 0.007 | 0.002 |
| | | | 0.114 | 0.152 | 0.128 | 0.117 | 0.138 |
| | BOP | TURBINE | 0.006 | 0.003 | 0.021 | 0.011 | 0.006 |
| | | GEN | 0.001 | 0.003 | 0.001 | 0.000 | 0.000 |
| | | COND | 0.009 | 0.002 | 0.005 | 0.001 | 0.002 |
| | | CW/SW/CCW | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 |
| | | | 0.016 | 0.011 | 0.029 | 0.014 | 0.009 |
| | ECONOMIC | | 0.002 | 0.005 | 0.007 | 0.006 | 0.009 |
| | HUMAN | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.006 | 0.007 | 0.008 | 0.003 | 0.006 |
| | TOTAL | | 0.138 | 0.175 | 0.172 | 0.141 | 0.161 |
| REGULATORY | | | 0.036 | 0.047 | 0.031 | 0.053 | 0.164 |
| UNKNOWN | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.336 | 0.377 | 0.304 | 0.330 | 0.437 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.664 | 0.623 | 0.696 | 0.670 | 0.563 |

## Table 2.26 - (Continued)

ENERGY AVAIL. LOSSES
1980 - 1984

UNITED STATES
ALL PWR'S

04/11/86

| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| | | DATA: | (41) | (46) | (47) | (49) | (52) |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.021 | 0.034 | 0.036 | 0.012 | 0.021 |
| | | SG | 0.015 | 0.008 | 0.033 | 0.009 | 0.008 |
| | | REFUEL | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | | OTHER | 0.017 | 0.010 | 0.010 | 0.006 | 0.007 |
| | | | 0.053 | 0.053 | 0.078 | 0.029 | 0.036 |
| | BOP | TURBINE | 0.013 | 0.020 | 0.013 | 0.007 | 0.003 |
| | | GEN | 0.005 | 0.015 | 0.009 | 0.027 | 0.021 |
| | | COND | 0.016 | 0.018 | 0.018 | 0.009 | 0.012 |
| | | CW/SW/CCW | 0.002 | 0.001 | 0.005 | 0.005 | 0.001 |
| | | OTHER | 0.003 | 0.011 | 0.006 | 0.002 | 0.002 |
| | | | 0.040 | 0.065 | 0.050 | 0.049 | 0.039 |
| | ECONOMIC | | 0.016 | 0.020 | 0.015 | 0.016 | 0.015 |
| | HUMAN | | 0.003 | 0.004 | 0.004 | 0.003 | 0.009 |
| | OTHER | | 0.003 | 0.004 | 0.004 | 0.002 | 0.002 |
| | TOTAL | | 0.115 | 0.146 | 0.151 | 0.098 | 0.101 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.002 | 0.004 | 0.003 | 0.010 | 0.009 |
| | | SG | 0.016 | 0.013 | 0.009 | 0.016 | 0.019 |
| | | REFUEL | 0.119 | 0.131 | 0.111 | 0.102 | 0.088 |
| | | OTHER | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 |
| | | | 0.137 | 0.150 | 0.123 | 0.130 | 0.118 |
| | BOP | TURBINE | 0.012 | 0.004 | 0.001 | 0.004 | 0.002 |
| | | GEN | 0.000 | 0.000 | 0.003 | 0.002 | 0.004 |
| | | COND | 0.002 | 0.003 | 0.005 | 0.002 | 0.003 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.003 | 0.000 | 0.001 |
| | | OTHER | 0.003 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | | 0.017 | 0.008 | 0.012 | 0.009 | 0.011 |
| | ECONOMIC | | 0.012 | 0.008 | 0.004 | 0.007 | 0.004 |
| | HUMAN | | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.000 | 0.004 | 0.009 | 0.049 | 0.026 |
| | TOTAL | | 0.166 | 0.171 | 0.148 | 0.196 | 0.158 |
| REGULATORY | | | 0.169 | 0.102 | 0.136 | 0.136 | 0.137 |
| UNKNOWN | | | 0.000 | 0.000 | 0.001 | 0.002 | 0.001 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.450 | 0.420 | 0.434 | 0.432 | 0.398 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.550 | 0.580 | 0.566 | 0.568 | 0.602 |

Table 2.26 - (Continued)

ENERGY AVAIL. LOSSES 1975 - 1984

UNITED STATES ALL PWR'S

04/11/86 DATA:52 PLANTS 407 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 |
| | | RCS | 0.025 |
| | | SG | 0.012 |
| | | REFUEL | 0.000 |
| | | OTHER | 0.012 |
| | | | 0.050 |
| | BOP | TURBINE | 0.013 |
| | | GEN | 0.012 |
| | | COND | 0.015 |
| | | CW/SW/CCW | 0.002 |
| | | OTHER | 0.005 |
| | | | 0.046 |
| | ECONOMIC | | 0.019 |
| | HUMAN | | 0.004 |
| | OTHER | | 0.006 |
| | TOTAL | | 0.126 |
| SCHEDULED | NSSS | FUEL | 0.000 |
| | | RCS | 0.008 |
| | | SG | 0.013 |
| | | REFUEL | 0.106 |
| | | OTHER | 0.003 |
| | | | 0.130 |
| | BOP | TURBINE | 0.007 |
| | | GEN | 0.002 |
| | | COND | 0.003 |
| | | CW/SW/CCW | 0.001 |
| | | OTHER | 0.001 |
| | | | 0.013 |
| | ECONOMIC | | 0.006 |
| | HUMAN | | 0.000 |
| | OTHER | | 0.013 |
| | TOTAL | | 0.163 |
| REGULATORY | | | 0.109 |
| UNKNOWN | | | 0.001 |

** TOTAL ENERGY AVAIL. LOSS ** 0.398

** ENERGY AVAIL. FACTOR ** 0.602

## Table 2.27
## U.S. PWR Energy Availability Losses
## By Reactor Age

ENERGY AVAIL. LOSSES BY REACTOR AGE — UNITED STATES
1975 - 1984 — ALL PWR'S

04/11/86

| | | | DATA: | (37) | (36) | (41) | (37) | (38) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 |
| | | RCS | | 0.041 | 0.040 | 0.020 | 0.040 | 0.021 |
| | | SG | | 0.005 | 0.004 | 0.011 | 0.011 | 0.013 |
| | | REFUEL | | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.021 | 0.027 | 0.022 | 0.006 | 0.007 |
| | | | | 0.067 | 0.074 | 0.054 | 0.058 | 0.041 |
| | BOP | TURBINE | | 0.034 | 0.011 | 0.006 | 0.012 | 0.017 |
| | | GEN | | 0.009 | 0.033 | 0.010 | 0.009 | 0.012 |
| | | COND | | 0.027 | 0.015 | 0.016 | 0.014 | 0.013 |
| | | CW/SW/CCW | | 0.003 | 0.003 | 0.000 | 0.003 | 0.001 |
| | | OTHER | | 0.011 | 0.014 | 0.002 | 0.008 | 0.007 |
| | | | | 0.084 | 0.076 | 0.034 | 0.046 | 0.050 |
| | ECONOMIC | | | 0.022 | 0.019 | 0.023 | 0.023 | 0.022 |
| | HUMAN | | | 0.005 | 0.009 | 0.004 | 0.005 | 0.003 |
| | OTHER | | | 0.029 | 0.005 | 0.006 | 0.004 | 0.003 |
| | TOTAL | | | 0.206 | 0.184 | 0.121 | 0.136 | 0.119 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.016 | 0.023 | 0.007 | 0.004 | 0.004 |
| | | SG | | 0.007 | 0.010 | 0.006 | 0.009 | 0.005 |
| | | REFUEL | | 0.045 | 0.099 | 0.147 | 0.126 | 0.110 |
| | | OTHER | | 0.011 | 0.004 | 0.001 | 0.004 | 0.000 |
| | | | | 0.079 | 0.136 | 0.161 | 0.143 | 0.119 |
| | BOP | TURBINE | | 0.011 | 0.011 | 0.002 | 0.004 | 0.002 |
| | | GEN | | 0.004 | 0.005 | 0.004 | 0.001 | 0.001 |
| | | COND | | 0.006 | 0.006 | 0.002 | 0.004 | 0.002 |
| | | CW/SW/CCW | | 0.001 | 0.001 | 0.001 | 0.000 | 0.002 |
| | | OTHER | | 0.001 | 0.002 | 0.000 | 0.002 | 0.001 |
| | | | | 0.023 | 0.025 | 0.009 | 0.011 | 0.008 |
| | ECONOMIC | | | 0.002 | 0.006 | 0.007 | 0.009 | 0.007 |
| | HUMAN | | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.017 | 0.009 | 0.009 | 0.010 | 0.002 |
| | TOTAL | | | 0.123 | 0.175 | 0.186 | 0.172 | 0.135 |
| REGULATORY | | | | 0.053 | 0.101 | 0.085 | 0.090 | 0.118 |
| UNKNOWN | | | | 0.001 | 0.000 | 0.000 | 0.000 | 0.002 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | | 0.383 | 0.460 | 0.392 | 0.398 | 0.374 |
| ** ENERGY AVAIL. FACTOR ** | | | | 0.617 | 0.540 | 0.608 | 0.602 | 0.626 |

Table 2.27 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE — UNITED STATES
1975 - 1984 — ALL PWR'S

04/11/86

| | | | DATA: | (38) | (35) | (34) | (29) | (26) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.022 | 0.032 | 0.014 | 0.016 | 0.014 |
| | | SG | | 0.005 | 0.005 | 0.014 | 0.012 | 0.024 |
| | | REFUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | | 0.011 | 0.012 | 0.005 | 0.006 | 0.008 |
| | | | | 0.038 | 0.049 | 0.033 | 0.034 | 0.046 |
| | BOP | TURBINE | | 0.013 | 0.019 | 0.014 | 0.010 | 0.002 |
| | | GEN | | 0.001 | 0.030 | 0.004 | 0.009 | 0.006 |
| | | COND | | 0.015 | 0.014 | 0.014 | 0.010 | 0.009 |
| | | CW/SW/CCW | | 0.004 | 0.000 | 0.001 | 0.000 | 0.001 |
| | | OTHER | | 0.003 | 0.002 | 0.001 | 0.002 | 0.001 |
| | | | | 0.036 | 0.065 | 0.034 | 0.031 | 0.019 |
| | ECONOMIC | | | 0.018 | 0.019 | 0.016 | 0.018 | 0.015 |
| | HUMAN | | | 0.003 | 0.005 | 0.002 | 0.004 | 0.004 |
| | OTHER | | | 0.002 | 0.002 | 0.004 | 0.004 | 0.003 |
| | TOTAL | | | 0.098 | 0.141 | 0.090 | 0.092 | 0.086 |
| SCHEDULED | NSSS | FUEL | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | | 0.001 | 0.010 | 0.006 | 0.012 | 0.005 |
| | | SG | | 0.006 | 0.026 | 0.015 | 0.024 | 0.018 |
| | | REFUEL | | 0.105 | 0.126 | 0.114 | 0.097 | 0.101 |
| | | OTHER | | 0.003 | 0.001 | 0.001 | 0.003 | 0.002 |
| | | | | 0.115 | 0.163 | 0.136 | 0.136 | 0.126 |
| | BOP | TURBINE | | 0.006 | 0.011 | 0.008 | 0.010 | 0.002 |
| | | GEN | | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 |
| | | COND | | 0.005 | 0.003 | 0.006 | 0.002 | 0.001 |
| | | CW/SW/CCW | | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 |
| | | OTHER | | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 |
| | | | | 0.012 | 0.015 | 0.016 | 0.013 | 0.004 |
| | ECONOMIC | | | 0.006 | 0.009 | 0.005 | 0.005 | 0.013 |
| | HUMAN | | | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| | OTHER | | | 0.017 | 0.011 | 0.009 | 0.025 | 0.023 |
| | TOTAL | | | 0.149 | 0.200 | 0.165 | 0.179 | 0.165 |
| REGULATORY | | | | 0.134 | 0.112 | 0.132 | 0.094 | 0.106 |
| UNKNOWN | | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | | 0.382 | 0.454 | 0.388 | 0.366 | 0.357 |
| ** ENERGY AVAIL. FACTOR ** | | | | 0.618 | 0.546 | 0.612 | 0.634 | 0.643 |

## Table 2.27 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE — UNITED STATES
1975 - 1984 — ALL PWR'S

04/11/86

| | | | DATA: (15) | (11) | ( 6) | ( 5) | ( 3) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 11 | 12 | 13 | 14 | 15 |
| FORCED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.015 | 0.016 | 0.048 | 0.001 | 0.000 |
| | | SG | 0.016 | 0.033 | 0.063 | 0.007 | 0.011 |
| | | REFUEL | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| | | OTHER | 0.003 | 0.001 | 0.002 | 0.037 | 0.000 |
| | | | 0.034 | 0.050 | 0.114 | 0.045 | 0.011 |
| | BOP | TURBINE | 0.007 | 0.002 | 0.006 | 0.004 | 0.002 |
| | | GEN | 0.010 | 0.005 | 0.000 | 0.000 | 0.016 |
| | | COND | 0.013 | 0.011 | 0.005 | 0.005 | 0.006 |
| | | CW/SW/CCW | 0.010 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.002 | 0.003 | 0.000 | 0.018 | 0.008 |
| | | | 0.042 | 0.021 | 0.011 | 0.027 | 0.032 |
| | ECONOMIC | | 0.017 | 0.013 | 0.004 | 0.009 | 0.012 |
| | HUMAN | | 0.005 | 0.006 | 0.003 | 0.000 | 0.001 |
| | OTHER | | 0.004 | 0.003 | 0.001 | 0.004 | 0.001 |
| | TOTAL | | 0.102 | 0.096 | 0.133 | 0.086 | 0.056 |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | RCS | 0.005 | 0.002 | 0.000 | 0.001 | 0.000 |
| | | SG | 0.008 | 0.000 | 0.016 | 0.182 | 0.012 |
| | | REFUEL | 0.088 | 0.123 | 0.137 | 0.090 | 0.054 |
| | | OTHER | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 |
| | | | 0.101 | 0.126 | 0.153 | 0.274 | 0.066 |
| | BOP | TURBINE | 0.001 | 0.001 | 0.002 | 0.003 | 0.002 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | 0.003 | 0.002 | 0.002 | 0.001 | 0.000 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | 0.005 | 0.003 | 0.004 | 0.004 | 0.002 |
| | ECONOMIC | | 0.007 | 0.003 | 0.000 | 0.000 | 0.001 |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.022 | 0.039 | 0.000 | 0.005 | 0.000 |
| | TOTAL | | 0.135 | 0.170 | 0.158 | 0.283 | 0.070 |
| REGULATORY | | | 0.084 | 0.048 | 0.263 | 0.141 | 0.288 |
| UNKNOWN | | | 0.003 | 0.002 | 0.002 | 0.001 | 0.001 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.324 | 0.315 | 0.556 | 0.510 | 0.415 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.676 | 0.685 | 0.444 | 0.490 | 0.585 |

## Table 2.27 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE — UNITED STATES
1975 - 1984 — ALL PWR'S

04/11/86 — DATA: ( 2) ( 2) ( 0) ( 0) ( 0)

| | | | AGE: 16 | 17 | | | |
|---|---|---|---|---|---|---|---|
| FORCED | NSSS | FUEL | 0.000 | 0.000 | | | |
| | | RCS | 0.002 | 0.025 | | | |
| | | SG | 0.000 | 0.000 | | | |
| | | REFUEL | 0.000 | 0.000 | | | |
| | | OTHER | 0.000 | 0.001 | | | |
| | | | 0.002 | 0.026 | | | |
| | BOP | TURBINE | 0.000 | 0.000 | | | |
| | | GEN | 0.000 | 0.004 | | | |
| | | COND | 0.002 | 0.000 | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | | | |
| | | OTHER | 0.000 | 0.000 | | | |
| | | | 0.002 | 0.004 | | | |
| | ECONOMIC | | 0.010 | 0.005 | | | |
| | HUMAN | | 0.000 | 0.002 | | | |
| | OTHER | | 0.001 | 0.000 | | | |
| | TOTAL | | 0.016 | 0.037 | | | |
| SCHEDULED | NSSS | FUEL | 0.000 | 0.000 | | | |
| | | RCS | 0.000 | 0.000 | | | |
| | | SG | 0.000 | 0.000 | | | |
| | | REFUEL | 0.079 | 0.077 | | | |
| | | OTHER | 0.000 | 0.000 | | | |
| | | | 0.079 | 0.077 | | | |
| | BOP | TURBINE | 0.017 | 0.001 | | | |
| | | GEN | 0.000 | 0.000 | | | |
| | | COND | 0.000 | 0.003 | | | |
| | | CW/SW/CCW | 0.000 | 0.000 | | | |
| | | OTHER | 0.000 | 0.000 | | | |
| | | | 0.017 | 0.004 | | | |
| | ECONOMIC | | 0.000 | 0.016 | | | |
| | HUMAN | | 0.000 | 0.000 | | | |
| | OTHER | | 0.000 | 0.040 | | | |
| | TOTAL | | 0.096 | 0.136 | | | |
| REGULATORY | | | 0.517 | 0.460 | | | |
| UNKNOWN | | | 0.000 | 0.001 | | | |

** TOTAL ENERGY AVAIL. LOSS ** 0.629 0.634

** ENERGY AVAIL. FACTOR ** 0.371 0.366

## Table 2.28
## U.S. BWR Energy Availability Losses
## By Year

ENERGY AVAIL. LOSSES — UNITED STATES
1975 - 1979 — ALL BWR'S

04/11/86

| | | | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| | | DATA: | (18) | (19) | (21) | (21) | (22) |
| FORCED | NSSS | FUEL | 0.032 | 0.034 | 0.024 | 0.014 | 0.012 |
| | | RCS | 0.032 | 0.032 | 0.019 | 0.025 | 0.016 |
| | | SG | | | | | |
| | | REFUEL | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.012 | 0.010 | 0.010 | 0.012 | 0.004 |
| | | | 0.076 | 0.077 | 0.054 | 0.051 | 0.033 |
| | BOP | TURBINE | 0.004 | 0.010 | 0.016 | 0.007 | 0.004 |
| | | GEN | 0.002 | 0.002 | 0.014 | 0.003 | 0.004 |
| | | COND | 0.031 | 0.013 | 0.023 | 0.014 | 0.014 |
| | | CW/SW/CCW | 0.018 | 0.009 | 0.004 | 0.000 | 0.001 |
| | | OTHER | 0.102 | 0.066 | 0.005 | 0.012 | 0.017 |
| | | | 0.157 | 0.101 | 0.062 | 0.037 | 0.039 |
| | ECONOMIC | | 0.017 | 0.019 | 0.020 | 0.021 | 0.016 |
| | HUMAN | | 0.004 | 0.005 | 0.006 | 0.006 | 0.009 |
| | OTHER | | 0.007 | 0.006 | 0.011 | 0.015 | 0.010 |
| | TOTAL | | 0.262 | 0.208 | 0.153 | 0.129 | 0.108 |
| SCHEDULED | NSSS | FUEL | 0.014 | 0.017 | 0.016 | 0.012 | 0.009 |
| | | RCS | 0.058 | 0.015 | 0.008 | 0.006 | 0.005 |
| | | SG | | | | | |
| | | REFUEL | 0.057 | 0.095 | 0.165 | 0.089 | 0.084 |
| | | OTHER | 0.026 | 0.028 | 0.007 | 0.006 | 0.007 |
| | | | 0.156 | 0.155 | 0.196 | 0.113 | 0.105 |
| | BOP | TURBINE | 0.000 | 0.002 | 0.002 | 0.000 | 0.000 |
| | | GEN | 0.000 | 0.005 | 0.004 | 0.000 | 0.001 |
| | | COND | 0.004 | 0.007 | 0.005 | 0.004 | 0.004 |
| | | CW/SW/CCW | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.001 | 0.001 | 0.000 | 0.001 | 0.002 |
| | | | 0.007 | 0.015 | 0.010 | 0.005 | 0.007 |
| | ECONOMIC | | 0.001 | 0.002 | 0.011 | 0.012 | 0.018 |
| | HUMAN | | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.005 | 0.008 | 0.004 | 0.002 | 0.003 |
| | TOTAL | | 0.169 | 0.180 | 0.221 | 0.131 | 0.133 |
| REGULATORY | | | 0.074 | 0.058 | 0.024 | 0.059 | 0.083 |
| UNKNOWN | | | 0.001 | 0.000 | 0.000 | 0.006 | 0.005 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.506 | 0.446 | 0.399 | 0.325 | 0.329 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.494 | 0.554 | 0.601 | 0.675 | 0.671 |

## Table 2.28 - (Continued)

ENERGY AVAIL. LOSSES 1980 - 1984 — UNITED STATES ALL BWR'S

04/11/86

| | | | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| | | DATA: | (22) | (22) | (22) | (23) | (25) |
| FORCED | NSSS | FUEL | 0.008 | 0.010 | 0.005 | 0.006 | 0.004 |
| | | RCS | 0.036 | 0.034 | 0.078 | 0.021 | 0.015 |
| | | SG | | | | | |
| | | REFUEL | 0.000 | 0.007 | 0.000 | 0.001 | 0.000 |
| | | OTHER | 0.017 | 0.029 | 0.014 | 0.010 | 0.009 |
| | | | 0.061 | 0.079 | 0.097 | 0.037 | 0.027 |
| | BOP | TURBINE | 0.005 | 0.019 | 0.028 | 0.007 | 0.024 |
| | | GEN | 0.003 | 0.000 | 0.004 | 0.004 | 0.001 |
| | | COND | 0.018 | 0.019 | 0.013 | 0.009 | 0.018 |
| | | CW/SW/CCW | 0.001 | 0.004 | 0.001 | 0.001 | 0.002 |
| | | OTHER | 0.005 | 0.008 | 0.002 | 0.003 | 0.006 |
| | | | 0.033 | 0.051 | 0.048 | 0.024 | 0.050 |
| | ECONOMIC | | 0.011 | 0.011 | 0.010 | 0.011 | 0.008 |
| | HUMAN | | 0.004 | 0.006 | 0.012 | 0.007 | 0.011 |
| | OTHER | | 0.006 | 0.009 | 0.005 | 0.003 | 0.002 |
| | TOTAL | | 0.114 | 0.156 | 0.172 | 0.082 | 0.098 |
| SCHEDULED | NSSS | FUEL | 0.007 | 0.010 | 0.001 | 0.007 | 0.003 |
| | | RCS | 0.005 | 0.002 | 0.007 | 0.024 | 0.022 |
| | | SG | | | | | |
| | | REFUEL | 0.118 | 0.070 | 0.049 | 0.091 | 0.081 |
| | | OTHER | 0.004 | 0.037 | 0.003 | 0.012 | 0.010 |
| | | | 0.134 | 0.119 | 0.060 | 0.134 | 0.116 |
| | BOP | TURBINE | 0.012 | 0.023 | 0.017 | 0.011 | 0.007 |
| | | GEN | 0.001 | 0.000 | 0.000 | 0.004 | 0.000 |
| | | COND | 0.004 | 0.004 | 0.001 | 0.015 | 0.002 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| | | OTHER | 0.003 | 0.003 | 0.000 | 0.000 | 0.002 |
| | | | 0.021 | 0.030 | 0.018 | 0.031 | 0.012 |
| | ECONOMIC | | 0.024 | 0.015 | 0.037 | 0.024 | 0.022 |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 |
| | OTHER | | 0.001 | 0.001 | 0.004 | 0.019 | 0.050 |
| | TOTAL | | 0.180 | 0.166 | 0.120 | 0.209 | 0.199 |
| REGULATORY | | | 0.114 | 0.092 | 0.121 | 0.157 | 0.218 |
| UNKNOWN | | | 0.001 | 0.001 | 0.002 | 0.003 | 0.001 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.408 | 0.413 | 0.415 | 0.452 | 0.517 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.592 | 0.587 | 0.585 | 0.548 | 0.483 |

Table 2.28 - (Continued)

ENERGY AVAIL. LOSSES 1975 - 1984

UNITED STATES ALL BWR'S

04/11/86 DATA:25 PLANTS 215 PLANT-YEARS

| | | | AVERAGE OVER ALL YEARS |
|---|---|---|---|
| FORCED | NSSS | FUEL | 0.014 |
| | | RCS | 0.031 |
| | | SG | |
| | | REFUEL | 0.001 |
| | | OTHER | 0.013 |
| | | | 0.058 |
| | BOP | TURBINE | 0.013 |
| | | GEN | 0.004 |
| | | COND | 0.017 |
| | | CW/SW/CCW | 0.004 |
| | | OTHER | 0.020 |
| | | | 0.057 |
| | ECONOMIC | | 0.014 |
| | HUMAN | | 0.007 |
| | OTHER | | 0.007 |
| | TOTAL | | 0.144 |
| SCHEDULED | NSSS | FUEL | 0.008 |
| | | RCS | 0.014 |
| | | SG | |
| | | REFUEL | 0.090 |
| | | OTHER | 0.014 |
| | | | 0.127 |
| | BOP | TURBINE | 0.008 |
| | | GEN | 0.001 |
| | | COND | 0.005 |
| | | CW/SW/CCW | 0.001 |
| | | OTHER | 0.001 |
| | | | 0.016 |
| | ECONOMIC | | 0.017 |
| | HUMAN | | 0.000 |
| | OTHER | | 0.010 |
| | TOTAL | | 0.171 |
| REGULATORY | | | 0.104 |
| UNKNOWN | | | 0.002 |

** TOTAL ENERGY AVAIL. LOSS ** 0.420

** ENERGY AVAIL. FACTOR ** 0.580

<u>Table 2.29</u>
U.S. BWR Energy Availability Losses
By Reactor Age

ENERGY AVAIL. LOSSES BY REACTOR AGE — UNITED STATES
1975 - 1984 — ALL BWR'S

04/11/86

| | | | DATA: | (14) | (12) | (17) | (19) | (20) |
|---|---|---|---|---|---|---|---|---|
| | | | AGE: | 1 | 2 | 3 | 4 | 5 |
| FORCED | NSSS | FUEL | | 0.020 | 0.026 | 0.028 | 0.029 | 0.022 |
| | | RCS | | 0.043 | 0.040 | 0.033 | 0.020 | 0.016 |
| | | SG | | | | | | |
| | | REFUEL | | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| | | OTHER | | 0.012 | 0.010 | 0.011 | 0.006 | 0.011 |
| | | | | 0.075 | 0.076 | 0.072 | 0.056 | 0.050 |
| | BOP | TURBINE | | 0.005 | 0.015 | 0.015 | 0.005 | 0.006 |
| | | GEN | | 0.022 | 0.004 | 0.004 | 0.004 | 0.002 |
| | | COND | | 0.026 | 0.016 | 0.022 | 0.015 | 0.016 |
| | | CW/SW/CCW | | 0.003 | 0.001 | 0.015 | 0.007 | 0.004 |
| | | OTHER | | 0.122 | 0.096 | 0.014 | 0.003 | 0.004 |
| | | | | 0.178 | 0.132 | 0.070 | 0.034 | 0.032 |
| | ECONOMIC | | | 0.020 | 0.021 | 0.020 | 0.016 | 0.016 |
| | HUMAN | | | 0.012 | 0.009 | 0.006 | 0.006 | 0.010 |
| | OTHER | | | 0.009 | 0.007 | 0.009 | 0.011 | 0.009 |
| | TOTAL | | | 0.293 | 0.246 | 0.177 | 0.124 | 0.118 |
| SCHEDULED | NSSS | FUEL | | 0.010 | 0.012 | 0.020 | 0.014 | 0.014 |
| | | RCS | | 0.001 | 0.010 | 0.036 | 0.028 | 0.009 |
| | | SG | | | | | | |
| | | REFUEL | | 0.000 | 0.121 | 0.112 | 0.139 | 0.094 |
| | | OTHER | | 0.039 | 0.011 | 0.012 | 0.011 | 0.033 |
| | | | | 0.050 | 0.154 | 0.180 | 0.192 | 0.150 |
| | BOP | TURBINE | | 0.000 | 0.002 | 0.001 | 0.001 | 0.001 |
| | | GEN | | 0.000 | 0.002 | 0.000 | 0.005 | 0.004 |
| | | COND | | 0.001 | 0.003 | 0.004 | 0.006 | 0.007 |
| | | CW/SW/CCW | | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 |
| | | OTHER | | 0.001 | 0.000 | 0.001 | 0.003 | 0.002 |
| | | | | 0.003 | 0.007 | 0.006 | 0.016 | 0.014 |
| | ECONOMIC | | | 0.001 | 0.006 | 0.005 | 0.006 | 0.016 |
| | HUMAN | | | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | OTHER | | | 0.031 | 0.007 | 0.003 | 0.006 | 0.002 |
| | TOTAL | | | 0.085 | 0.174 | 0.192 | 0.220 | 0.182 |
| REGULATORY | | | | 0.122 | 0.073 | 0.068 | 0.091 | 0.072 |
| UNKNOWN | | | | 0.001 | 0.005 | 0.004 | 0.002 | 0.001 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | | 0.501 | 0.497 | 0.439 | 0.437 | 0.373 |
| ** ENERGY AVAIL. FACTOR ** | | | | 0.499 | 0.503 | 0.561 | 0.563 | 0.627 |

## Table 2.29 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE — UNITED STATES
1975 - 1984 — ALL BWR'S

04/11/86

| | | | DATA: (21) | (21) | (21) | (19) | (16) |
|---|---|---|---|---|---|---|---|
| | | AGE: | 6 | 7 | 8 | 9 | 10 |
| FORCED | NSSS | FUEL | 0.014 | 0.009 | 0.010 | 0.004 | 0.003 |
| | | RCS | 0.027 | 0.031 | 0.018 | 0.017 | 0.022 |
| | | SG | | | | | |
| | | REFUEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.029 | 0.008 | 0.012 | 0.008 | 0.017 |
| | | | 0.070 | 0.048 | 0.040 | 0.029 | 0.042 |
| | BOP | TURBINE | 0.012 | 0.026 | 0.005 | 0.014 | 0.004 |
| | | GEN | 0.001 | 0.002 | 0.003 | 0.001 | 0.004 |
| | | COND | 0.020 | 0.012 | 0.017 | 0.009 | 0.010 |
| | | CW/SW/CCW | 0.003 | 0.003 | 0.001 | 0.002 | 0.001 |
| | | OTHER | 0.006 | 0.011 | 0.016 | 0.004 | 0.004 |
| | | | 0.042 | 0.054 | 0.042 | 0.030 | 0.023 |
| | ECONOMIC | | 0.017 | 0.013 | 0.011 | 0.011 | 0.009 |
| | HUMAN | | 0.005 | 0.006 | 0.014 | 0.003 | 0.006 |
| | OTHER | | 0.011 | 0.007 | 0.005 | 0.006 | 0.005 |
| | TOTAL | | 0.145 | 0.128 | 0.111 | 0.080 | 0.083 |
| SCHEDULED | NSSS | FUEL | 0.014 | 0.006 | 0.008 | 0.005 | 0.002 |
| | | RCS | 0.006 | 0.015 | 0.011 | 0.014 | 0.014 |
| | | SG | | | | | |
| | | REFUEL | 0.084 | 0.096 | 0.086 | 0.085 | 0.081 |
| | | OTHER | 0.005 | 0.006 | 0.011 | 0.019 | 0.004 |
| | | | 0.109 | 0.123 | 0.116 | 0.123 | 0.101 |
| | BOP | TURBINE | 0.014 | 0.019 | 0.009 | 0.002 | 0.015 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.005 | 0.000 |
| | | COND | 0.003 | 0.014 | 0.002 | 0.006 | 0.006 |
| | | CW/SW/CCW | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.002 | 0.003 | 0.001 | 0.001 | 0.001 |
| | | | 0.019 | 0.036 | 0.012 | 0.014 | 0.022 |
| | ECONOMIC | | 0.016 | 0.015 | 0.023 | 0.017 | 0.053 |
| | HUMAN | | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.001 | 0.005 | 0.012 | 0.022 | 0.009 |
| | TOTAL | | 0.144 | 0.181 | 0.163 | 0.174 | 0.186 |
| REGULATORY | | | 0.089 | 0.076 | 0.107 | 0.172 | 0.087 |
| UNKNOWN | | | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.380 | 0.387 | 0.383 | 0.427 | 0.357 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.620 | 0.613 | 0.617 | 0.573 | 0.643 |

# Table 2.29 - (Continued)

ENERGY AVAIL. LOSSES BY REACTOR AGE 1975 - 1984 — UNITED STATES, ALL BWR'S

04/11/86

| | | | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|
| | | DATA: | (10) | (10) | ( 5) | ( 3) | ( 2) |
| FORCED | NSSS | FUEL | 0.003 | 0.002 | 0.002 | 0.000 | 0.000 |
| | | RCS | 0.043 | 0.013 | 0.193 | 0.097 | 0.010 |
| | | SG | | | | | |
| | | REFUEL | 0.013 | 0.000 | 0.000 | 0.005 | 0.000 |
| | | OTHER | 0.014 | 0.018 | 0.014 | 0.003 | 0.000 |
| | | | 0.073 | 0.033 | 0.209 | 0.105 | 0.010 |
| | BOP | TURBINE | 0.025 | 0.010 | 0.073 | 0.001 | 0.004 |
| | | GEN | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | 0.021 | 0.023 | 0.024 | 0.000 | 0.014 |
| | | CW/SW/CCW | 0.001 | 0.002 | 0.000 | 0.000 | 0.008 |
| | | OTHER | 0.005 | 0.003 | 0.001 | 0.000 | 0.023 |
| | | | 0.060 | 0.038 | 0.098 | 0.001 | 0.049 |
| | ECONOMIC | | 0.011 | 0.008 | 0.004 | 0.008 | 0.003 |
| | HUMAN | | 0.004 | 0.006 | 0.003 | 0.000 | 0.009 |
| | OTHER | | 0.003 | 0.003 | 0.002 | 0.002 | 0.000 |
| | TOTAL | | 0.151 | 0.089 | 0.316 | 0.117 | 0.070 |
| SCHEDULED | NSSS | FUEL | 0.003 | 0.002 | 0.000 | 0.001 | 0.004 |
| | | RCS | 0.003 | 0.003 | 0.003 | 0.011 | 0.148 |
| | | SG | | | | | |
| | | REFUEL | 0.086 | 0.107 | 0.031 | 0.144 | 0.079 |
| | | OTHER | 0.002 | 0.002 | 0.000 | 0.057 | 0.003 |
| | | | 0.094 | 0.114 | 0.034 | 0.213 | 0.234 |
| | BOP | TURBINE | 0.022 | 0.003 | 0.017 | 0.029 | 0.000 |
| | | GEN | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | COND | 0.005 | 0.003 | 0.001 | 0.002 | 0.001 |
| | | CW/SW/CCW | 0.002 | 0.003 | 0.000 | 0.000 | 0.000 |
| | | OTHER | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | | | 0.029 | 0.010 | 0.018 | 0.031 | 0.001 |
| | ECONOMIC | | 0.025 | 0.015 | 0.049 | 0.026 | 0.008 |
| | HUMAN | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | | 0.001 | 0.002 | 0.000 | 0.028 | 0.128 |
| | TOTAL | | 0.149 | 0.142 | 0.103 | 0.298 | 0.372 |
| REGULATORY | | | 0.101 | 0.181 | 0.210 | 0.148 | 0.192 |
| UNKNOWN | | | 0.002 | 0.003 | 0.001 | 0.001 | 0.000 |
| ** TOTAL ENERGY AVAIL. LOSS ** | | | 0.403 | 0.415 | 0.630 | 0.564 | 0.634 |
| ** ENERGY AVAIL. FACTOR ** | | | 0.597 | 0.585 | 0.370 | 0.436 | 0.366 |

## Table 2.30 - U.S. Capacity Factor Distributions

| By Year | PWR | | | BWR | | |
|---|---|---|---|---|---|---|
| | Mean | σ | # Data | Mean | σ | # Data |
| 75 | 0.664 | 0.132 | 27 | 0.494 | 0.177 | 18 |
| 76 | 0.623 | 0.150 | 30 | 0.554 | 0.176 | 19 |
| 77 | 0.696 | 0.104 | 36 | 0.601 | 0.129 | 21 |
| 78 | 0.670 | 0.168 | 39 | 0.675 | 0.125 | 21 |
| 79 | 0.563 | 0.209 | 40 | 0.671 | 0.147 | 22 |
| 80 | 0.550 | 0.208 | 41 | 0.592 | 0.130 | 22 |
| 81 | 0.580 | 0.213 | 46 | 0.587 | 0.142 | 22 |
| 82 | 0.566 | 0.220 | 47 | 0.585 | 0.190 | 22 |
| 83 | 0.568 | 0.236 | 49 | 0.548 | 0.213 | 23 |
| 84 | 0.602 | 0.234 | 52 | 0.483 | 0.261 | 25 |

| By Age | PWR | | | BWR | | |
|---|---|---|---|---|---|---|
| | Mean | σ | # Data | Mean | σ | # Data |
| 1 | 0.617 | 0.156 | 37 | 0.499 | 0.180 | 14 |
| 2 | 0.540 | 0.201 | 36 | 0.503 | 0.180 | 12 |
| 3 | 0.607 | 0.183 | 41 | 0.561 | 0.112 | 17 |
| 4 | 0.601 | 0.201 | 37 | 0.563 | 0.139 | 19 |
| 5 | 0.626 | 0.187 | 38 | 0.628 | 0.174 | 20 |
| 6 | 0.617 | 0.202 | 38 | 0.621 | 0.120 | 21 |
| 7 | 0.546 | 0.230 | 35 | 0.614 | 0.181 | 21 |
| 8 | 0.612 | 0.202 | 34 | 0.617 | 0.188 | 21 |
| 9 | 0.634 | 0.214 | 29 | 0.573 | 0.184 | 19 |
| 10 | 0.642 | 0.189 | 26 | 0.643 | 0.166 | 16 |
| 11 | 0.675 | 0.132 | 15 | 0.597 | 0.169 | 10 |
| 12 | 0.686 | 0.154 | 11 | 0.585 | 0.225 | 10 |
| 13 | 0.445 | 0.206 | 6 | 0.371 | 0.295 | 5 |
| 14 | 0.490 | 0.309 | 5 | 0.436 | 0.295 | 3 |
| 15 | 0.585 | 0.326 | 3 | 0.366 | 0.312 | 2 |
| 16 | 0.371 | 0.371 | 2 | | | |
| 17 | 0.366 | 0.292 | 2 | | | |

Figure 2.45
U.S. PWR Capacity Factor Distribution
By Year

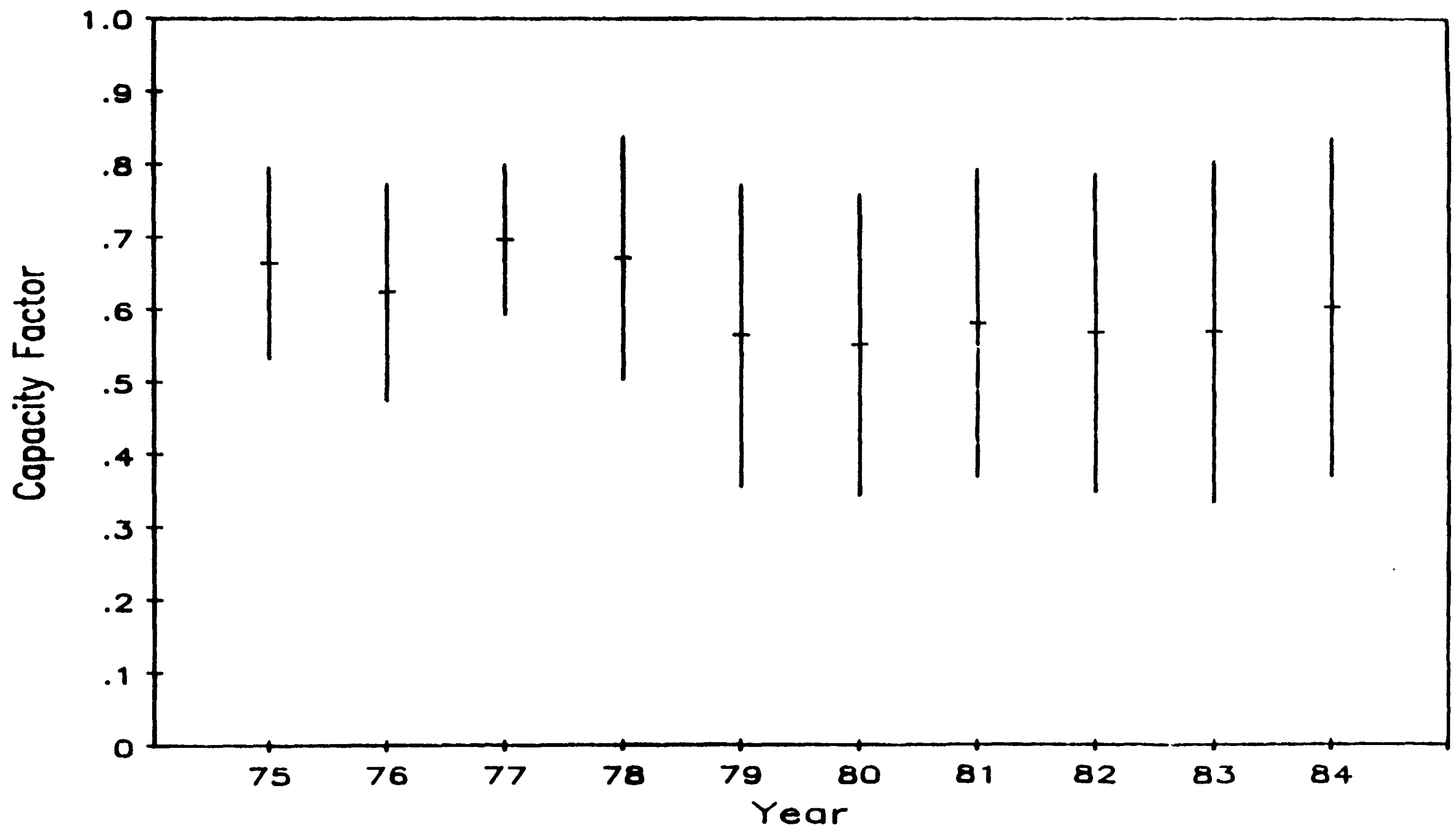
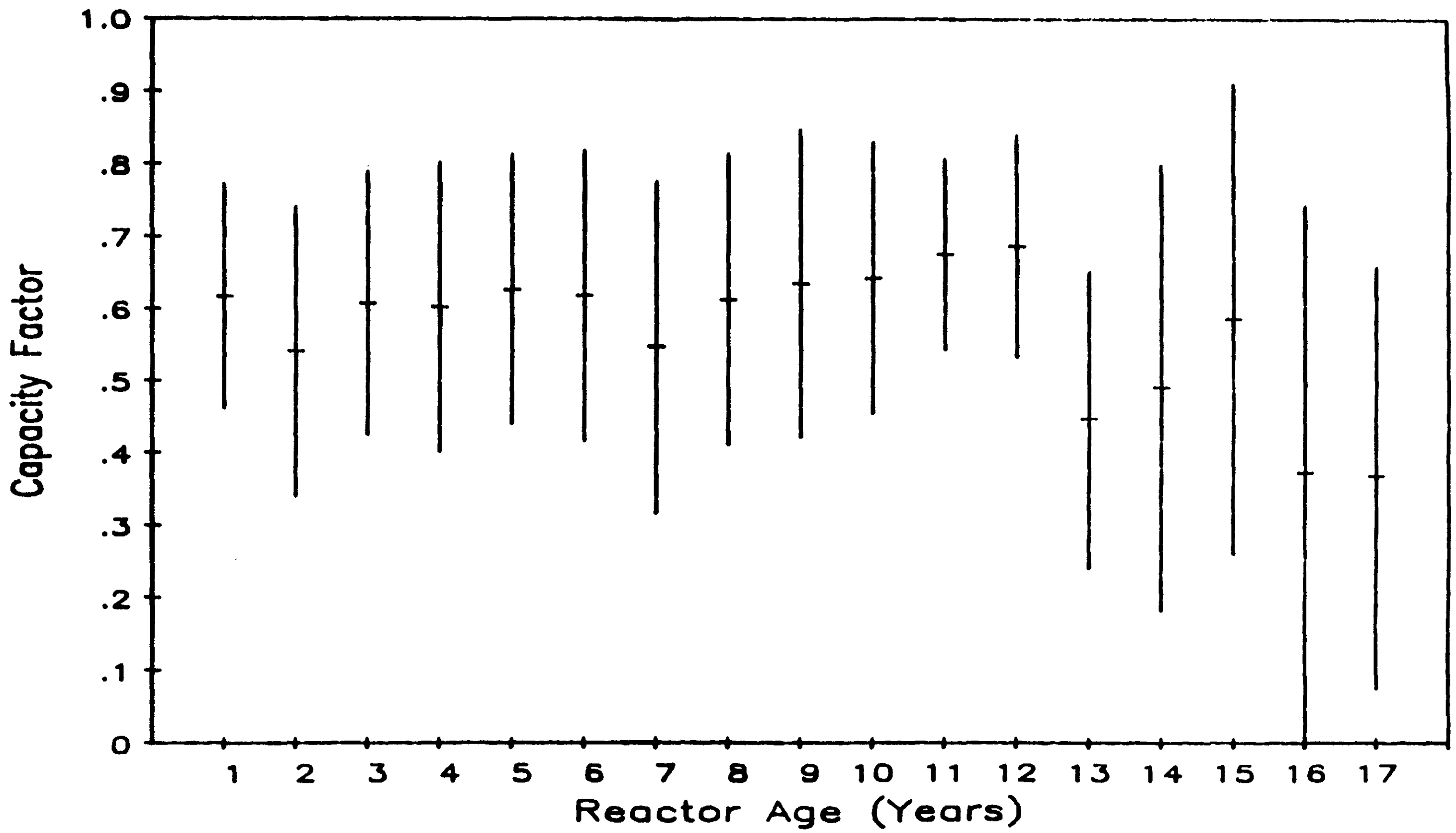
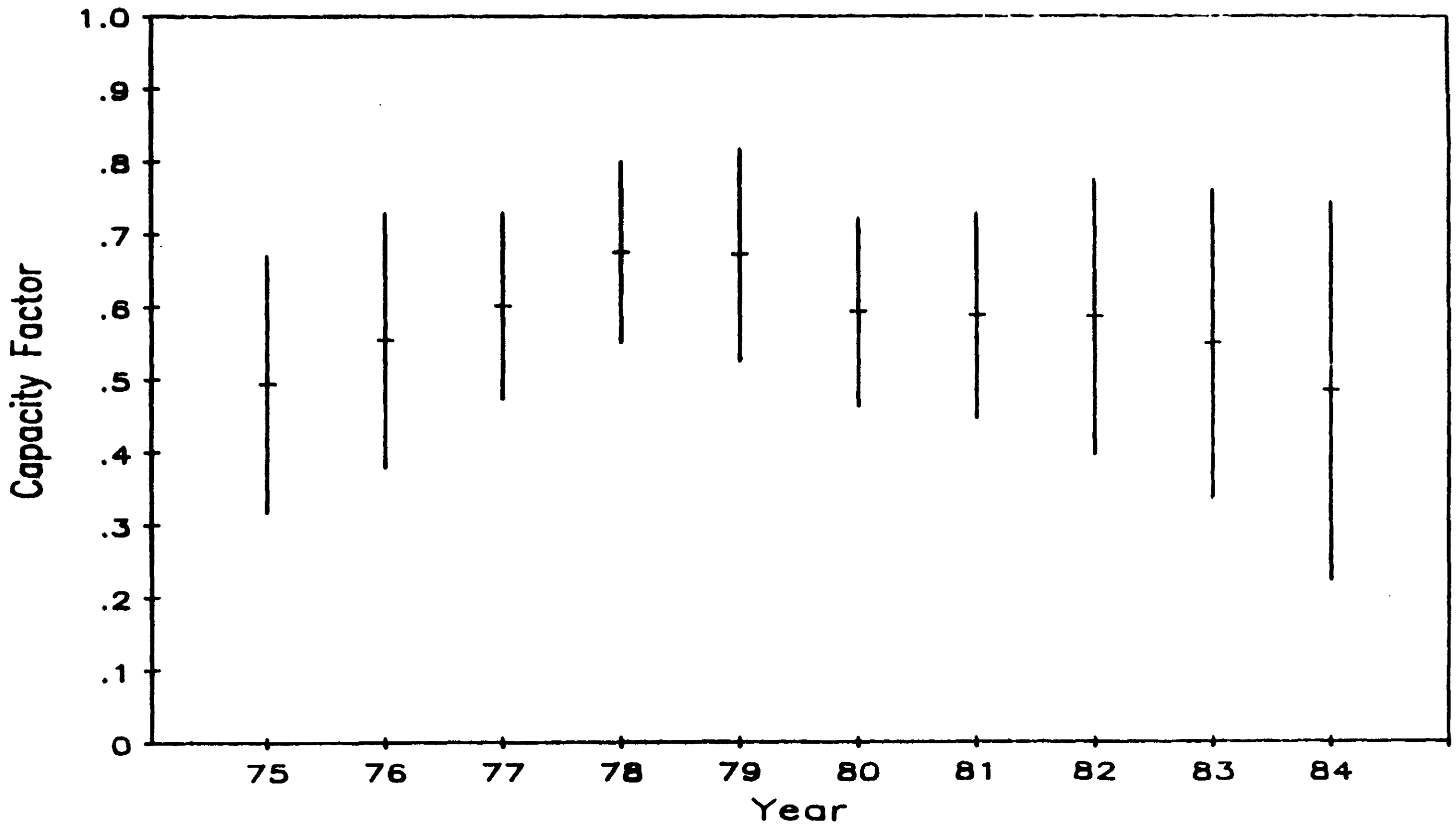


**Figure 2.46**
U.S. PWR Capacity Factor Distribution
By Reactor Age



## Figure 2.47
## U.S. BWR Capacity Factor Distribution By Year



# Figure 2.48

U.S. BWR Capacity Factor Distribution
By Reactor Age

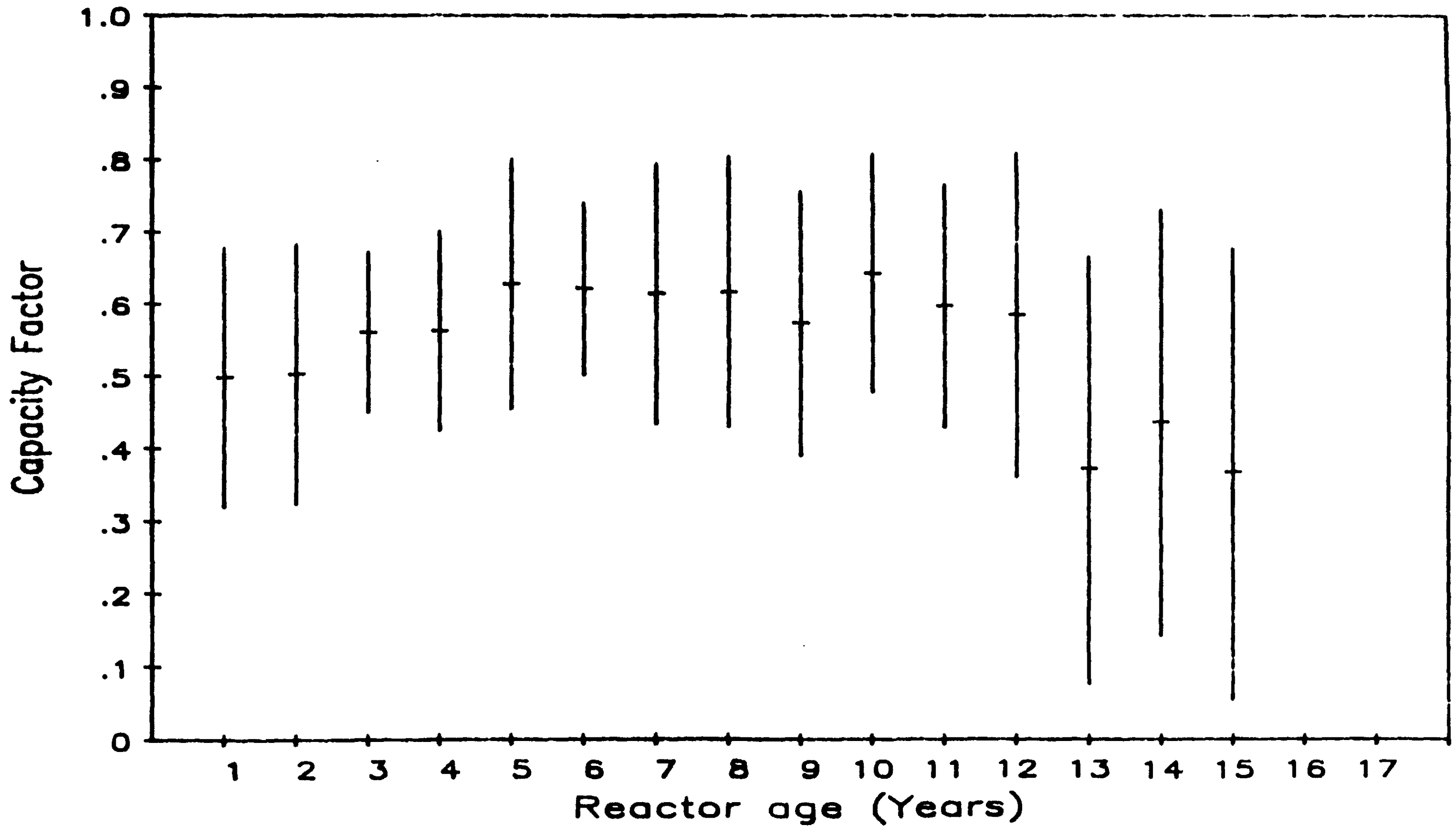
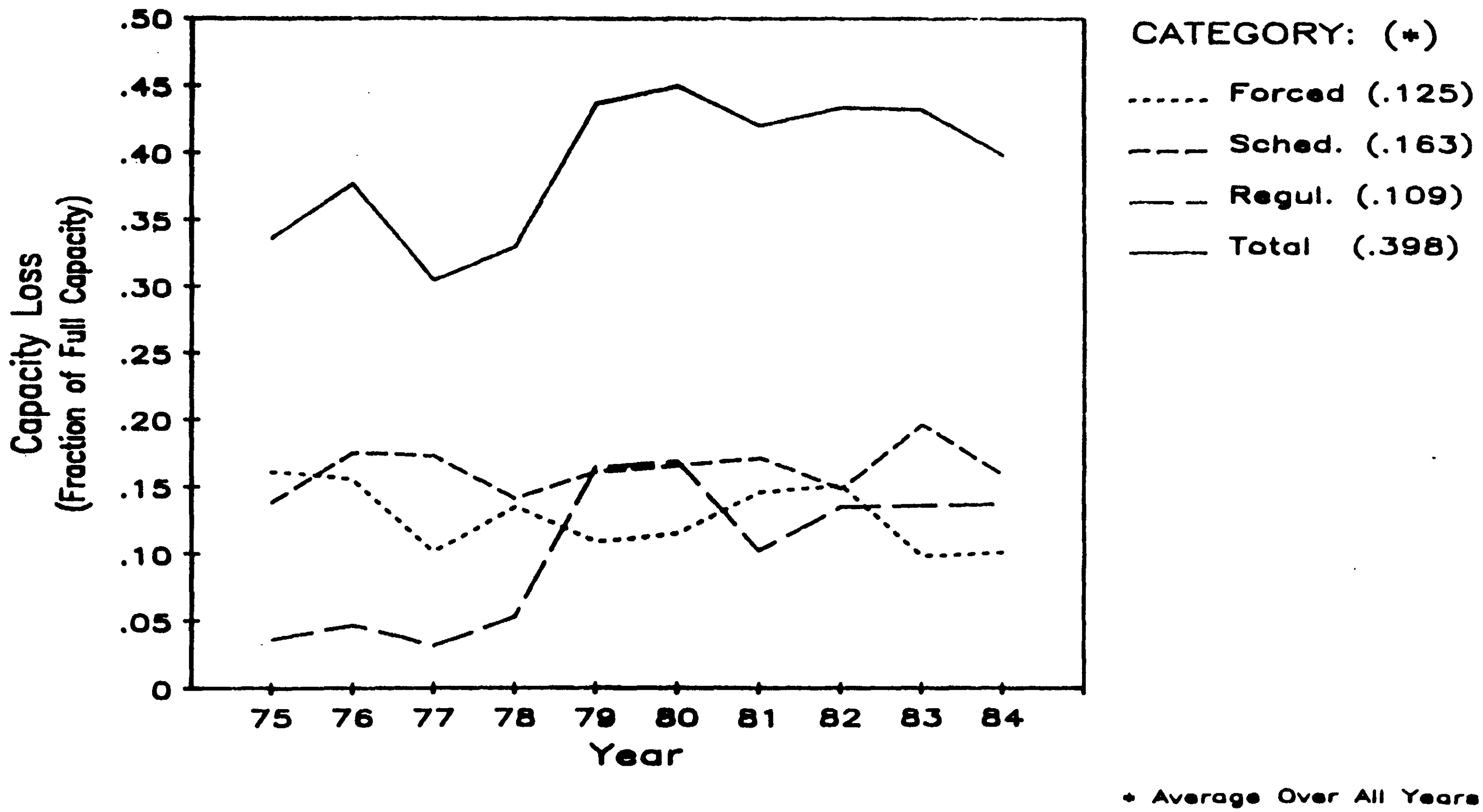


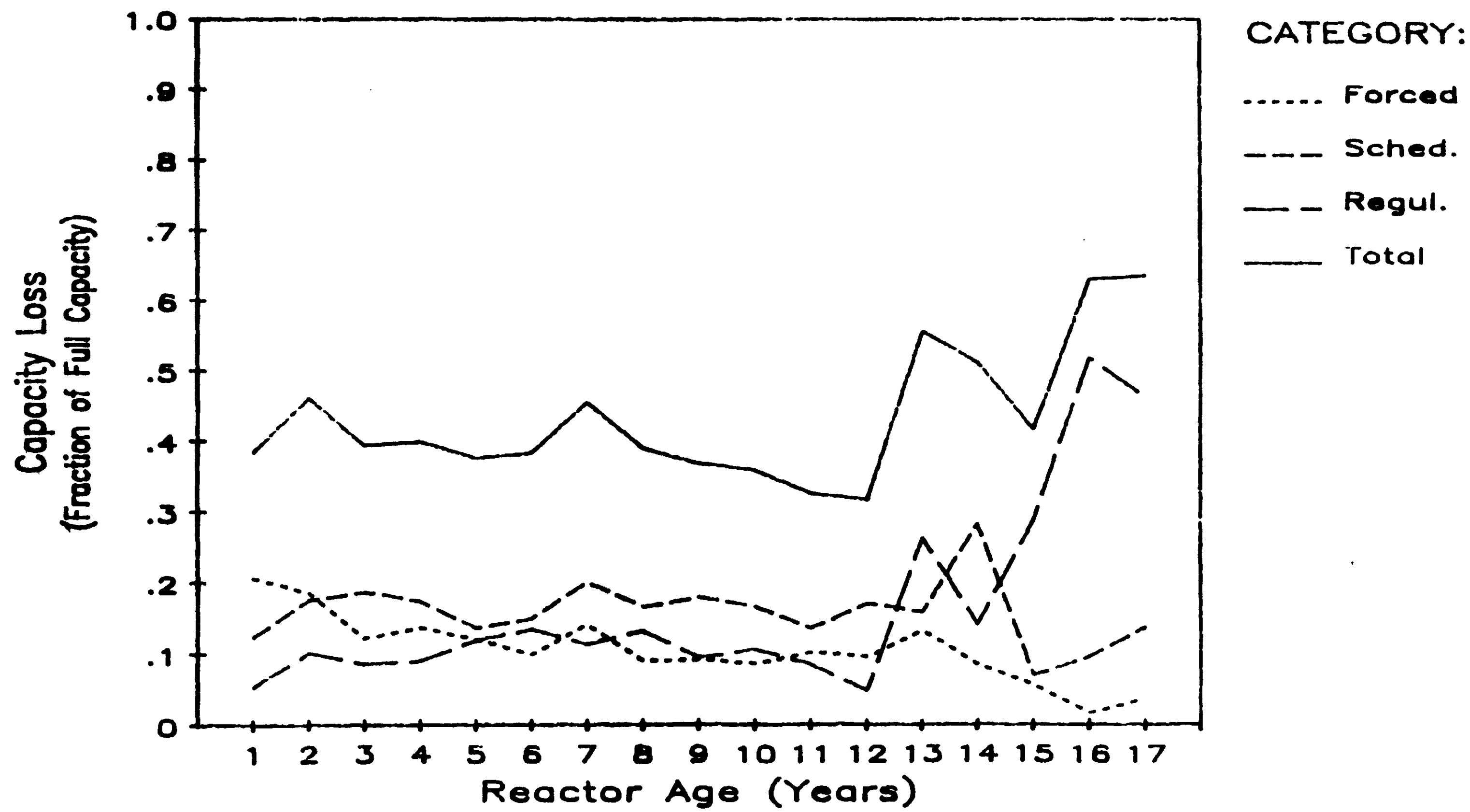
Figure 2.49

U.S. PWR Capacity Losses By Year
Forced, Scheduled, and Regulatory



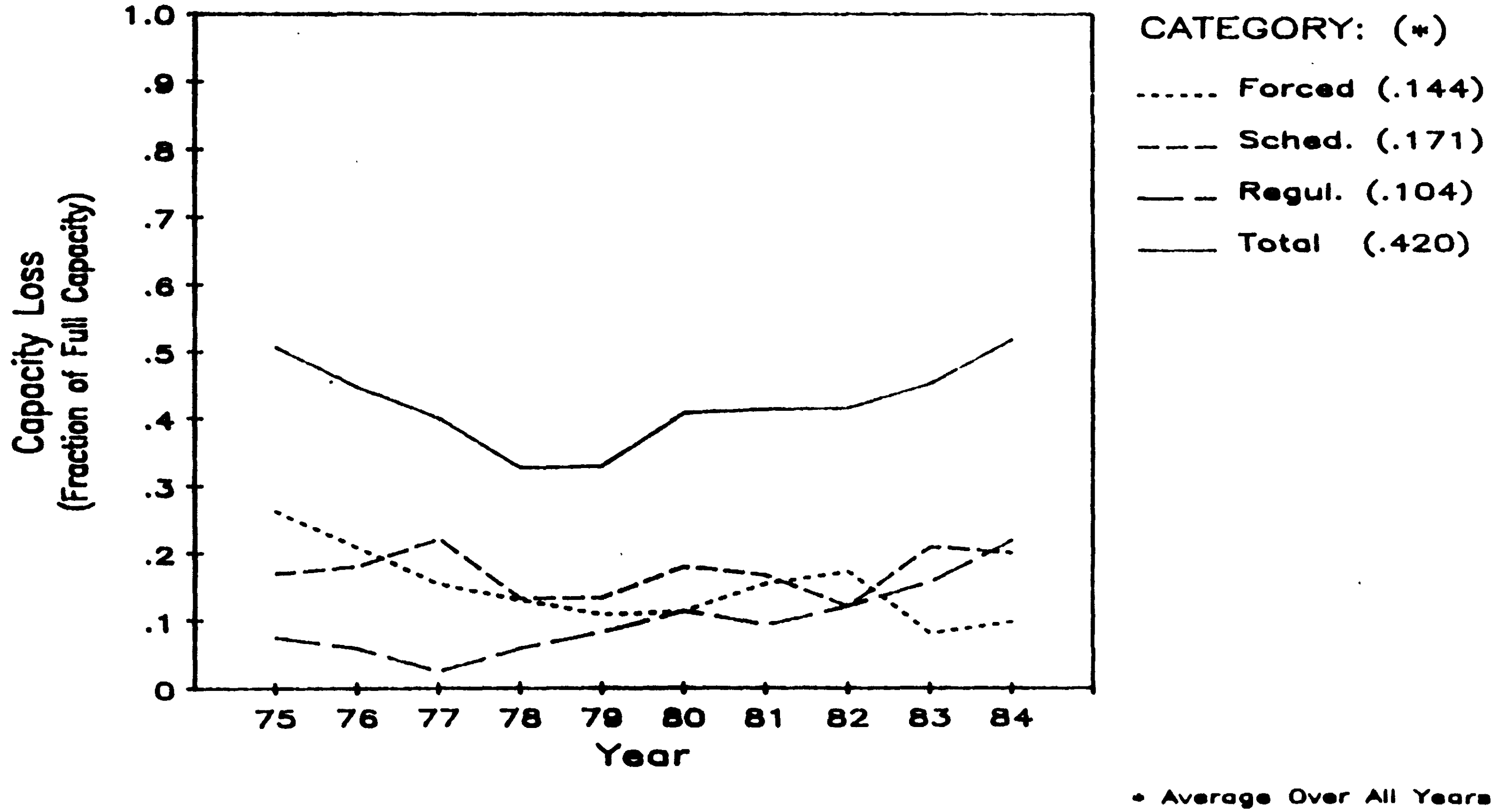
## Figure 2.50

U.S. PWR Capacity Losses By Reactor Age
Forced, Scheduled, and Regulatory



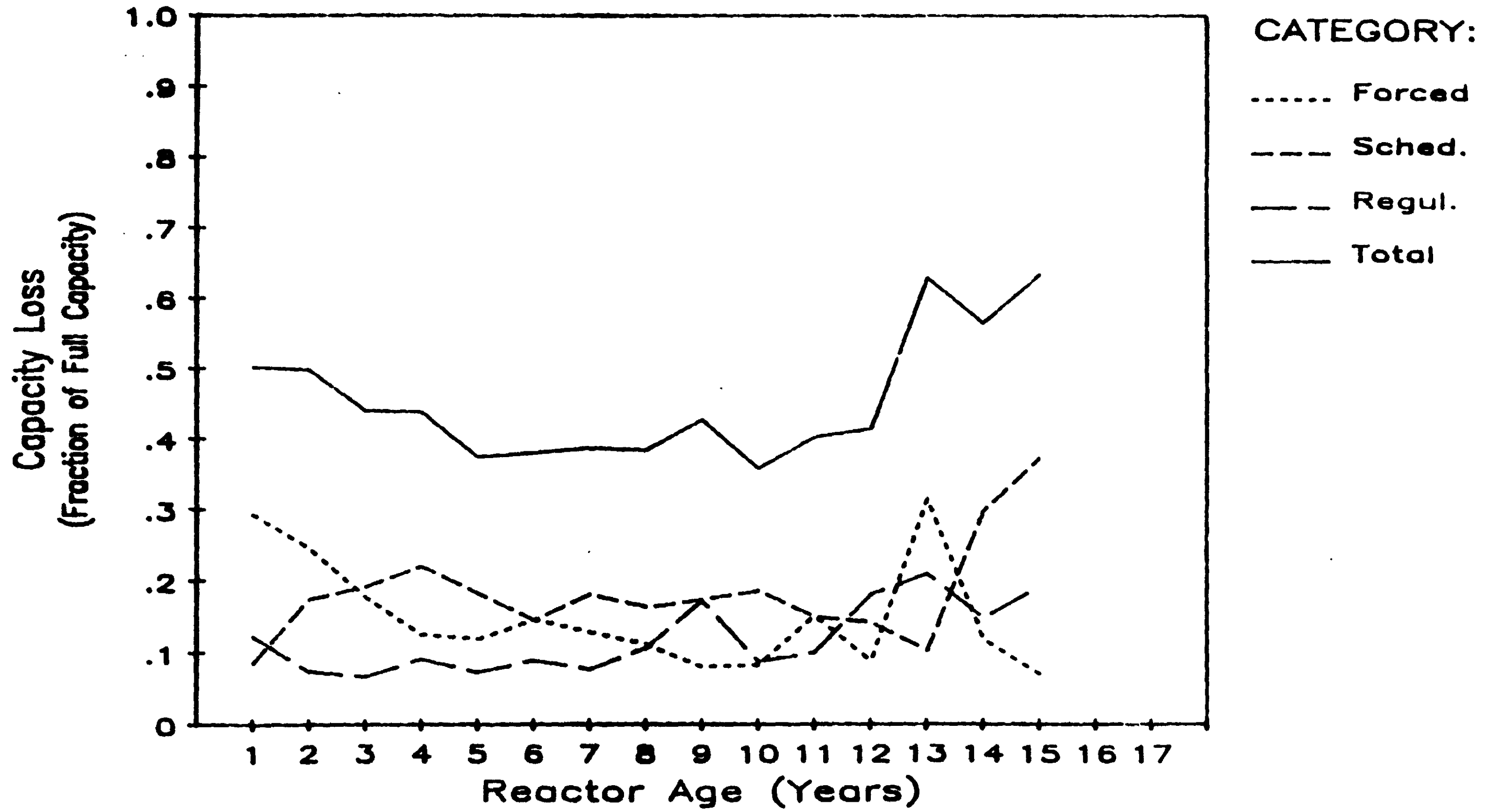
# Figure 2.51

## U.S. BWR Capacity Losses By Year
## Forced, Scheduled, and Regulatory



## Figure 2.52

U.S. BWR Capacity Losses By Reactor Age
Forced, Scheduled, and Regulatory



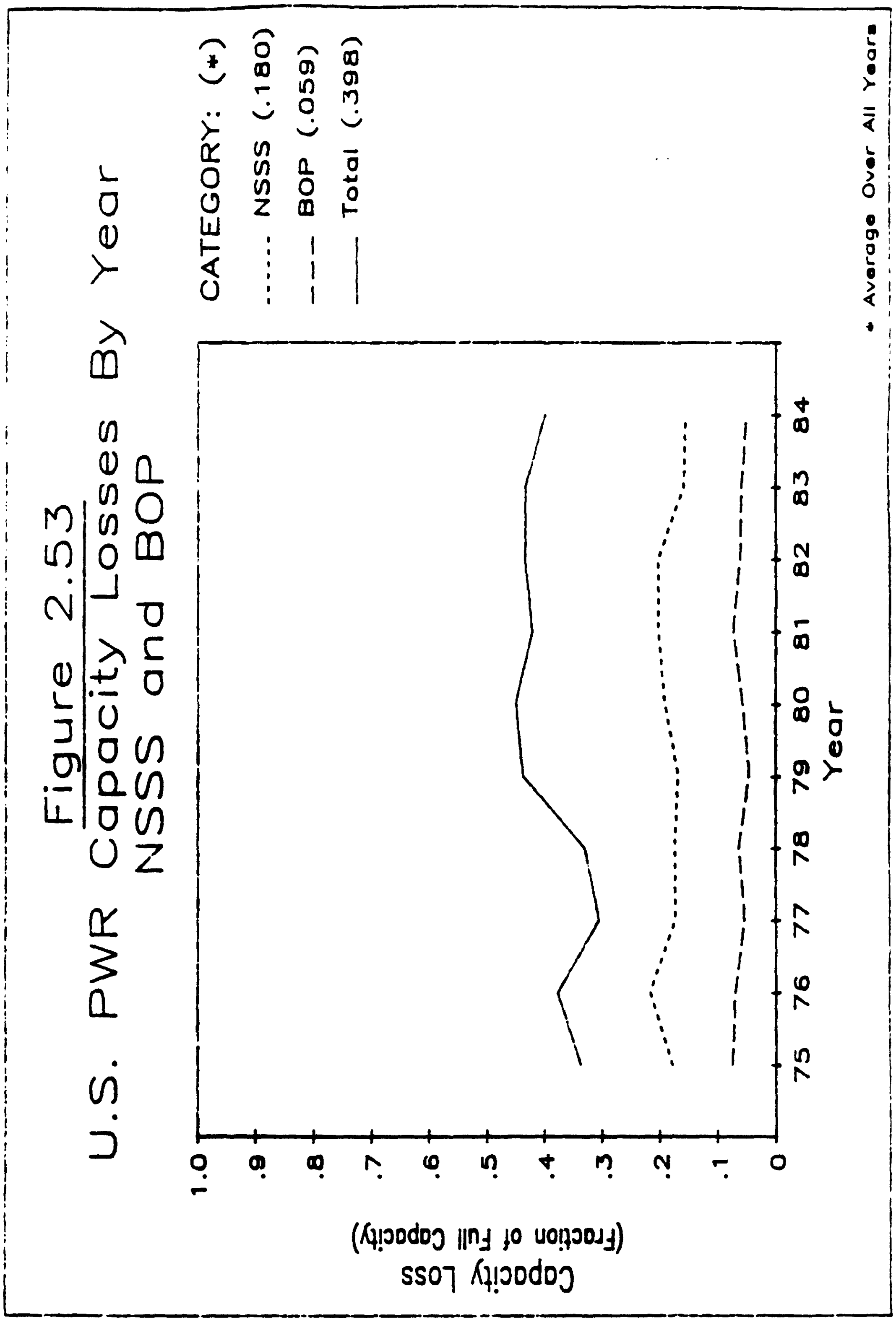
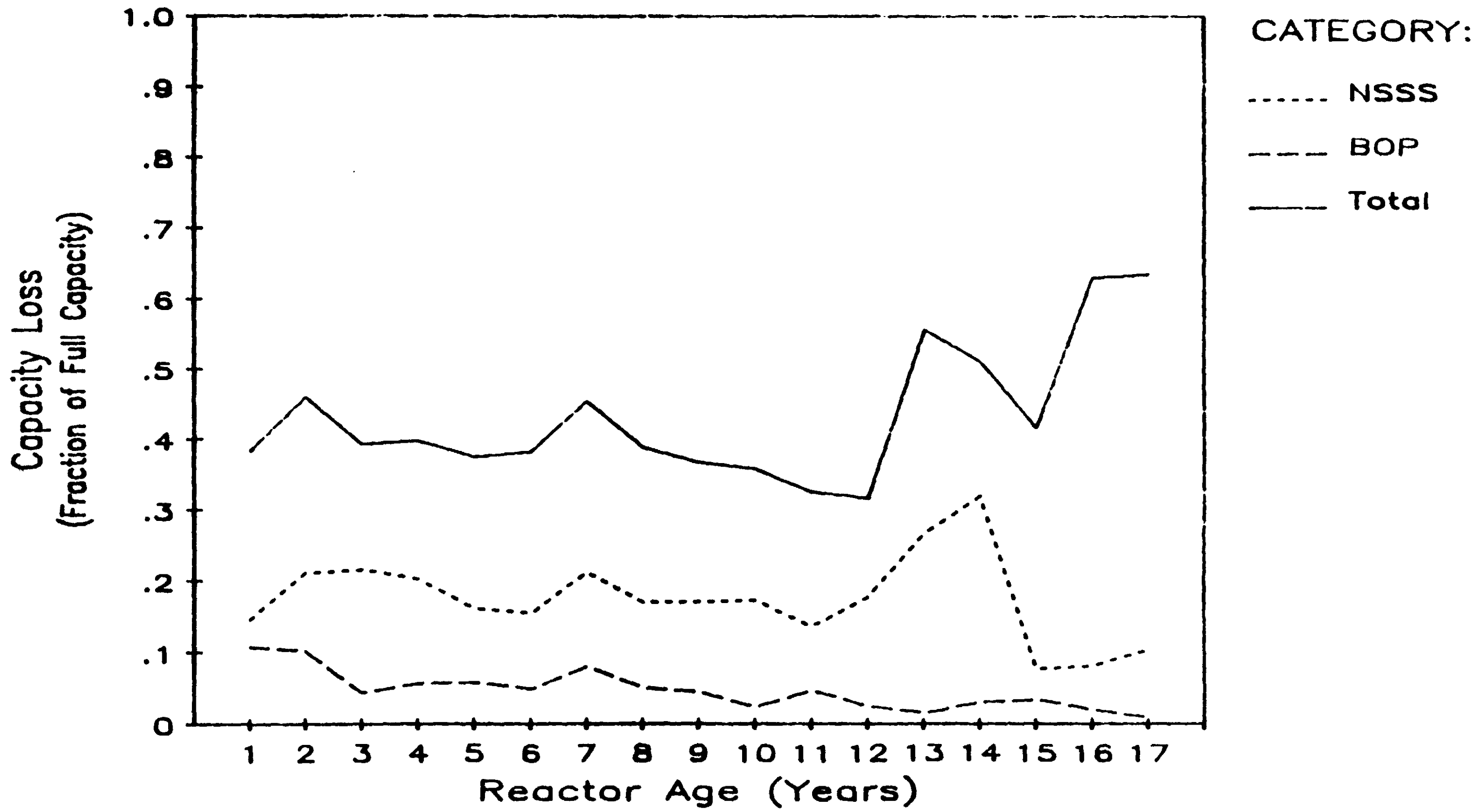



Figure 2.53
U.S. PWR Capacity Losses By Year
NSSS and BOP

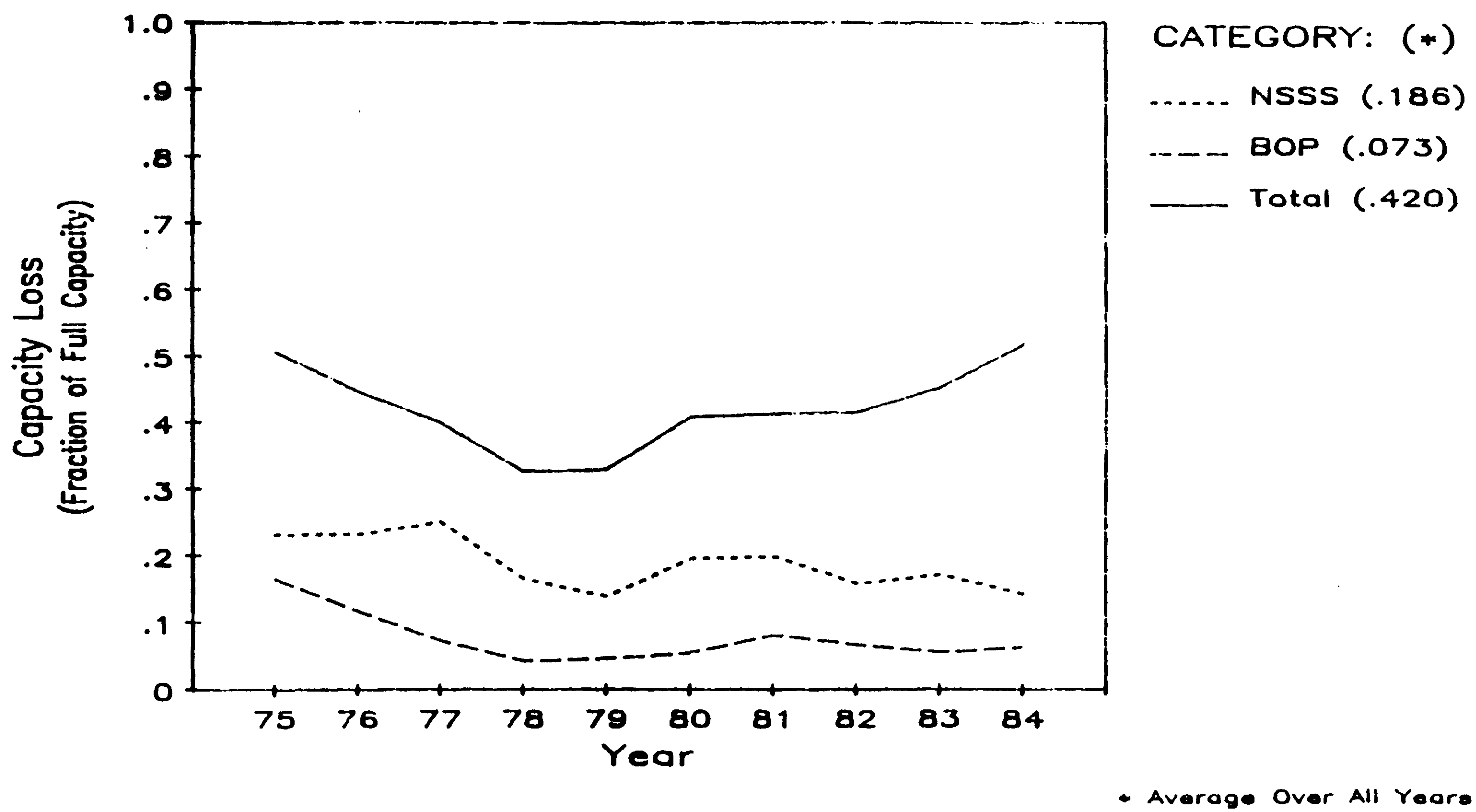
# Figure 2.54

U.S. PWR Capacity Losses By Reactor Age
NSSS and BOP



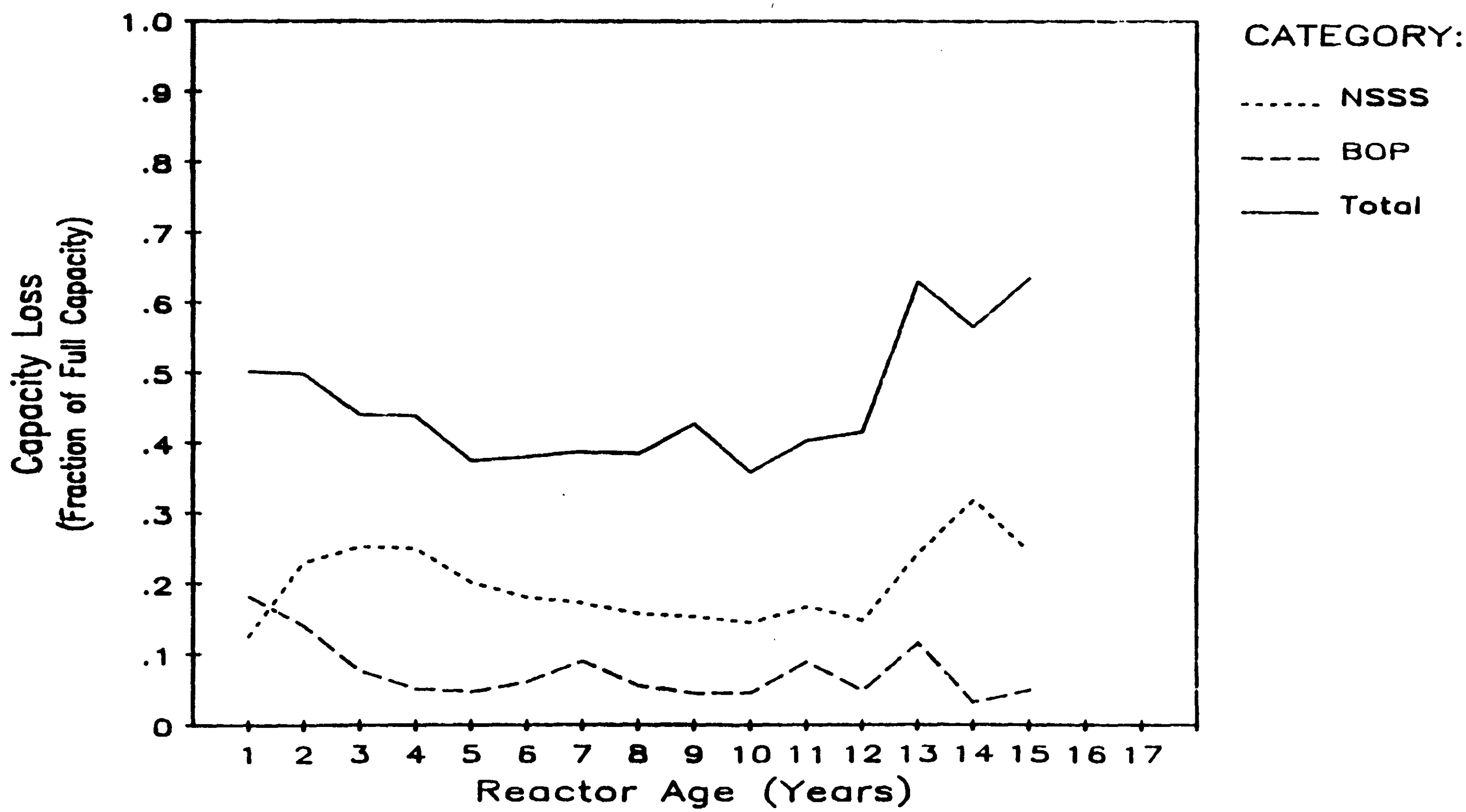
## Figure 2.55

U.S. BWR Capacity Losses By Year
NSSS and BOP



## Figure 2.56

U.S. BWR Capacity Losses By Reactor Age
NSSS and BOP



## 3.0 Performance Losses by Category

In this section the capacity factors and performance losses for each of the categories presented in Section 1.4.1 are compared for all of the countries. All comparisons were done as a function of calendar year and reactor age for both PWR's and BWR's. Some guidelines and notes to be used when making data comparisons and examining the figures in this report are given below. The guidelines presented in Section 2.0 should also be kept in mind. An understanding of the composition of the data for each country is also necessary to prevent misinterpretation of the data. Information on the data composition can be found in Section 1.4 and in Appendix C.

In the guidelines presented in Section 2.0, two tables were provided to aid in the determination of the statistical significance of the data. The tables contained the number of plants over which the data was averaged. These tables are reproduced as Tables 3.1 and 3.2 for convenience. Again, it is up to the reader to determine the statistical significance of trends and observations made in this report.

As mentioned in Section 1.4.4, two slightly dissimilar performance indices were used in this study, capacity and energy availability. Since energy availability eliminates the influence of economic and non-economic grid losses (externally caused losses), the actual performance of a plant may be less than what the energy availability

Table 3.1 - Number of Nuclear Plant Data Points by Year

| Country | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 |
|---|---|---|---|---|---|---|---|---|---|---|
| France | | | | | | | | | | |
| PWR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 19 | 24 |
| Germany | | | | | | | | | | |
| PWR | 3 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 7 |
| BWR | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 4 | 4 | 4 |
| Japan | | | | | | | | | | |
| PWR | 4 | 5 | 6 | 6 | 8 | 8 | 9 | 10 | 10 | 11 |
| BWR | 3 | 5 | 5 | 9 | 10 | 10 | 10 | 11 | 11 | 13 |
| Sweden | | | | | | | | | | |
| PWR | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 |
| BWR | 2 | 4 | 4 | 5 | 5 | 5 | 7 | 7 | 7 | 7 |
| Switzerland | | | | | | | | | | |
| PWR | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| BWR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| United States | | | | | | | | | | |
| PWR | 27 | 30 | 36 | 39 | 40 | 41 | 46 | 47 | 49 | 52 |
| BWR | 18 | 19 | 21 | 21 | 22 | 22 | 22 | 22 | 23 | 25 |

Table 3.2 - Number of Nuclear Plant Data Points by Rx Age

| Country | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| France | | | | | | | | | | | | | | | | | |
| PWR | 8 | 14 | 14 | 13 | 6 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Germany | | | | | | | | | | | | | | | | | |
| PWR | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 0 |
| BWR | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Japan | | | | | | | | | | | | | | | | | |
| PWR | 9 | 9 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| BWR | 11 | 10 | 10 | 9 | 10 | 9 | 5 | 5 | 5 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| Sweden | | | | | | | | | | | | | | | | | |
| PWR | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BWR | 5 | 6 | 6 | 6 | 5 | 5 | 5 | 4 | 4 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Switzerland | | | | | | | | | | | | | | | | | |
| PWR | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| BWR | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| United States | | | | | | | | | | | | | | | | | |
| PWR | 37 | 36 | 41 | 37 | 38 | 38 | 35 | 34 | 29 | 26 | 15 | 11 | 6 | 5 | 3 | 2 | 2 |
| BWR | 14 | 12 | 17 | 19 | 20 | 21 | 21 | 21 | 19 | 16 | 10 | 10 | 5 | 3 | 2 | 0 | 0 |

indicates. For the countries in which capacity was used, it can be assumed that the grid losses are small and the difference between capacity and energy availability negligible. However, in the countries where energy availability was used, the difference can be significant. There are two areas where this difference appears. The first is in the category of economic losses since this is the category where most of the grid losses are placed. The other is in the comparison of the capacity and availability factors which include the economic losses in their calculations. When comparing economic losses as well as capacity and energy availability factors, the index used for each country as well as the difference between the indices must be considered.

Another important item that needs to be addressed when making comparisons is the composition of the Swiss data. As discussed in Section 1.4.4, for two of the three Swiss PWR's the refueling maintenance losses were not included with the refueling losses but were placed in the appropriate systems or operations category. The result is that these categories are somewhat larger than they would be had all the refueling maintenance losses been placed under refueling losses. When examining the figures care must be taken not to misinterpret as a trend something that is a result of this discrepancy. The BWR data is not affected by this as the refueling maintenance losses were reported as refueling losses.

Most of the figures in this chapter are presented with the forced and scheduled losses combined. However, for France and Sweden disaggregate scheduled losses could not be obtained. Therefore, in figures where specific forced and scheduled categories are combined, the French and Swedish data will not appear.

## 3.1 Capacity Factors

In this section the capacity and energy availability factors are compared for the six countries. As mentioned above, the difference between capacity and energy availability must be kept in mind when comparing these figures. Since the overall performance of a nuclear plant is a complex composite comprised of the performances of the all systems in the plant, it is not easy to identify the causes of time or age dependencies. However, where possible, trends and their causes will be given.

*PWR* performance capacity factors are plotted by year in Figure 3.1. The Swiss have had the best PWR performance with an average capacity factor of 85.8%. The curve shows two periods of improvement: from 1975 to 1978, and from 1980 to 1985. The drop in 1980 occurred as a result of losses for a new plant just coming on in that year. The largest non-refueling loss contributor for the Swiss PWR's was the reactor coolant system with an average contribution of 23.9% of the total losses.

German PWR's have had good performance with an average energy availability factor of 78.2%. The figure shows that performance dropped 18 percentage points between 1975 and 1979 and then rebounded 15 points to nearly return to its 1975 level. This occurred as a result of larger refueling losses in those years. The biggest non-refueling contributor to German losses was the generator, representing an average of 1.0 percentage point or 4.6% of the total PWR losses.

Although very little data was available for the French PWR's, the data that was obtained shows that they have been increasing performance steeply from 1982 to 1984. During this period the average energy availability factor climbed from 63.1% to 81.6%, yielding an average of 73.1% over the three years. From 1982 to 1983 the improvement was caused by reductions in forced NSSS OTHER losses, while from 1983 to 1984 it was caused by reductions in scheduled losses. It should be remembered that the French load follow with their plants and so their capacity factor is lower, averaging 68.5% over the same three years. It is not possible to determine what the largest non-refueling loss was for French PWR's.

Japanese PWR performance, as the figure depicts, fluctuated from 1975 to 1979, with the low performance in 1979 the result of large refueling shutdowns for inspection and maintenance. These large losses for inspection and maintenance may have been the result of the Three Mile Island (TMI) accident that year. From 1979 to the present the Japanese PWR's have raised their performance from a low of 34.5% to a plateau of approximately 73% by reducing the length of their refueling outages for inspections and maintenance. The largest non-refueling loss contributor over the last ten years in the Japanese PWR's has been steam generator losses with a 10 year average of 1.6%, or 4.4% of the total losses.

The U.S. PWR performance has not been quite as high as the performance of the other countries from 1975 to 1984. The U.S. energy availability factors varied a few percentage points from 1975 to 1978, but dropped 10.7 points in 1979 as a result of the TMI accident. Performance has slowly started to increase since that year but has not yet reached its pre-TMI level. From 1980 to 1984, 3.5 to 5.0 percentage points of the U.S. losses can be directly attributed to the two out of service TMI units. The largest non-refueling contributor to U.S. losses from 1975 to 1984 was regulatory losses. The regulatory losses averaged 10.9%, representing 27.4% of the total U.S. PWR losses.

The only PWR's with a performance lower than those of the U.S. were Sweden's, with an average capacity factor of 54.4%. Swedish capacity factors from 1975 to 1980 are from only one PWR and vary as a result of several different losses. From 1981 to 1984 two more PWR's went into operation in Sweden. The average capacity factors in these years show a drop of 21.0 percentage points in 1981 and 1982 with performance returning to an even higher level by 1984. The causes for this decrease in performance were several large outages for regulatory losses and steam generator repairs. The regulatory losses may have actually been for steam generator problems, making steam generators responsible for the entire drop in performance.

In Figure 3.2, the PWR performance factors are plotted as a function of reactor age. Swiss PWR's show a period of increasing performance during the first five years which then levels out as the plants get older. The lower performance during the first five years was due to below average performance of a new plant that was the only contributor to ages 1 through 3.

German PWR's, with the second best performance record, show a slight improvement over age with approximately ± 5 percentage points of variation from year to year. However, this trend is probably not significant because of its small magnitude and the low number of plants at each age.

The French reactor performance as a function of age displays fluctuation from year to year with no age dependency apparent.

The Japanese PWR's show no age dependency.

U.S. PWR performance improves slightly through age 12, after which it decreases. The slow improvement over the first 12 years is too small to accurately be identified.

The decrease and fluctuation after age 12 is primarily from large regulatory losses at the plants that make up those ages.

The Swedish losses also show a slight age dependence with performance increasing with age. However, the number of plants contributing to this data is small and such a trend may not have any significance.

*BWR* performance losses are plotted over time in Figure 3.3. Switzerland's only BWR clearly has the best performance, operating with an average capacity factor of 88.0%. The curve shows a small but steady improvement over the ten year period. The improvement exhibited was a result of decreasing turbine and economic losses.

Swedish BWR's have the second best performance with an average capacity factor of 71.9%. Substantial improvement over time is visible with the capacity factor increasing from below 60% to over 70%. The cause of this improvement was the reduction of forced balance of plant losses. Further identification of the cause is not possible.

The Japanese BWR's follow the Swedish plants in performance with an average capacity factor of 61.0%. Performance fluctuated greatly prior to 1978 as a result of large variations in refueling losses. From 1978 on, performance has continually improved, increasing from 50% in 1978 to 72% in 1984. Most of this improvement was from reductions in refueling outage losses.

The U.S. is next with an average BWR energy availability of 58.0% The curve shows a peak of 67% in 1978 and 1979 with performance falling off to less than 50% on both sides of the peak. Prior to 1978, the increase in performance was caused by decreased losses in several systems including OTHER BOP. The decline after 1979 was the result of substantial increases in regulatory losses.

The German BWR performance has been the lowest with an average energy availability factor of 51.1%. The plot of performance over time shows a steep drop of 58 percentage points from 1975 to 1979, and then a steep climb back to an energy availability of 79%. The cause of this large drop was RCS pipe replacements made under the Basis Safety Concept and some large regulatory outages. No time dependence is apparent in the German BWR performance.

Figure 3.4 plots the BWR performance by reactor age. The Swiss plant shows a small increase in performance with age as this curve duplicates the one in the previous figure. Swedish BWR performance exhibits an age dependency with performance increasing with age. The cause for the improvement is difficult to pinpoint, but examination of the data indicates that reductions in several areas contributed, including forced BOP losses. Japanese performance fluctuates, showing a slight age dependency with performance decreasing. This trend may be insignificant because of the small magnitude of the trend and the fluctuation present. U.S. BWR performance plotted over age does not display any consistent age dependency, however, there is a period of improvement during the first few years. The drop in performance after age 12 is from large steam generator and regulatory losses at only a couple of plants. Finally, German performance as a function of age shows large variations as a result of the pipe replacements that were time, not age dependent.

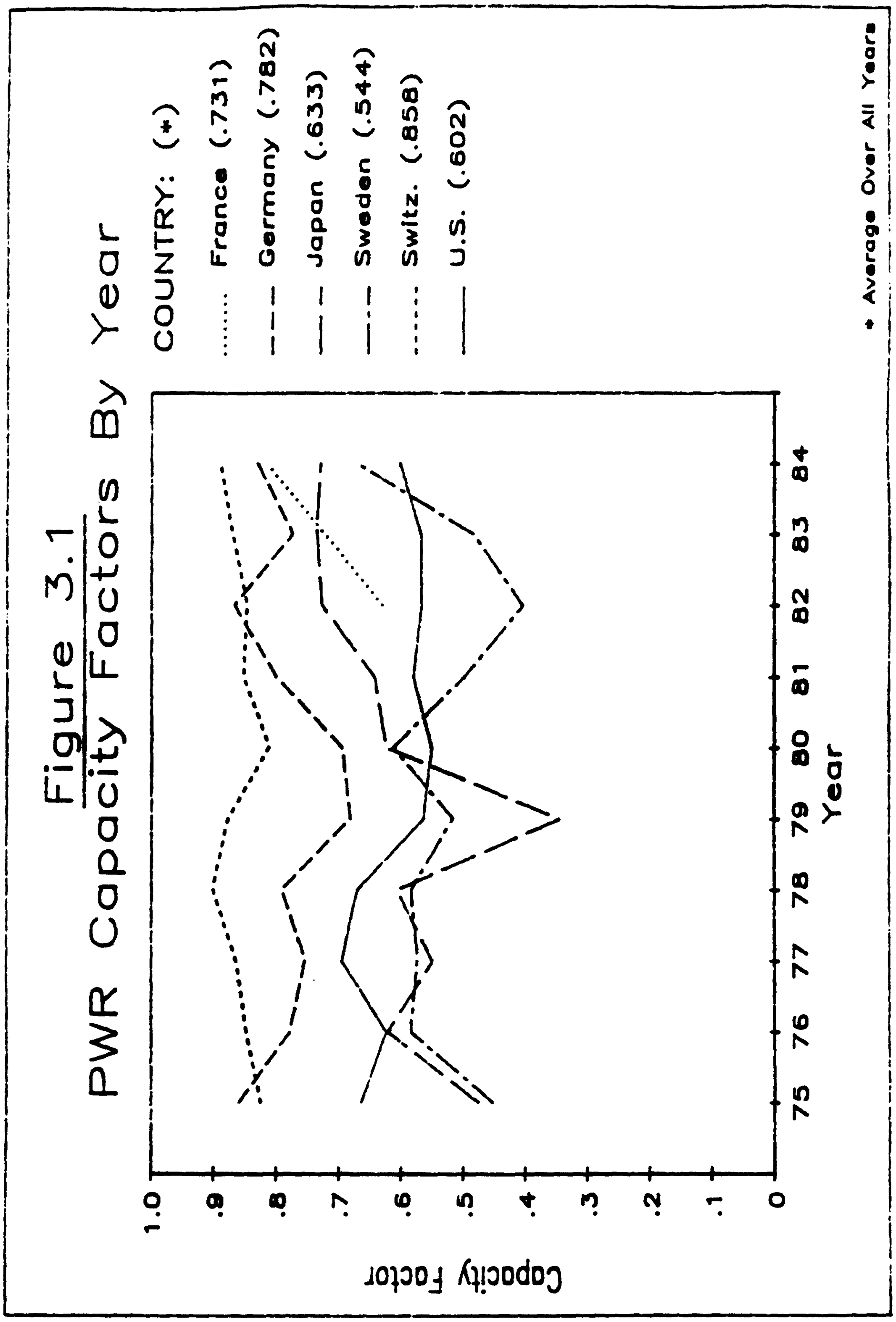



Figure 3.1
PWR Capacity Factors By Year

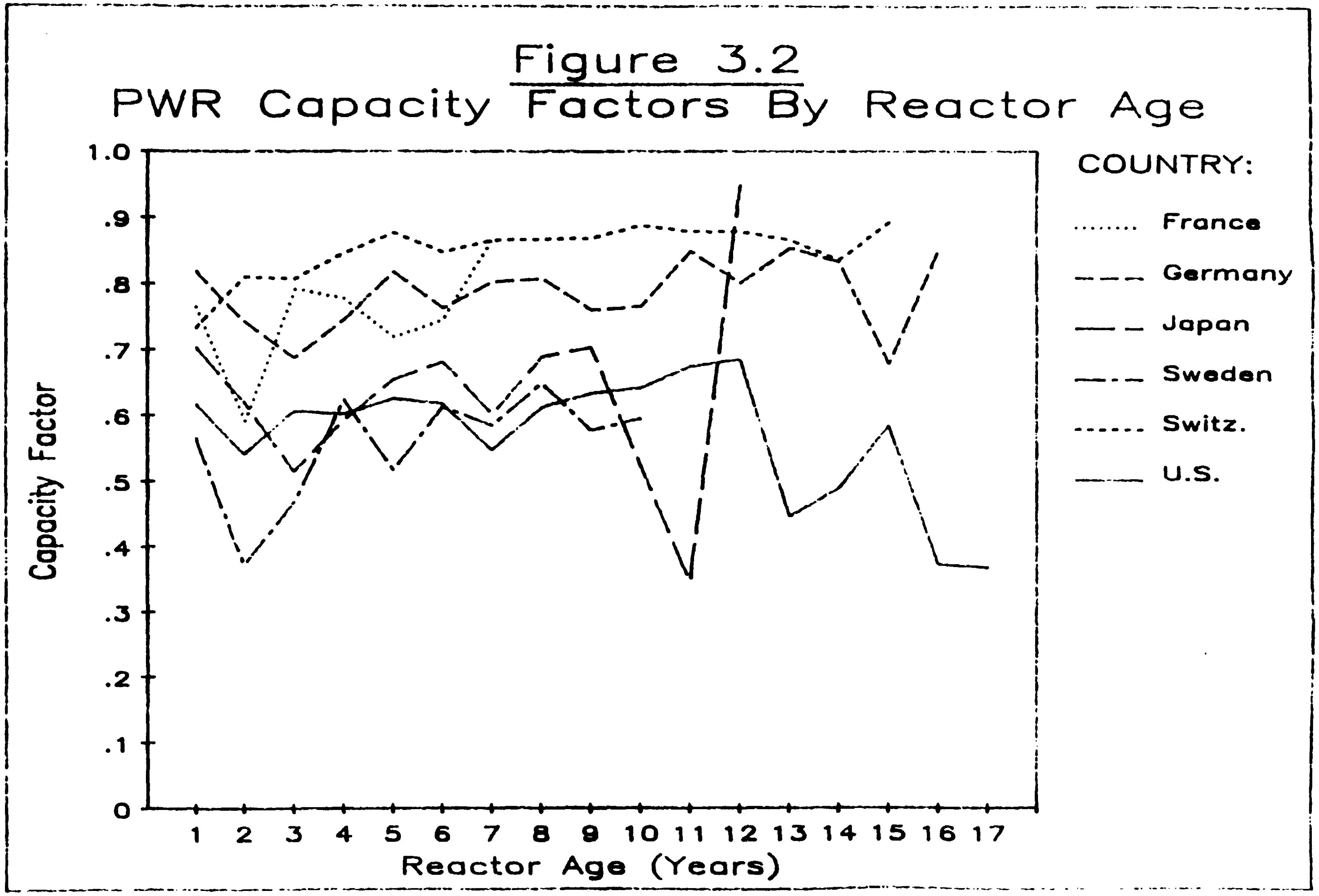
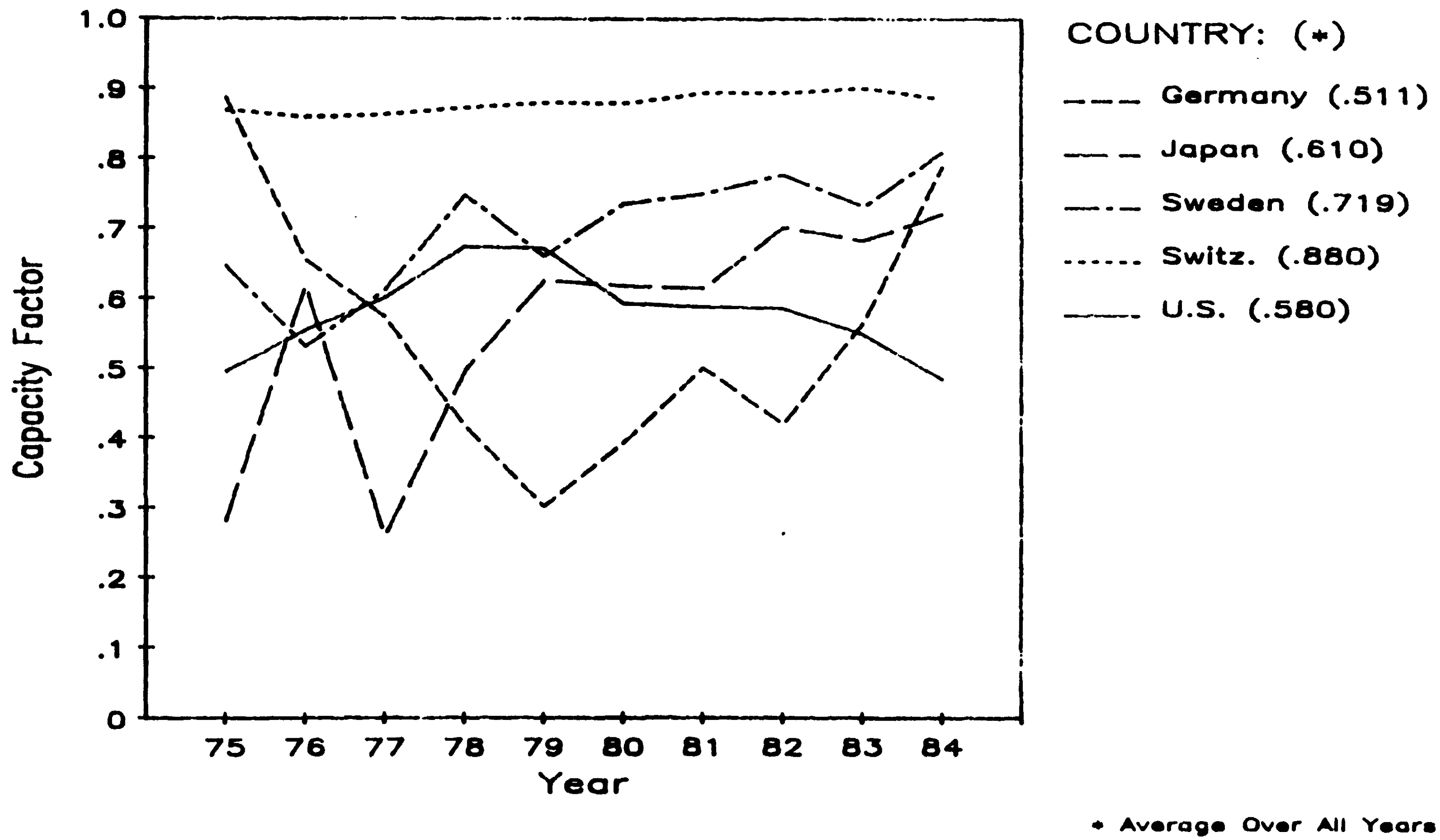
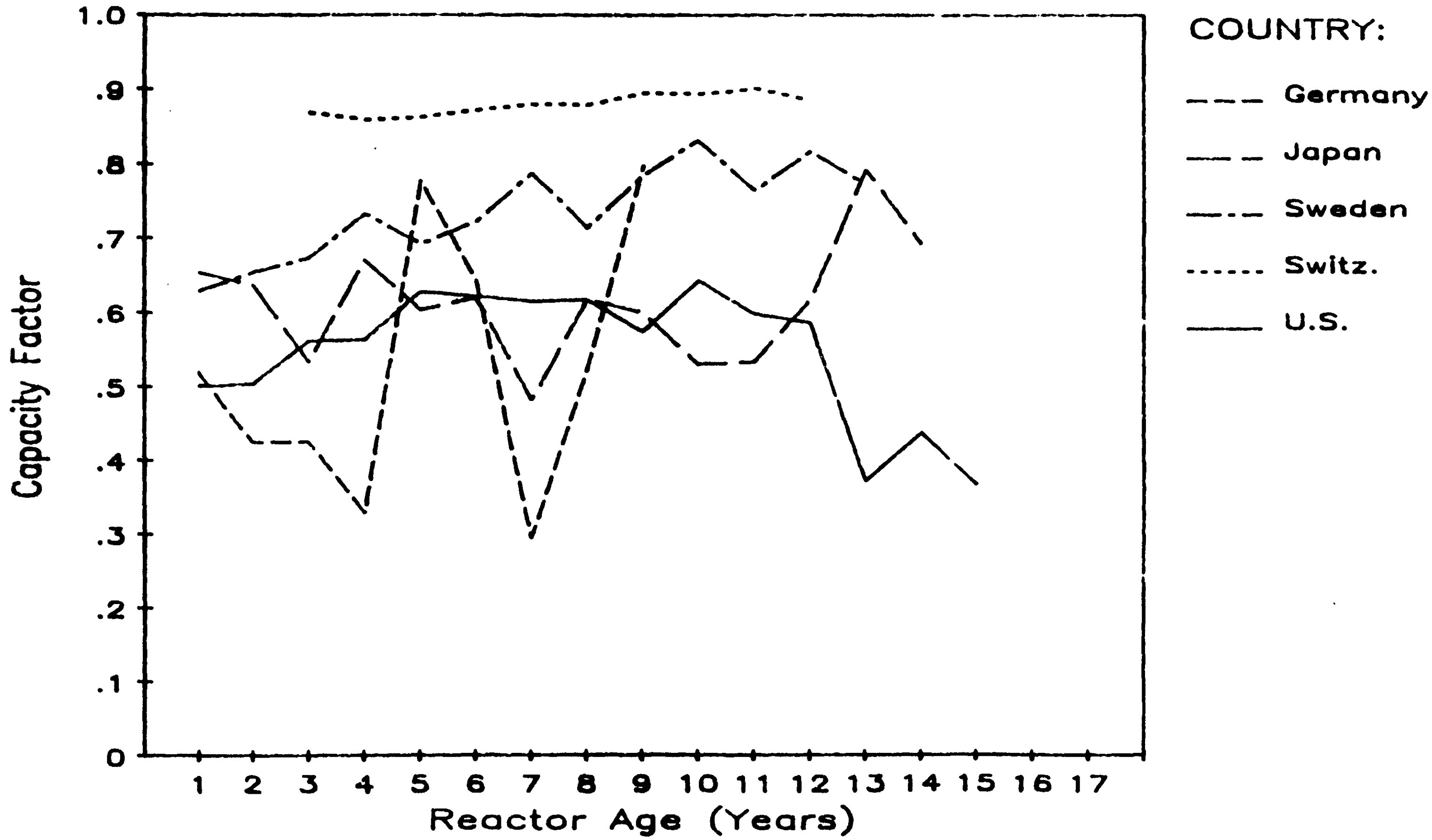


Figure 3.2
PWR Capacity Factors By Reactor Age
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Capacity Factor
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Reactor Age (Years)
COUNTRY:
France
Germany
Japan
Sweden
Switz.
U.S.

## Figure 3.3
## BWR Capacity Factors By Year



## Figure 3.4
## BWR Capacity Factors By Reactor Age



## 3.2 Nuclear Steam Supply System (NSSS)

In this section the Nuclear Steam Supply System losses are presented and compared for Germany, Japan, Switzerland, and the United States. Losses for France and Sweden could not be compared because they were not available in sufficient detail. The total NSSS losses are compared first, followed by fuel, reactor cooling system, steam generator, and refueling losses. PWR's and BWR's will be discussed separately in each category.

### 3.2.1 Total NSSS

*PWR* Nuclear Steam Supply System losses are plotted by year in Figure 3.5. All the countries have relatively constant NSSS losses except for Japan, which shows fluctuation prior to 1980. The Japanese losses were the largest with an average of 34.6% attributable to the NSSS. Beginning in 1980 the NSSS losses decreased over time. The high losses resulted from mandatory inspection and testing requirements that require the plant to shutdown for long refuelings. These extended refuelings made up over 93% of Japanese NSSS losses. The decline after 1980 was the result of reductions in refueling losses. The second largest contributor to the Japanese PWR NSSS losses was steam generators with 4.6% of the total NSSS loss. The U.S. was behind Japan with an average PWR NSSS loss of 18.0%. Refueling was the largest loss component, contributing 59.4% of the total NSSS loss, while the reactor coolant system and steam generators contributed 18.3% and 13.9% respectively. German PWR NSSS losses were almost as high as the U.S. with an average of 17.2%. Refueling was the highest contributor with 88.4% of the loss. Reactor cooling system losses made up another 4.7% of the total NSSS loss. The Swiss PWR NSSS losses were the smallest of all the countries with an average of only 11.0%. The largest fraction of this loss was refueling at 42.7% of the loss with the reactor cooling system contributing 30.9%. The true contribution of refueling is larger since four-fifths of the maintenance work done during refueling was not reported in the refueling losses. The Swiss curve shows two periods of declining losses from 1975 to 1978 and from 1980 to 1984. No specific system was responsible for the trends. The peak in 1980 was caused by increases in several categories, partially as a result of a new plant going online.

The NSSS losses are plotted by reactor age in Figure 3.6. The losses, while relatively constant, show slightly more fluctuation than those in Figure 3.5. The Swiss data appears to show an age dependency but this is due to the refueling discrepancy mentioned above.

*BWR* Nuclear Steam Supply System losses are illustrated in Figure 3.7. This figure depicts more variation in losses than existed in the PWR data. This is particularly apparent for Germany and Japan where there were large peaks in several years. The Japanese BWR NSSS losses were the highest with an average of 34.8%, which is nearly equal to the average for PWR's. The largest contributor to the loss was refueling with 95.1%. Fuel losses were the second largest contributors with 3.7%. From 1978 to 1984 the Japanese NSSS losses declined from 45.4% to 27.2% as a result of a similar decline in refueling losses. The German BWR NSSS losses were almost as high as the Japanese with an average of 32.2%. Refueling losses accounted for 36.6% while reactor coolant system losses were 54.3% of the total NSSS loss. The higher contribution of the RCS was the result of the Basis Safety Concept, discussed in Appendix C. U.S. BWR NSSS losses average 18.6%, which is slightly more than that for PWR's. Approximately 48.9% of these losses were attributed to refueling while another 24.2% of the total NSSS loss was assigned to the RCS. The U.S. NSSS losses show slight improvement over time, as a result of the drop in fuel losses which is discussed below in Section 3.2.2. The Swiss again had the smallest average NSSS losses averaging 9.4% with their only BWR. Refueling was the largest component of the NSSS loss with 93.6% of the total. The remainder of the NSSS losses were contributed by the RCS. Swiss NSSS losses have remained relatively constant over time.

The BWR NSSS losses are shown graphically as a function of reactor age in Figure 3.8. Similar to the PWR's NSSS losses in Figure 3.6, the BWR losses exhibit more variation by age than by year. Only the Swiss and the U.S. show any consistency by age. The U.S. BWR's exhibit a trend towards slightly less NSSS losses with age. This occurred as a result of reduced losses in several categories. The peak at ages 13 to 15 is from high RCS losses at several plants during those ages. The Swiss losses are identical to those in Figure 3.7.

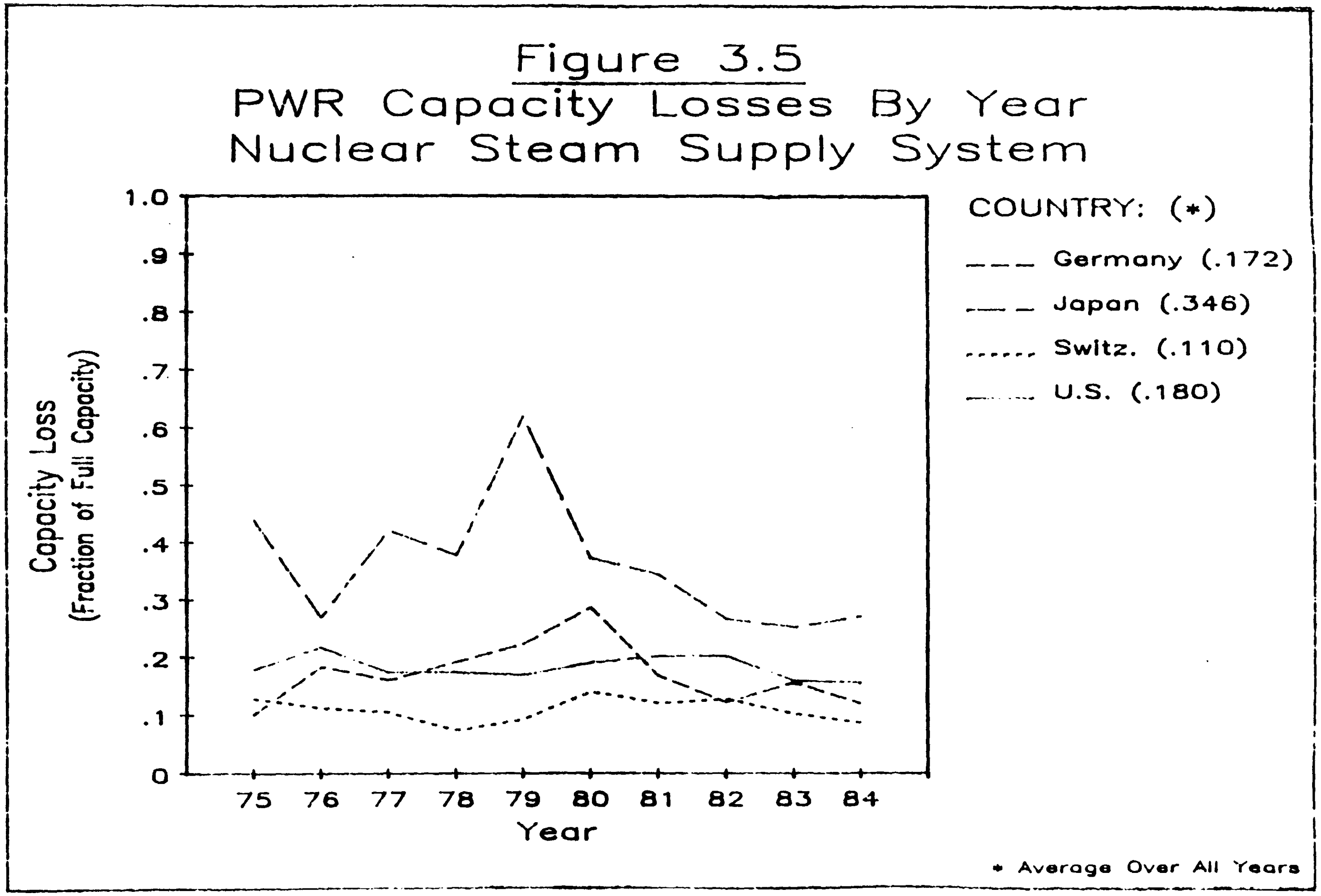
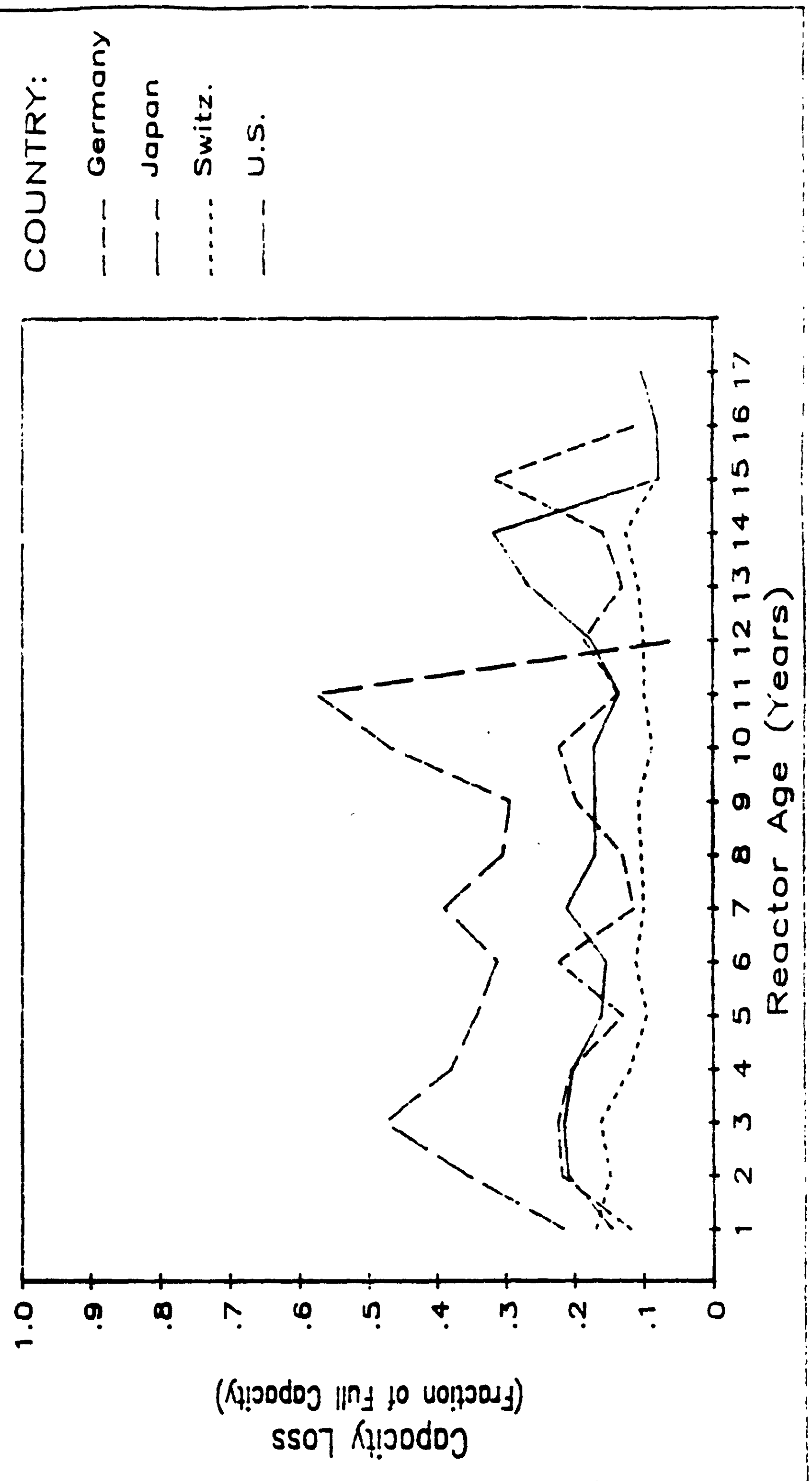
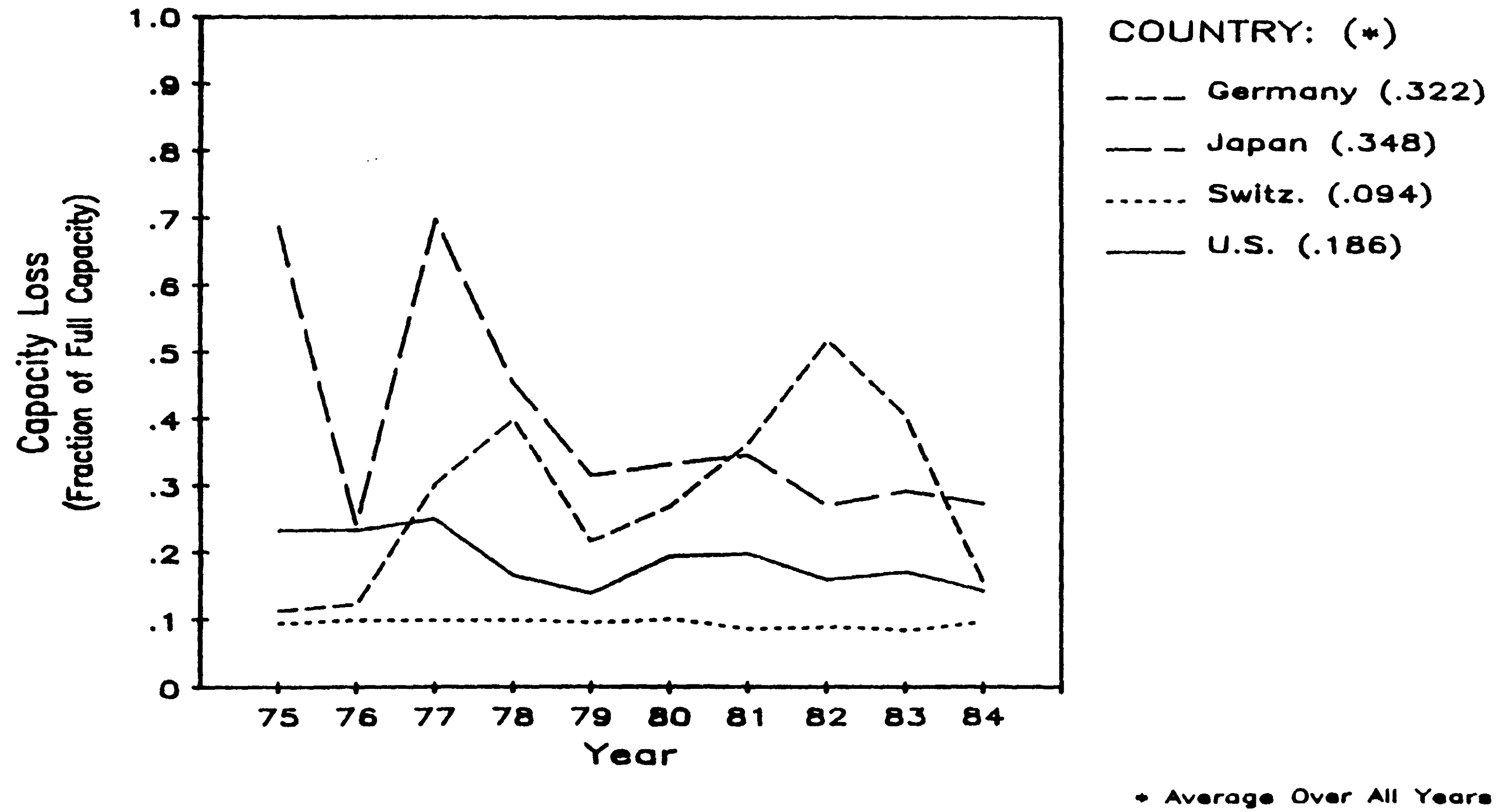


Figure 3.5
PWR Capacity Losses By Year
Nuclear Steam Supply System
Capacity Loss
(Fraction of Full Capacity)
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
75
76
77
78
79
80
81
82
83
84
Year
COUNTRY: (*)
Germany (.172)
Japan (.346)
Switz. (.110)
U.S. (.180)
* Average Over All Years

Figure 3.6
PWR Capacity Losses By Reactor Age
Nuclear Steam Supply System

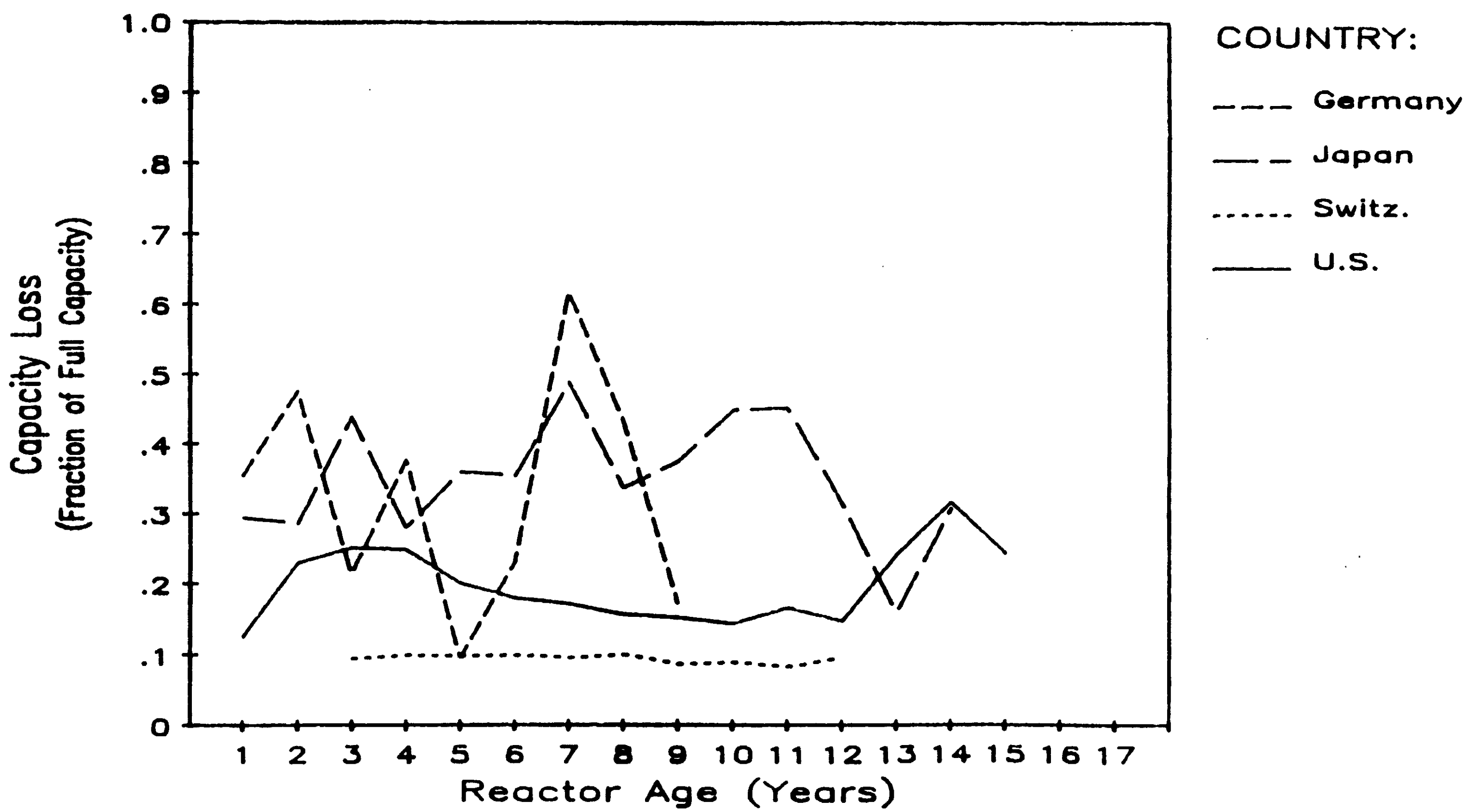


## Figure 3.7
## BWR Capacity Losses By Year
## Nuclear Steam Supply System



## Figure 3.8

BWR Capacity Losses By Reactor Age
Nuclear Steam Supply System



### 3.2.2 Fuel

*PWR* fuel losses are shown over time in Figure 3.9. Fuel losses in general have been very small, under 1.0%. There are no trends visible for any country. The German losses are all centered around 1979 and result from losses at a single plant in each year. The Japanese show an insignificant peak in 1976 which is due to an outage at one plant. The Swiss PWR's show losses starting in 1980, peaking in 1982 and falling off to zero in 1984. All the Swiss fuel losses are from the same plant each year and occurred over the first three years of operation. Since fuel cycles are generally one year in length, with three years needed to completely burn the first batch of fuel, the Swiss fuel problems appear to have occurred only in the initial batch of fuel at one of the three PWR's. This is not representative of all PWR's as the other two plants have run without problems since 1969 and 1972 respectively. Fuel losses in the U.S. BWR's have been negligible with the only discernable losses in 1975 and 1979.

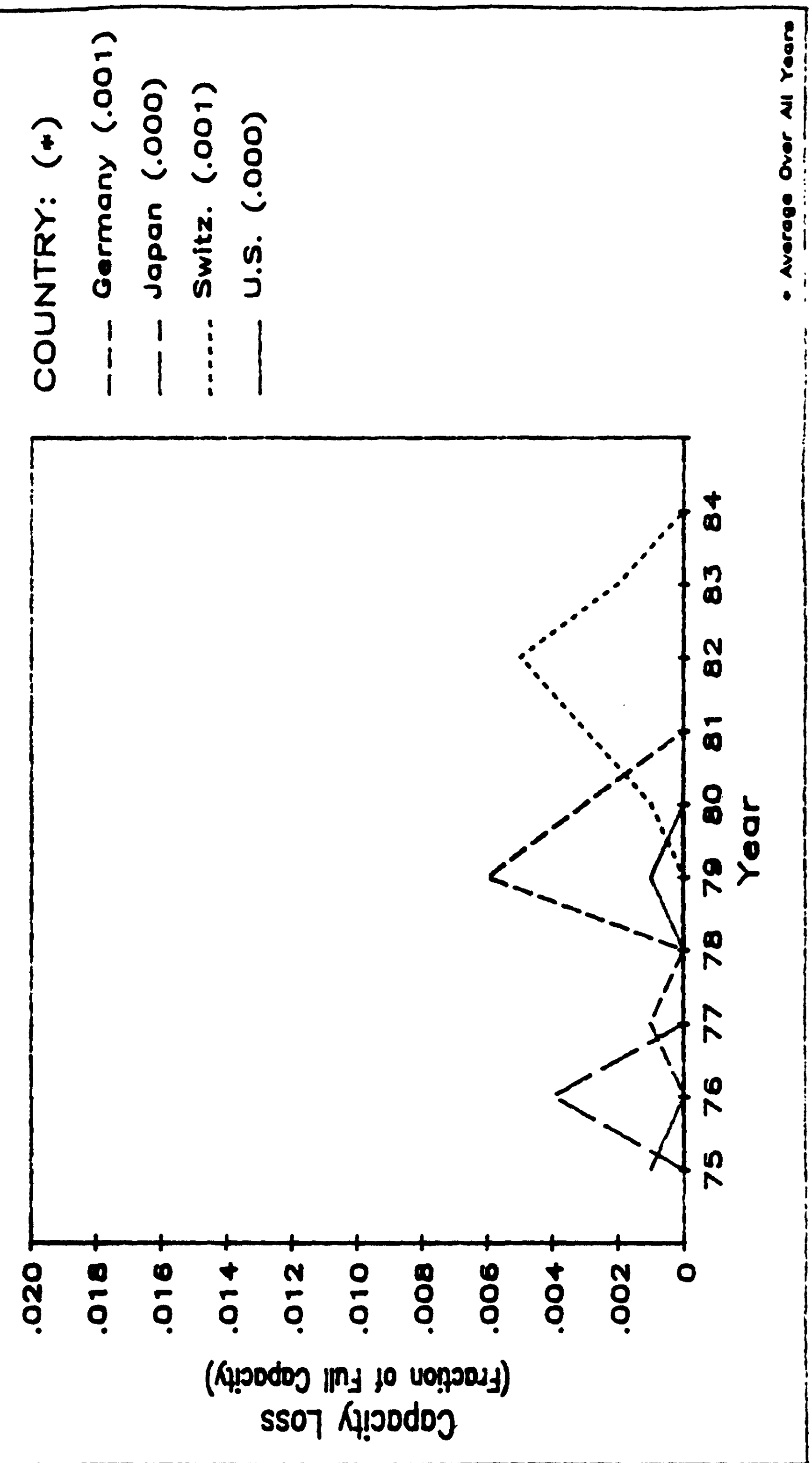
PWR Fuel losses as a function of reactor age are not plotted since the fuel is cycled through the core every three years. Any age dependency exhibited would have little meaning.

*BWR* fuel losses, shown in Figure 3.10, are generally much larger than PWR fuel losses. German and Swiss BWR's have had no reported fuel losses since 1975. The U.S. and

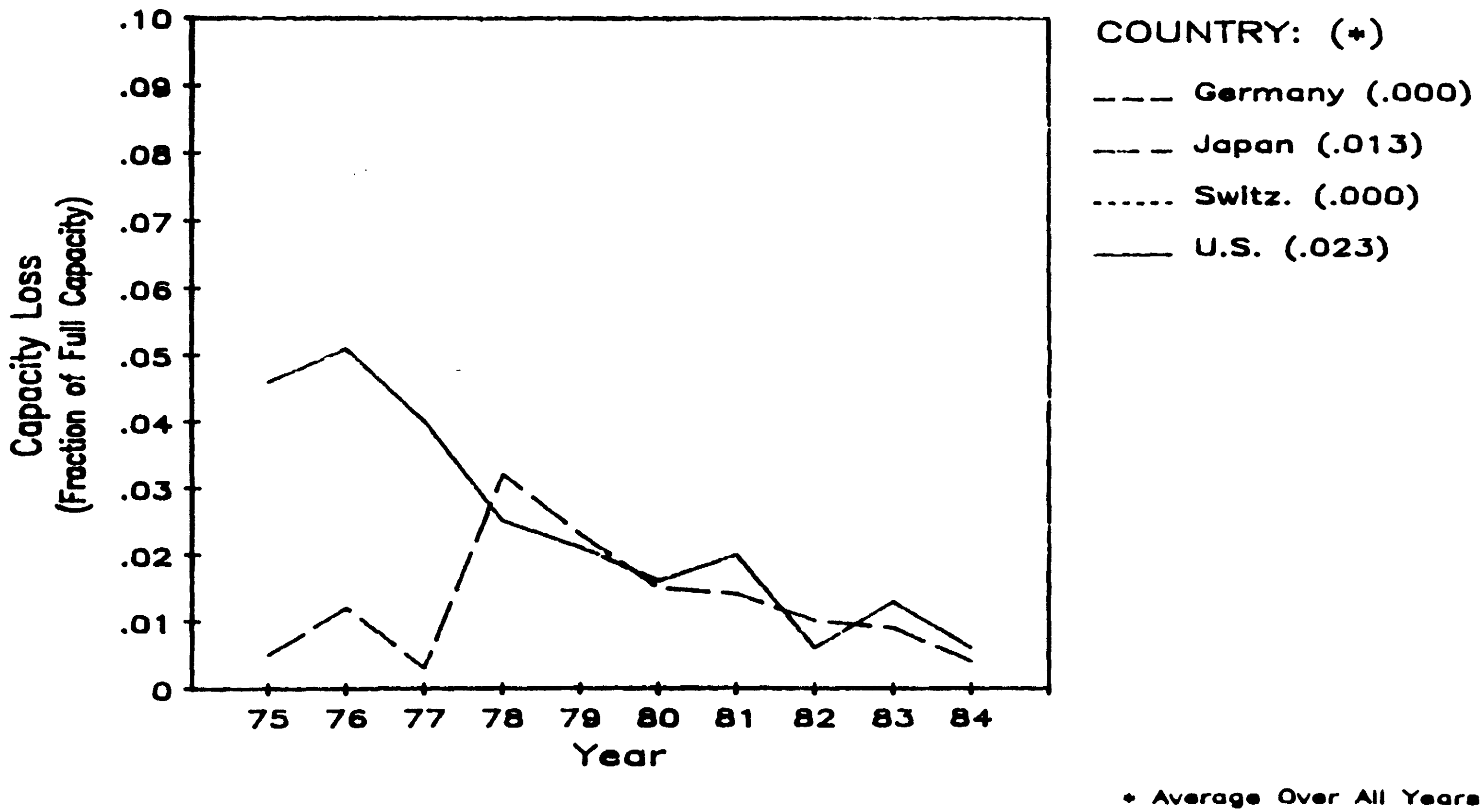
Japanese plants both show losses with averages of 2.3% and 1.3% respectively. In addition, each country shows a significant improvement over time. The U.S. losses drop from 5.1% in 1976 to 0.6% in 1984. At least half these losses and in some years almost all the losses were from the Preconditioning Interim Operating Management Recommendations (PCIOMR) developed by General Electric (GE). The PCIOMR losses have also shown the same improvement as the total losses, dropping from 3.7% in 1976 to 0.6% in 1984. Similarly, the Japanese BWR fuel losses have dropped from 3.2% in 1978 to 0.4% in 1984. The Japanese have been using some imported U.S. fuel and have been strictly following the GE PCIOMR with all their fuel. Despite this, the Japanese losses have been almost half that of the U.S. However, the Japanese and U.S. fuel losses have been approximately equal since 1978. This may indicate that the Japanese did not start using the PCIOMR until 1978. In both countries the losses were evenly distributed over nearly every commercial BWR so that the improvements indicated have significance.

The graph of fuel losses by reactor age is also not plotted because of the fuel cycling mentioned above for PWR's.

Figure 3.9
PWR Capacity Losses By Year
Fuel



## Figure 3.10
BWR Capacity Losses By Year
Fuel



### 3.2.3 Reactor Coolant System

*PWR* reactor coolant system (RCS) losses are displayed by year in Figure 3.11. Both the U.S. and Switzerland show much higher losses than Germany or Japan, at a cumulative average of approximately 3.3% with losses tending to decrease over time. The high Swiss losses may be the result of maintenance performed during refueling outages. If this is the case, then the losses would most likely be comparable with German and Japanese losses. The German RCS losses are relatively small except in 1975, 1978 and 1979 when they were more than double the average. This was primarily the result of relatively large outages at one or two of the plants operating at that time. Japanese losses have been small, arising from losses at only one of the several plants in operation in each year.

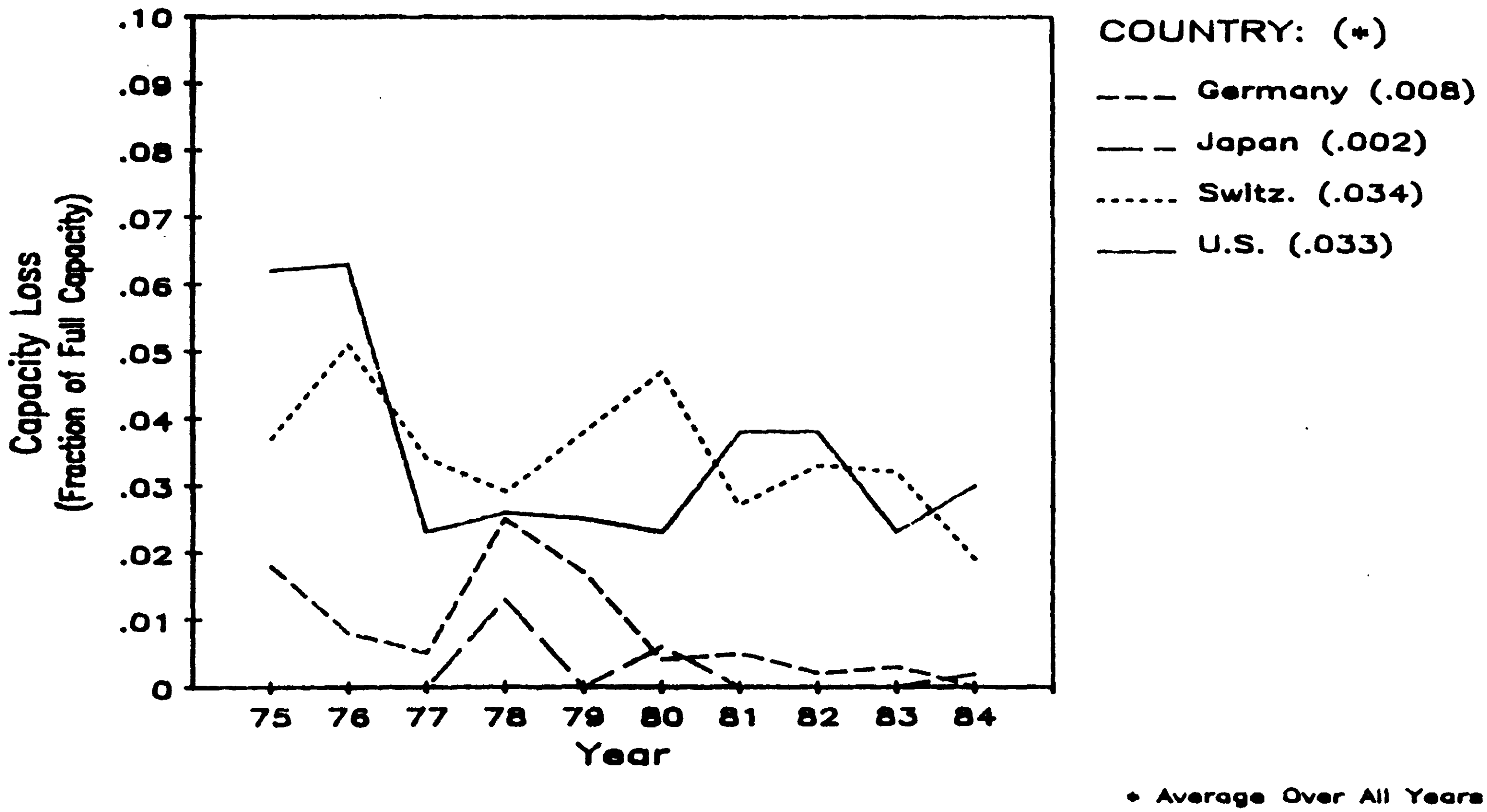
Examination of the RCS losses as a function of reactor age in Figure 3.12 yields several trends. The curve showing the Swiss losses indicates an age dependency with larger losses being incurred in the later ages. The peak at age 14 arises from losses at only one plant. The U.S. losses fluctuate with a general trend towards smaller losses with greater age. The cause of these trends cannot be determined from the data. The German losses are relatively uniform except in the early ages where there are two peaks corresponding to outages mentioned in the previous paragraph. Japanese operating experience ranges to age

12 but all the RCS losses occur in the first 5 years, again with only one plant contributing to each average loss.

*BWR* RCS losses are plotted by year in Figure 3.13. The figure shows that Germany had very large losses in 1977 and 1980 through 1983. These losses were from large outages for pipe replacement at one and four of the operating BWR's respectively. The large German pipe replacements were performed under a policy known as the "Basis Safety Concept" which is discussed further in Appendix C. The Japanese and the Swiss reactors exhibit small uniform losses that averaged less than 0.5% each. The Swiss losses were from their only BWR. RCS losses in the U.S. have been constant at around 4.0% except in 1975 and 1982 when they were doubled as a result of outages of greater than 10% at five and six reactors in each year respectively. This is almost ten times the losses at Japanese and Swiss plants.

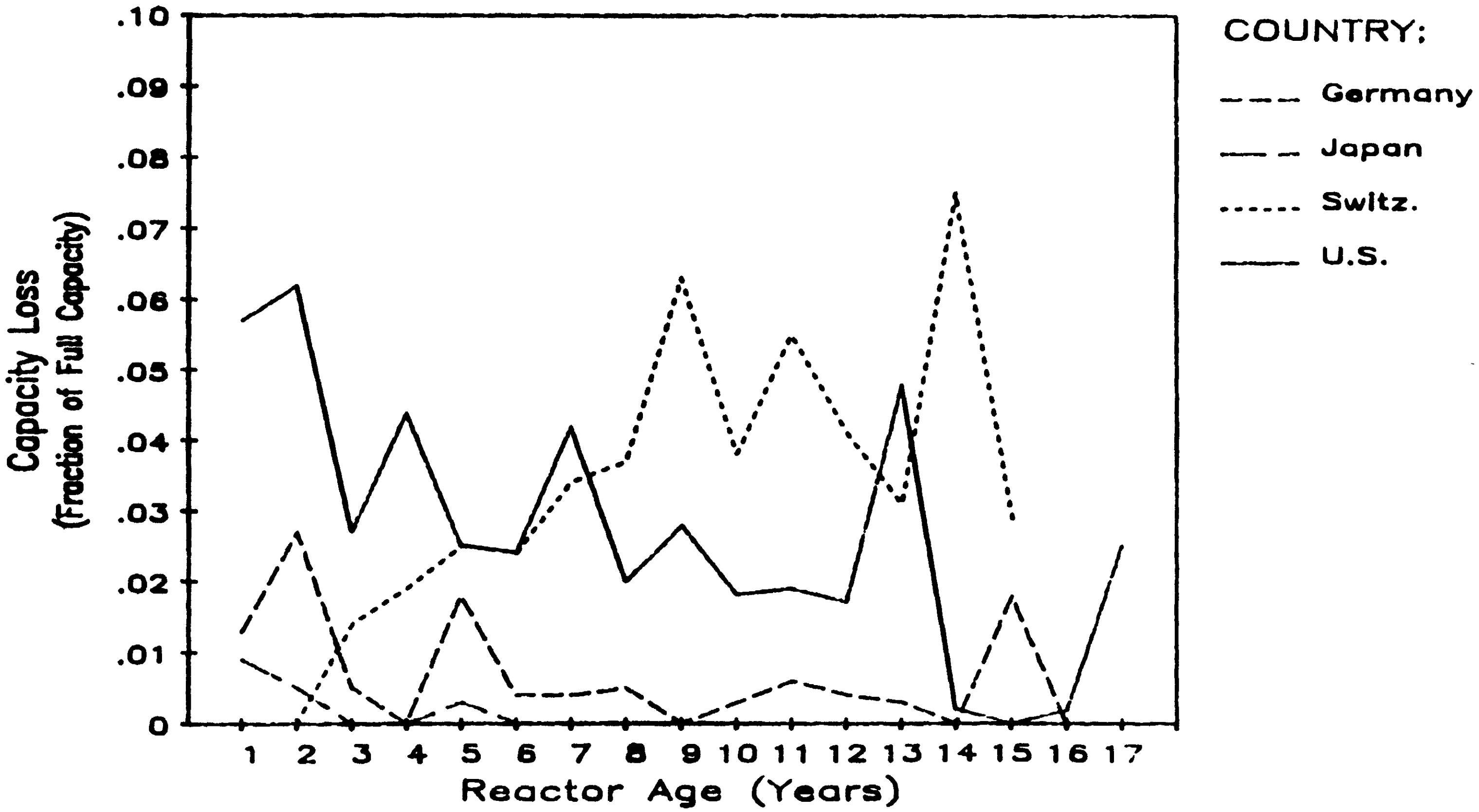
Figure 3.14 plots RCS losses by reactor age. No RCS age dependencies are indicated. The German data shows several peaks that correspond to the pipe replacement peaks in Figure 3.13. The Japanese and the Swiss plants have their losses uniformly distributed over age with an average of 0.3% and 0.5% respectively. The U.S. losses were fairly constant at approximately 4.0% with only a couple of plants showing large outages above age 12.

## Figure 3.11
## PWR Capacity Losses By Year
## Reactor Coolant System



## Figure 3.12

PWR Capacity Losses By Reactor Age
Reactor Coolant System



## Figure 3.13
BWR Capacity Losses By Year
Reactor Coolant System

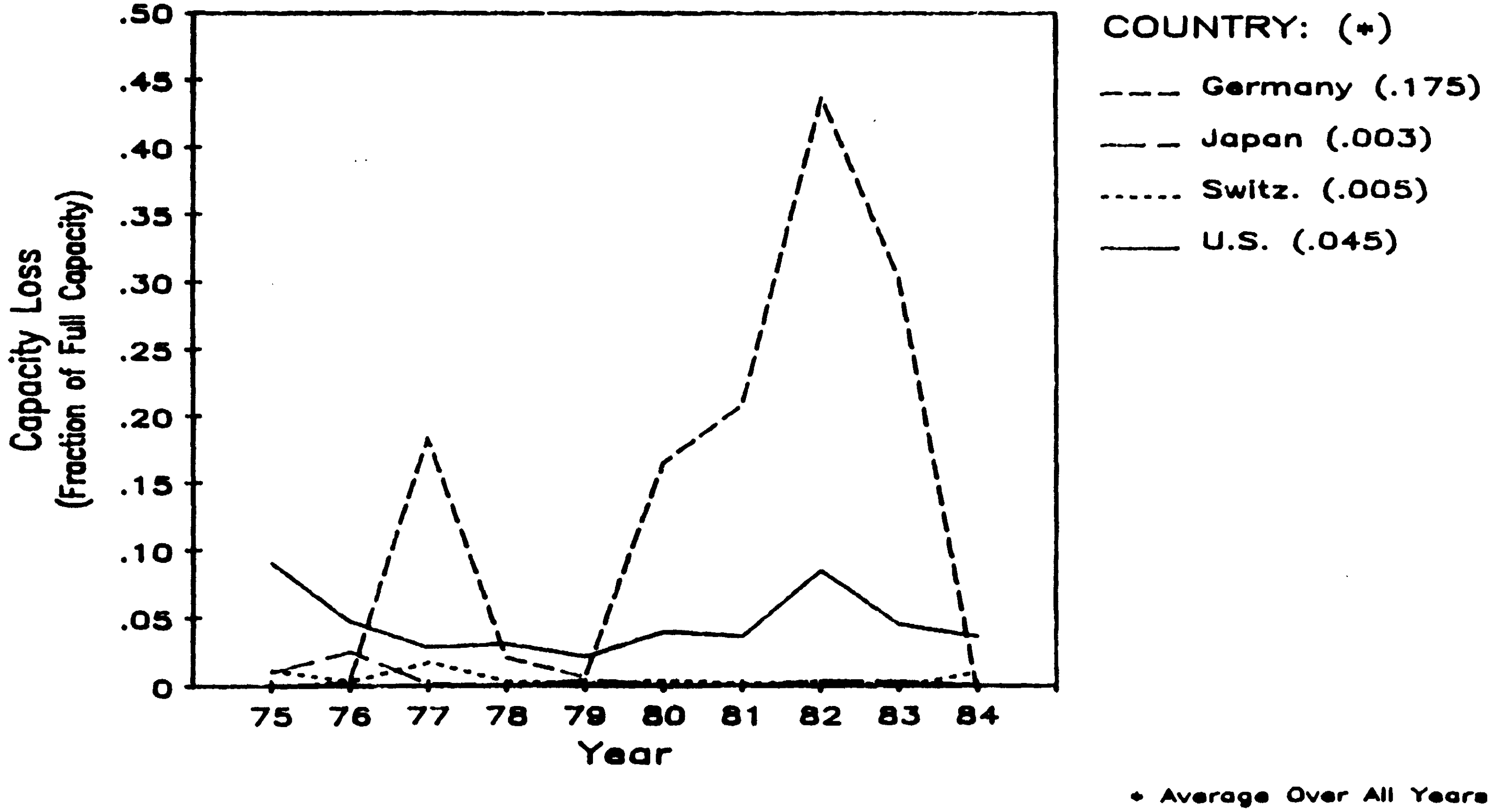
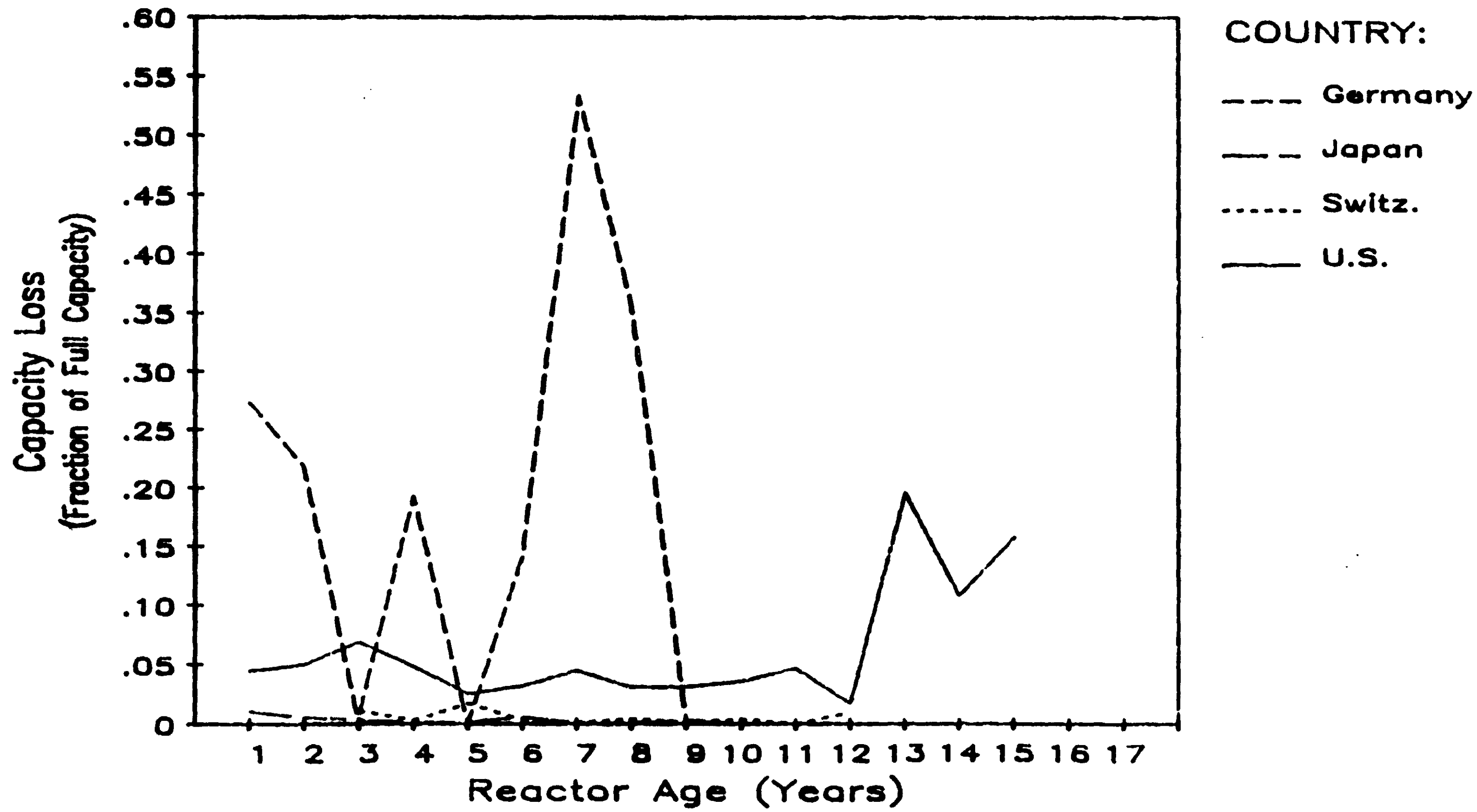


Figure 3.14
BWR Capacity Losses By Reactor Age
Reactor Coolant System



### 3.2.4 Steam Generators

*PWR* steam generator (SG) losses over time are illustrated in Figure 3.15. In general, the figure shows that all countries except Germany had large variations in SG losses. German reactors, with a ten year average of 0.5%, have had considerably smaller SG losses than have Japan, Switzerland and the U.S. Japanese losses occurred mainly in 1976, 1979, 1981, and 1983 as a result of outages at a single plant in each year. The Swiss plants have had the largest SG losses over the ten years with a large peak in 1975 from both PWR's. However, the large SG losses indicated were most likely the result of SG maintenance work done during refueling which were assigned to this category. The U.S. losses, with an average of 2.5%, have been almost as high as the Swiss and have generally increased with time.

Figure 3.16, which plots SG losses by plant age, shows a definite age dependence in SG losses for Switzerland and the U.S. The German and Japanese plants show no trends.

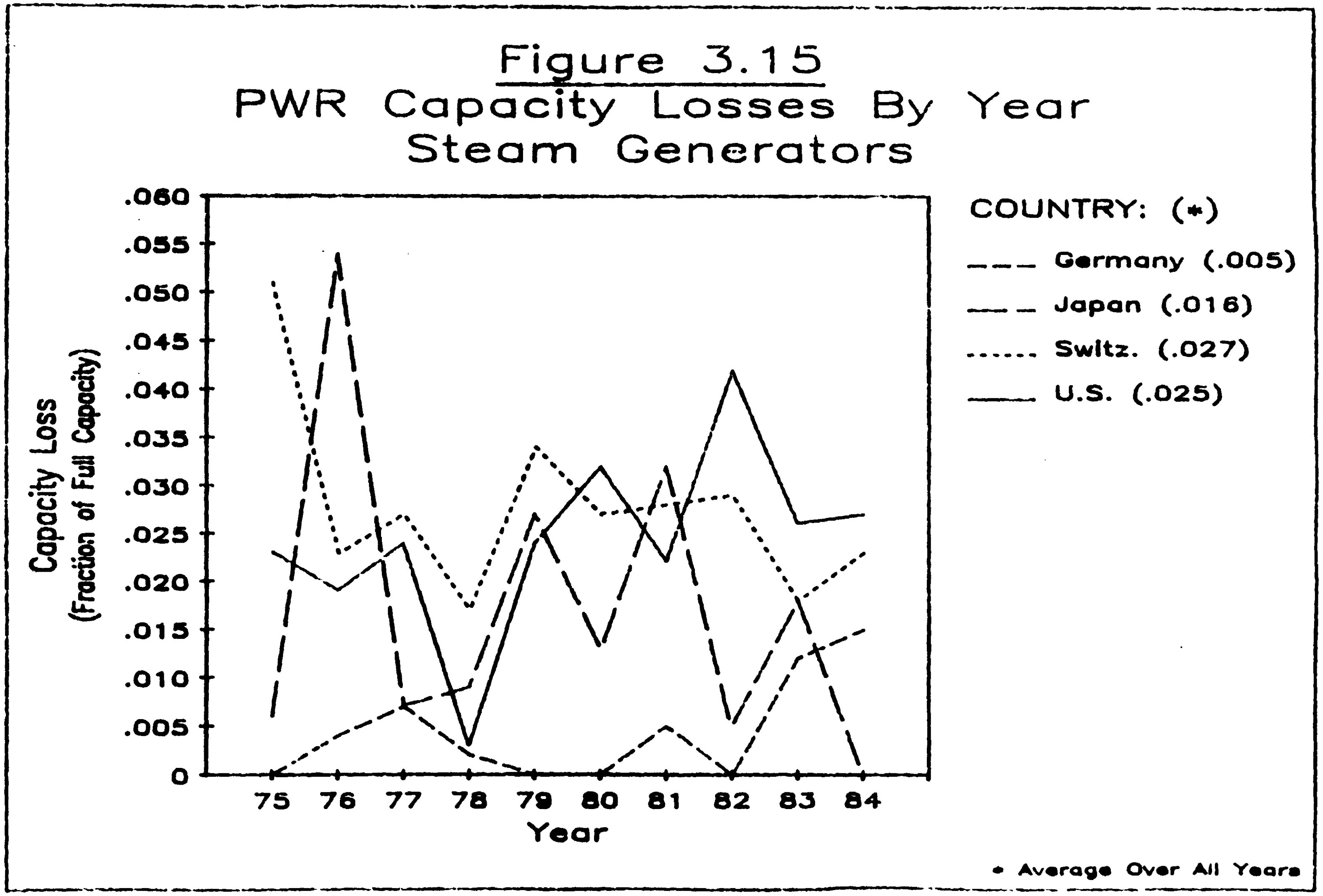
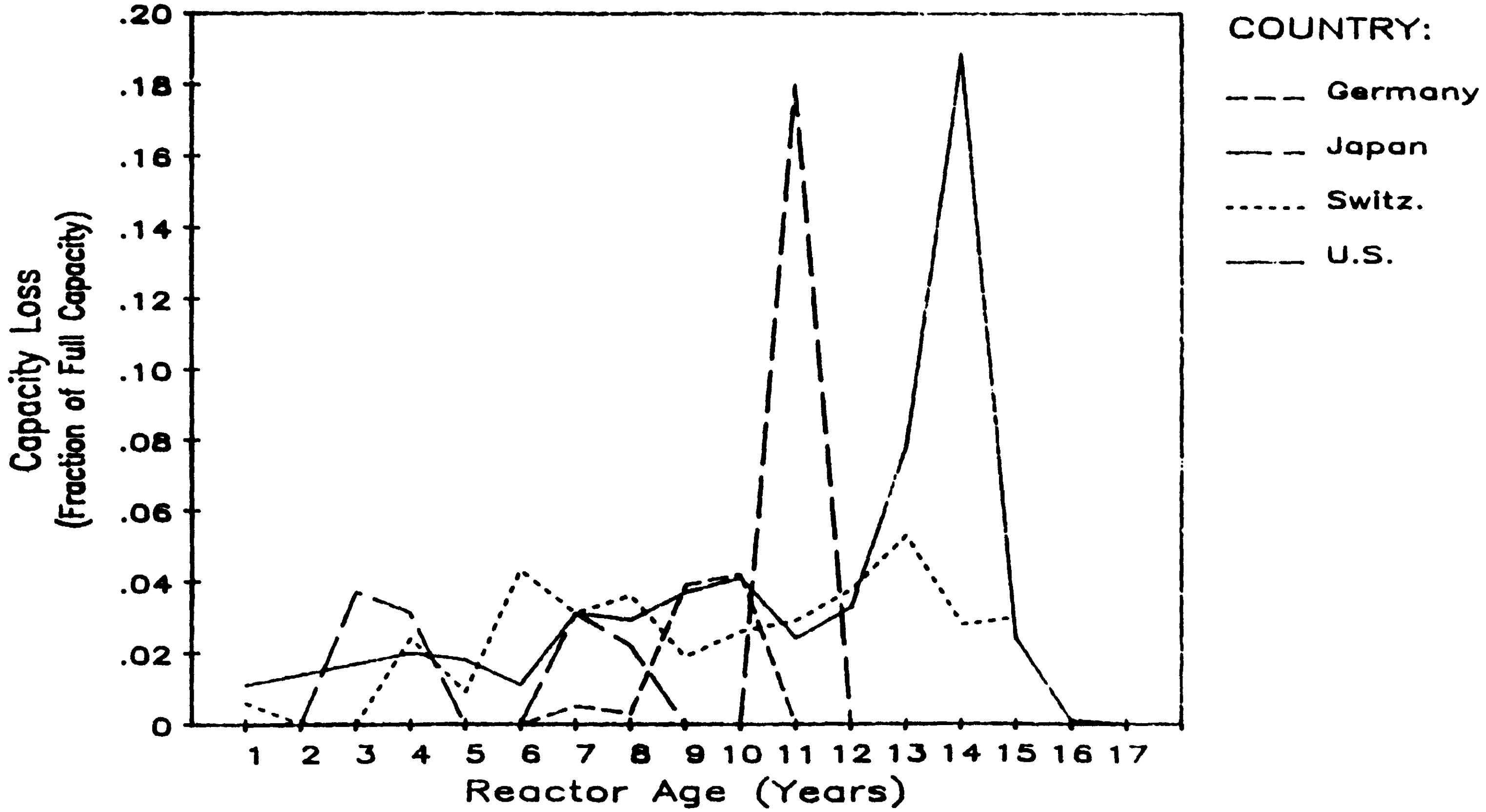


Figure 3.15
PWR Capacity Losses By Year
Steam Generators
Capacity Loss
(Fraction of Full Capacity)
.060
.055
.050
.045
.040
.035
.030
.025
.020
.015
.010
.005
0
75
76
77
78
79
80
81
82
83
84
Year
COUNTRY: (*)
Germany (.005)
Japan (.016)
Switz. (.027)
U.S. (.025)
* Average Over All Years

## Figure 3.16
PWR Capacity Losses By Reactor Age
Steam Generators



### 3.2.5 Refueling

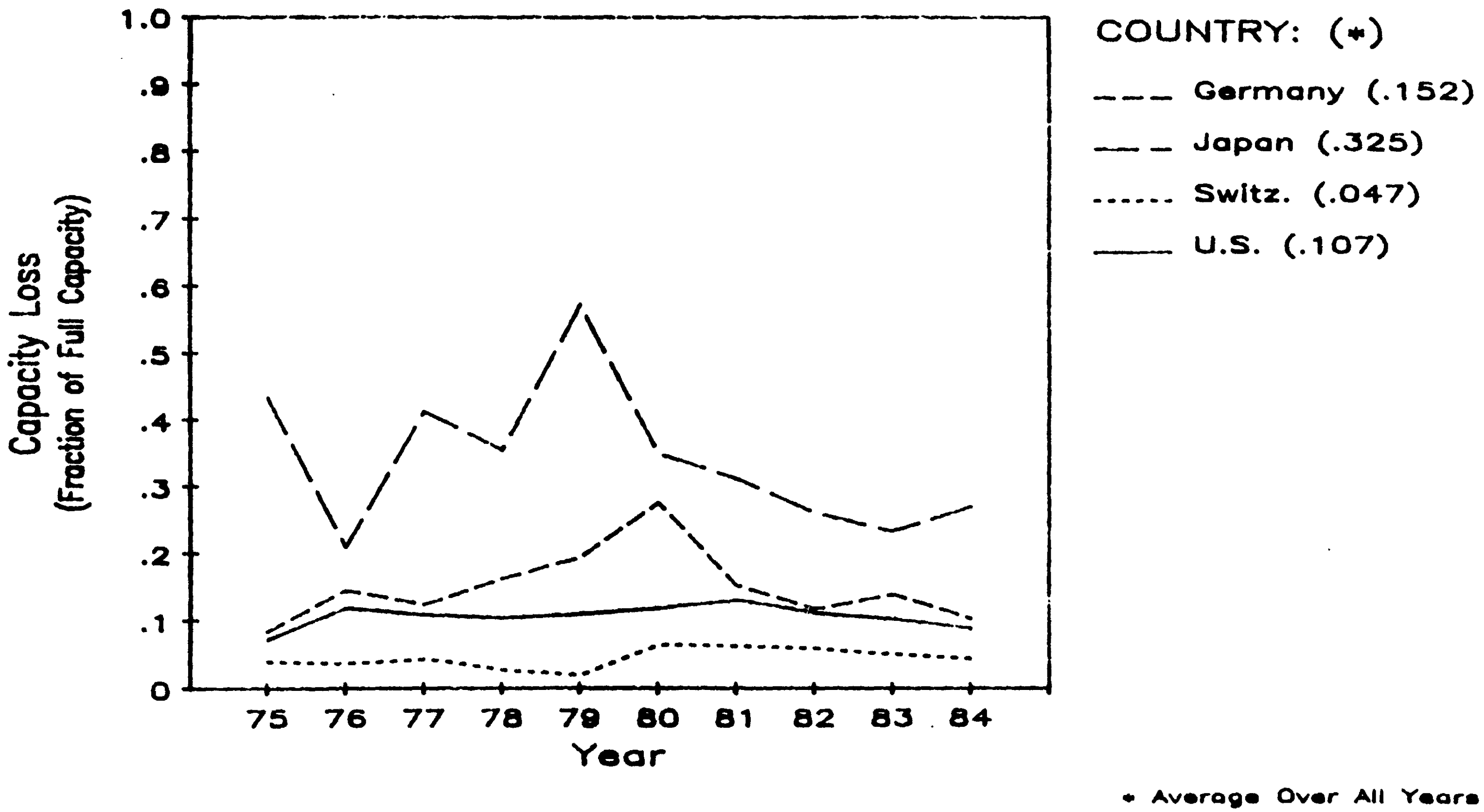
*PWR* refueling losses by year are illustrated in Figure 3.17. As shown, the Japanese plants have had significantly larger refueling outages than any of the other countries. The large outages were the result of annual inspections and maintenance that are required by law every year. These annual inspections average approximately 100 days. The maintenance work performed during these outages results in fewer outages later because equipment is better maintained. A fairly substantial peak occurred in 1979 which may correspond to the Three Mile Island accident that year. Whether or not this is the cause of the peak is unknown. German losses have averaged 15.2% with a peak occurring in 1980. This peak resulted from larger than average refueling losses at two plants. U.S. refueling outages have been relatively constant at 10.7%. The Swiss refueling losses are the lowest at an average of 4.7%, with an increase occurring in 1980. This is misleading because maintenance work done during refueling outages was not always reported as a refueling loss. Up until 1980, the reported refueling losses were for actual refueling work only, while after 1979 some refueling maintenance work was included in the reported losses. This accounts for the rise in 1980. If one considers only those plants reporting maintenance done during refueling as a refueling loss, the average is approximately 10.1%, which is comparable to the U.S. rate.

Figure 3.18 plots PWR refueling losses as a function of reactor age. Japanese losses, as shown in the previous figure, are the highest. The low refueling losses at age = 1 are probably caused by less stringent inspection requirements for plants just starting up, and because the core contains relatively new fuel, reducing the need for a full refueling in the first year. The 5.0% refueling loss for age = 12 was from a single plant that had a very small refueling and inspection outage for an unknown reason that year. The German refueling losses fluctuate ± 5.0% around an average of approximately 14.0% with no other apparent trend. The Swiss refueling losses appear to show a decrease as the plants get older. As in Figure 3.17, the trend indicated is misleading as it arises from the inconsistent reporting of refueling losses. The U.S. refueling losses were fairly uniform with no increasing or decreasing trend obvious. The lower refueling losses for ages 1 and 2 were most likely the result of less fuel movement being done during the first two refuelings because the fuel was relatively new.

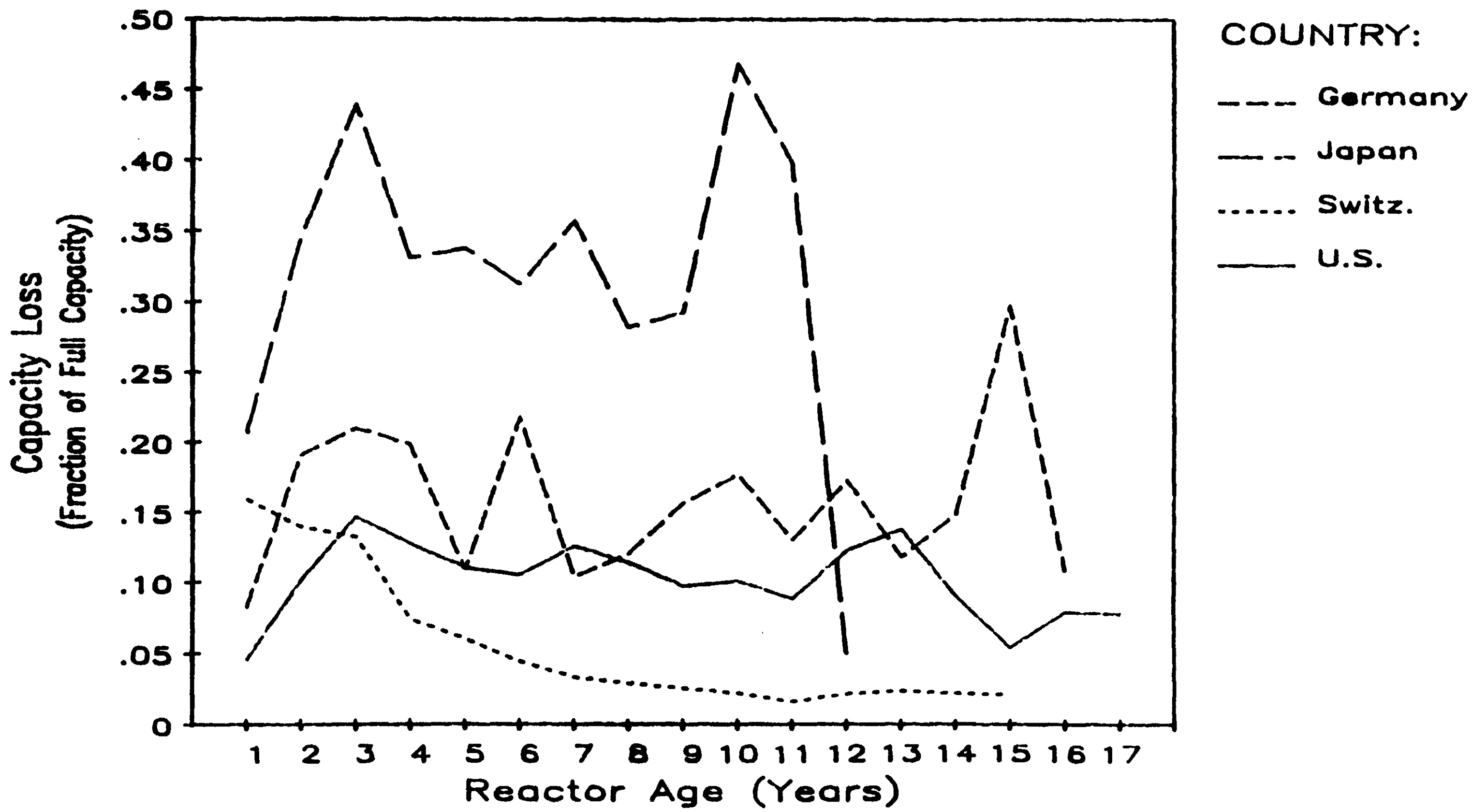
*BWR* losses as a function of calendar year are plotted in Figure 3.19. As with the PWR refueling losses, the Japanese losses are the largest of all the countries. Comparison of this figure with 3.18 shows that the PWR and BWR refueling losses are almost identical, which is what should be expected when the mandatory inspections and maintenance are critical path. The losses decreased with time starting in 1977. The remainder of the losses shown in Figure 3.19, for Germany, Switzerland, and the U.S., are almost equal with the three countries averaging approximately 10.0% refueling losses. No other trends are visible in this figure.

The BWR refueling losses by reactor age are shown in Figure 3.20. None of the countries exhibit any trends as a function of reactor age. The U.S. and Germany do show a peaking for the first several years after start-up. The cause for this is unknown.

## Figure 3.17
PWR Capacity Losses By Year
Refueling



## Figure 3.18
## PWR Capacity Losses By Reactor Age
## Refueling



## Figure 3.19

BWR Capacity Losses By Year
Refueling

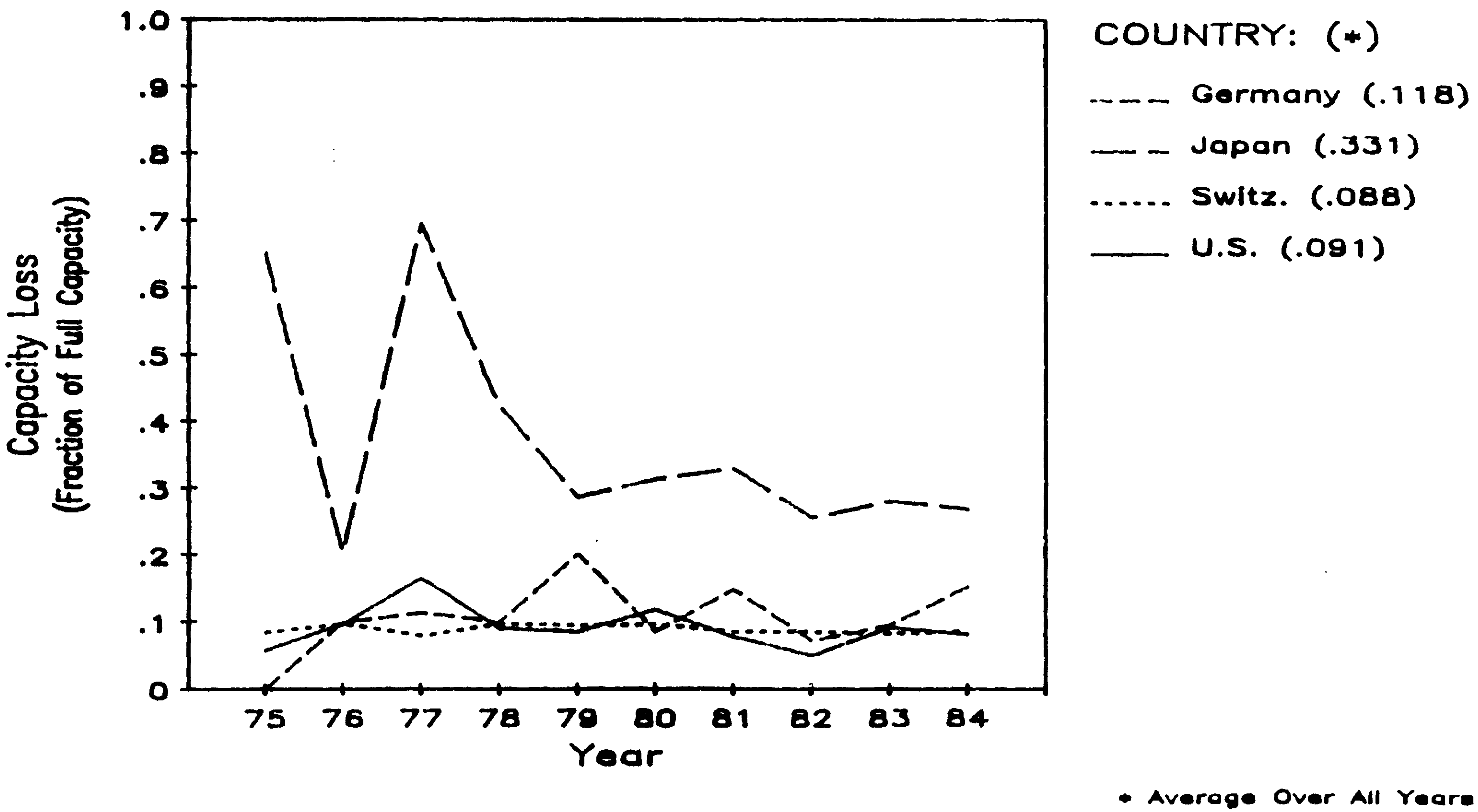
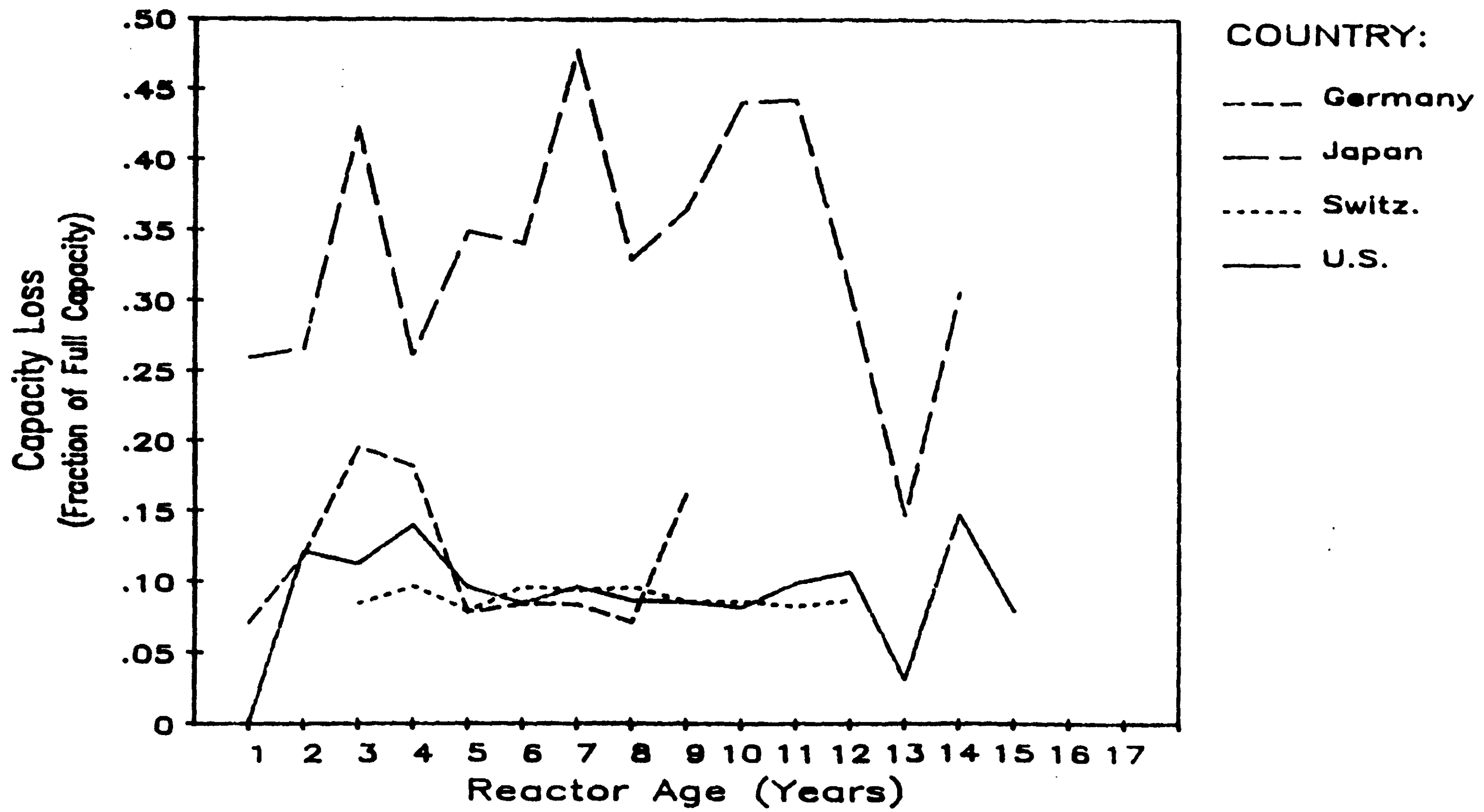


Figure 3.20
BWR Capacity Losses By Reactor Age
Refueling



## 3.3 Balance of Plant (BOP)

This section presents and compares all Balance of Plant losses for Germany, Japan, Switzerland, and the United States. Losses for France and Sweden could not be compared because they were not available in sufficient detail. Total BOP losses are compared first, followed by turbine, generator, condenser, and CW/SW/CCW losses. As with the NSSS losses, PWR's and BWR's are discussed separately.

### 3.3.1 Total BOP

*PWR* Balance of Plant losses are plotted over time in Figure 3.21. The U.S. has had the highest BOP losses with an average of 5.9%. This is more than double the losses of any other country. The largest part of this loss is from turbine and condenser problems which represent 33.9% and 20.5% of the total BOP losses respectively. The Swiss have the second highest overall losses with an average of 2.2%. Of this, 81.8% percent is from turbine losses and 13.6% is from CW/SW/CCW. As the figure illustrates, the Swiss BOP losses appear to be improving. However, because of the inconsistent reporting of the refueling losses, one of the PWR's did not have any scheduled BOP maintenance as did the other Swiss PWR's. Since this plant went into commercial operation in 1980, the decrease in BOP losses from 1981 on occurred because the losses that were reported were averaged over an additional plant. The German PWR's exhibit the third highest BOP loss with an average of 1.9%. The large yearly variations were from generator problems that contributed an average of 52.6% of the total BOP loss. Japan has had the lowest BOP losses with an average of 0.5%. The large amount of inspection and maintenance that is performed during refueling outages results in better maintained equipment. Such equipment is less likely to cause an outage, hence, the low BOP losses. As the figure shows, what little BOP losses the Japanese PWR's have been experiencing has been decreasing since 1975. Improvements in turbine and CW/SW/CCW losses over the ten years were responsible for the decreasing BOP losses.

Balance of Plant losses for PWR's are plotted as a function of reactor age in Figure 3.22. Consistent with the previous figure, the U.S. has the greatest losses by age. The U.S. BOP losses exhibit an obvious age dependence, decreasing with age. This age dependence was primarily the result of similar trends in condenser and turbine losses. The Japanese PWR's also exhibit a slight decline in BOP losses by age as a result of improvements in turbine performance. The remaining countries exhibit variation and do not show any age dependencies.

*BWR* Balance of Plant losses are shown graphically by year in Figure 3.23. Consistent with Figure 3.22, losses average 1% to 3%, with the exception of the U.S. The

U.S. losses were again the largest, averaging 7.3%. This is two and a half times the German BWR losses, which were the second highest. The U.S. losses show an interesting trend, decreasing steeply from 1975 to 1978 and then gradually increasing from 1979 to 1984. Examination of the data identifies OTHER BOP losses as responsible for the steep decline in BOP losses from 1975 to 1978, while turbine problems are responsible for the increasing BOP losses in BWR's since 1979. German losses averaged 2.7% over the 10 year period with variation in the magnitudes of the losses. Turbine problems contributed 40.7% of the average total BOP loss with condensers responsible for another 33.3% of the total. Both the Japanese and the Swiss have average BWR balance of plant losses of under 1.0%. The Swiss BWR losses show a slight improvement with age. This was due to decreases in the turbine losses.

The BWR balance of plant losses are plotted by reactor age in Figure 3.24. The U.S. losses show a steep decline during the first several years of operation as a result of decreasing losses that were attributed to OTHER BOP. The losses then level out and fluctuate after age 5. German BOP losses also decrease as a function of age in BWR's. This trend, however, is a statistical occurrence resulting from the combination of all data and cannot be attributed to a single system. The plot of the Swiss data is identical to that in Figure 3.23 because the Swiss have only one BWR. Japanese BWR BOP losses show no age dependent trend.

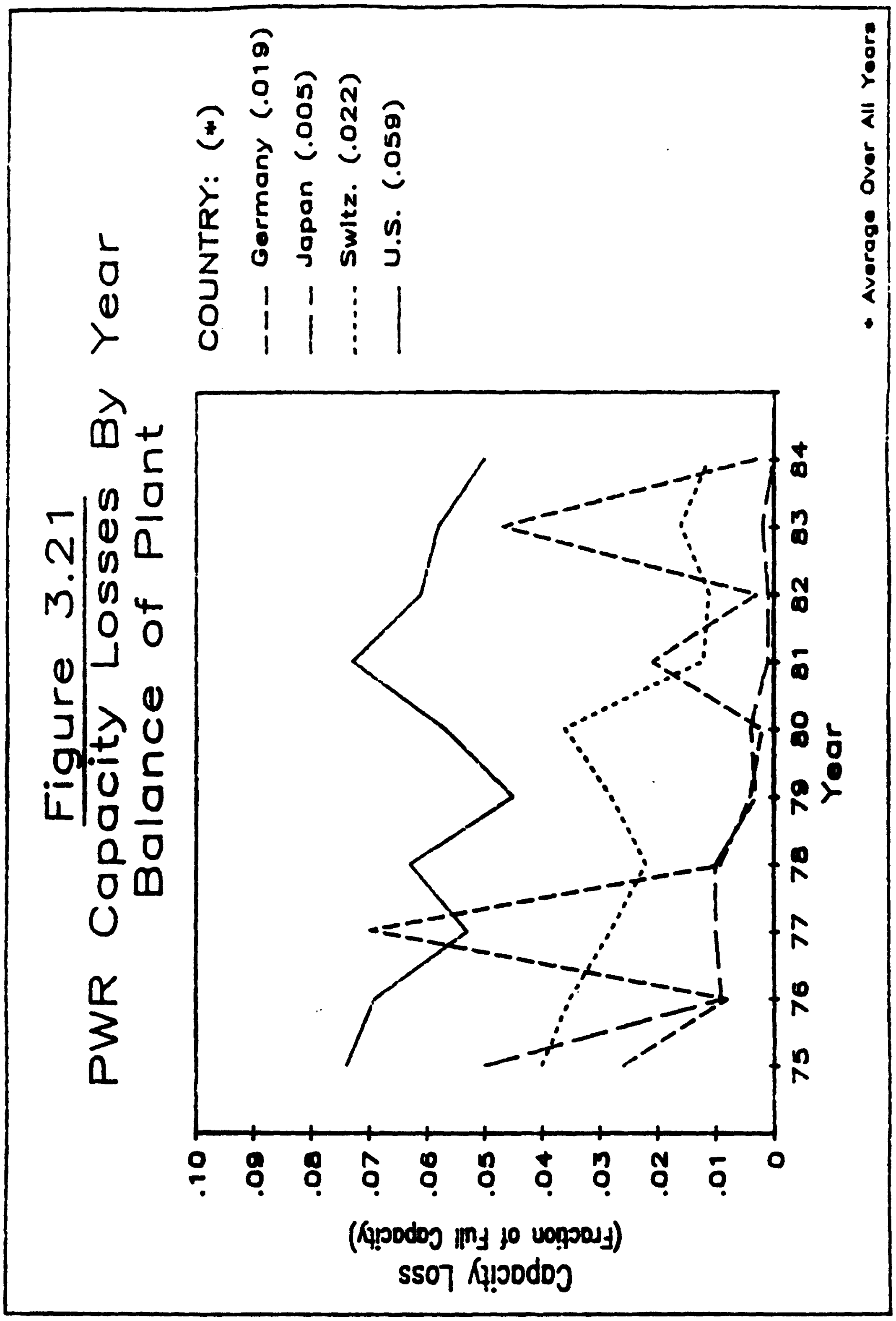
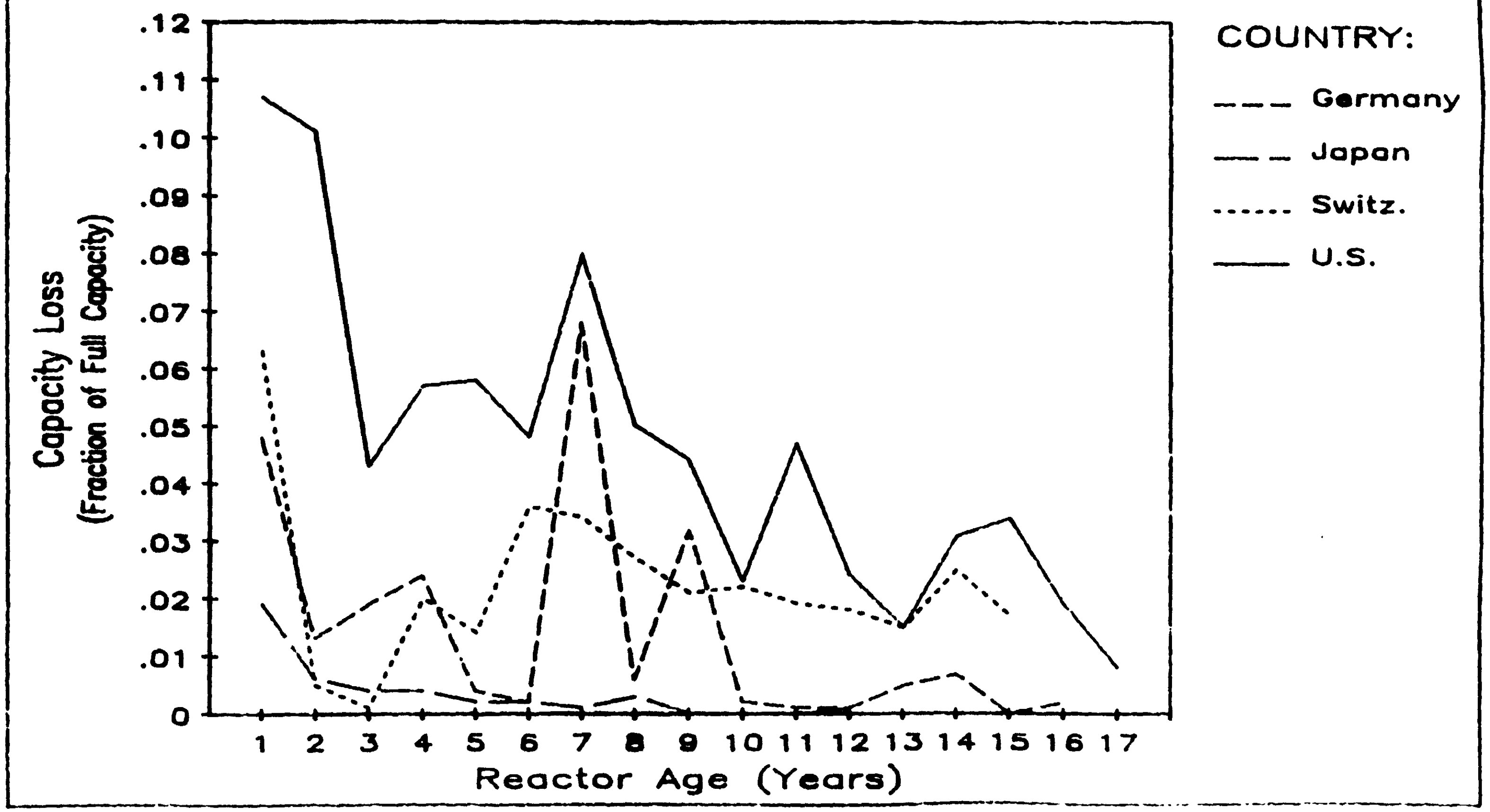



Figure 3.21
PWR Capacity Losses By Year
Balance of Plant

Figure 3.22
PWR Capacity Losses By Reactor Age
Balance Of Plant



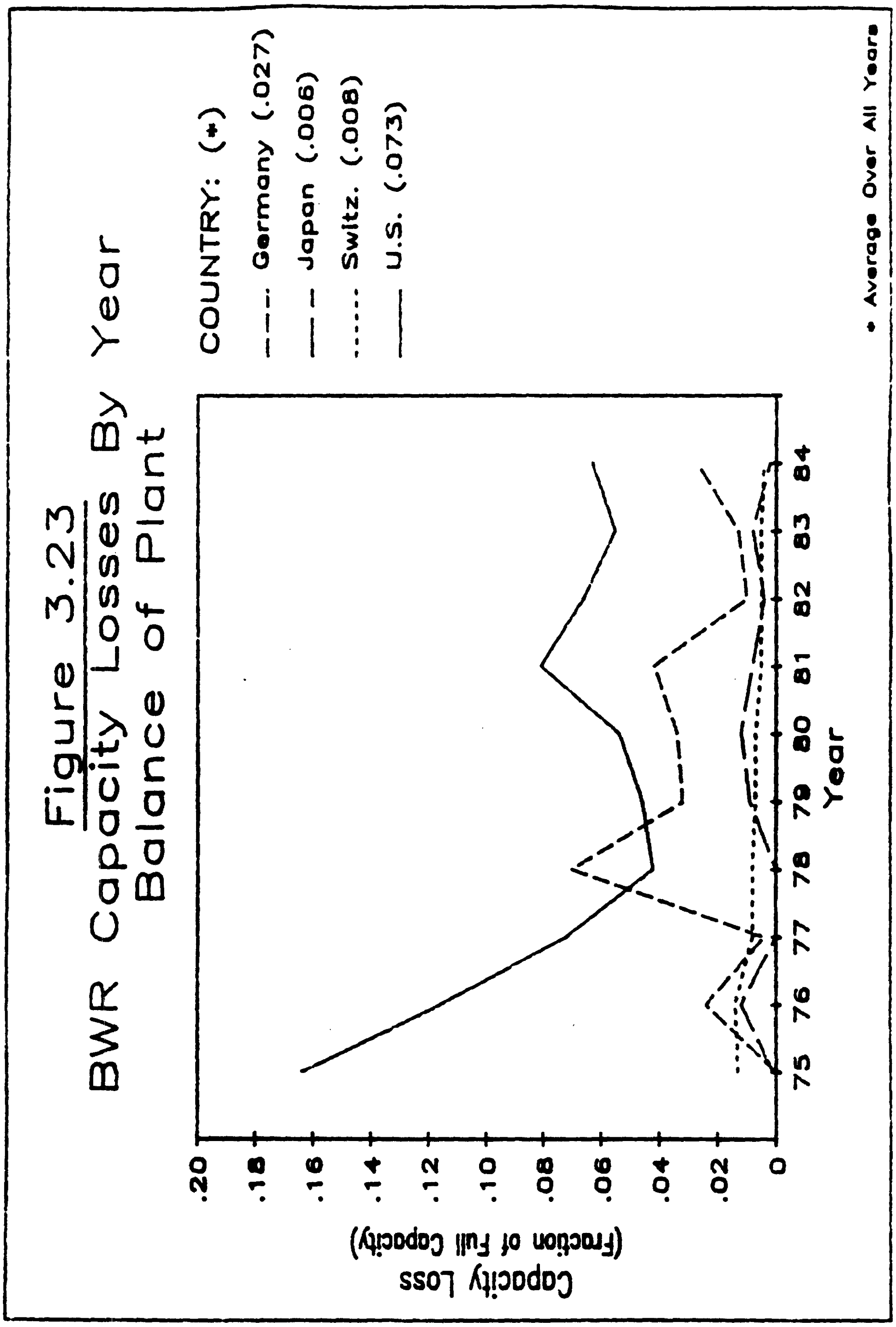
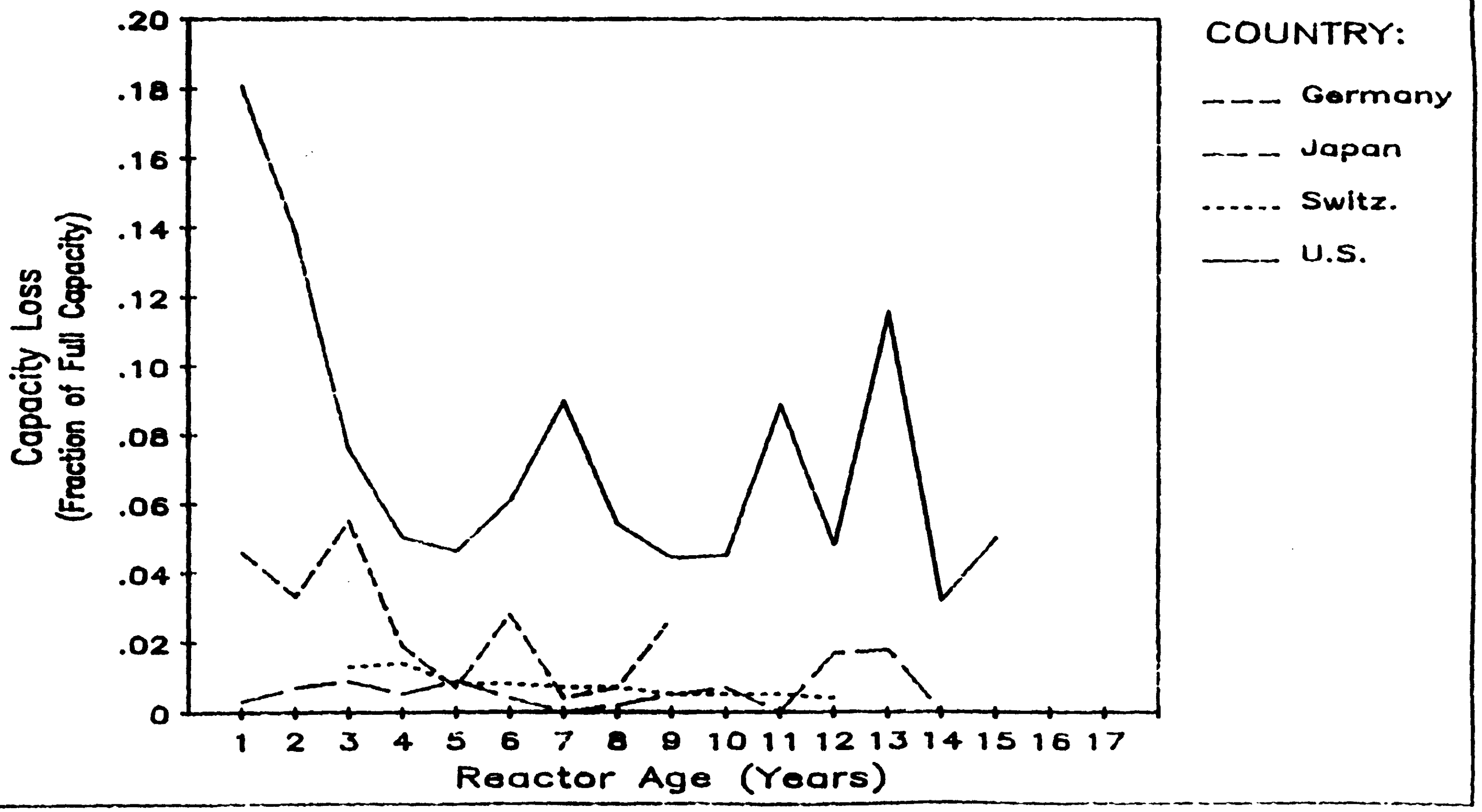



Figure 3.23
BWR Capacity Losses By Year
Balance of Plant

## Figure 3.24
BWR Capacity Losses By Reactor Age
Balance Of Plant



### 3.3.2 Turbines

*PWR* turbine losses are illustrated by calendar year in Figure 3.25. For all of the countries shown there is a common trend of decreasing losses with time. The losses of Switzerland and the U.S. were approximately six times the size of the German and Japanese losses. The reason for this is unknown although it may be hypothesized that the Japanese losses were low as a result of the extensive inspection and maintenance that occurs during refueling outages. The magnitude of the Swiss losses is deceiving because of the inconsistency in the reporting of maintenance performed during refueling.

Figure 3.26 plots the PWR turbine losses as a function of reactor age. The Japanese losses, which were relatively small, decrease with age. The U.S. losses show an unusually high peak for the first two years of operation due to outages at three plants lasting from two and a half to six months. German and Swiss losses exhibit no age dependencies.

*BWR* turbine losses are plotted by year in Figure 3.27. The plot of the German losses shows a small peak of 2% in 1976 and a larger peak of 6.2% in 1979. In both cases the peaks were primarily the result of losses at a single plant. The peak in 1984 was from larger losses at three of the four German BWR's. Japanese turbine losses were almost negligible, averaging 0.2%, and showing a slight decreasing trend with time. Like the Japanese curve, the losses from the only Swiss BWR also decreased with time. If all Swiss PWR refueling maintenance losses had been reported under refueling, the Swiss turbine losses would most likely average out to zero, based on the aggregate refueling losses reported by the one PWR that did so. U.S. turbine losses were on average nearly twice that of any of the other countries. The peak in 1981 and 1982 was a result of larger losses at 4 and 6 of the plants reporting turbine losses. In addition, U.S. losses appear to be increasing in recent years. The reason for this increase is unknown.

BWR turbine losses are shown by age in Figure 3.28. In this figure all countries except Switzerland exhibit fluctuation in the turbine losses with no significant trends identifiable. The Swiss curve is identical to that in Figure 3.27. The U.S. curve, although it has a large amount of variation, appears to show a tendency for BWR turbine losses to increase with reactor age. Examination of the data shows that most of the losses can be attributed to large outages at only one or two individual plants. As a result, the data does not show a trend representative of all the plants in the U.S.

Figure 3.25
PWR Capacity Losses By Year
Turbines

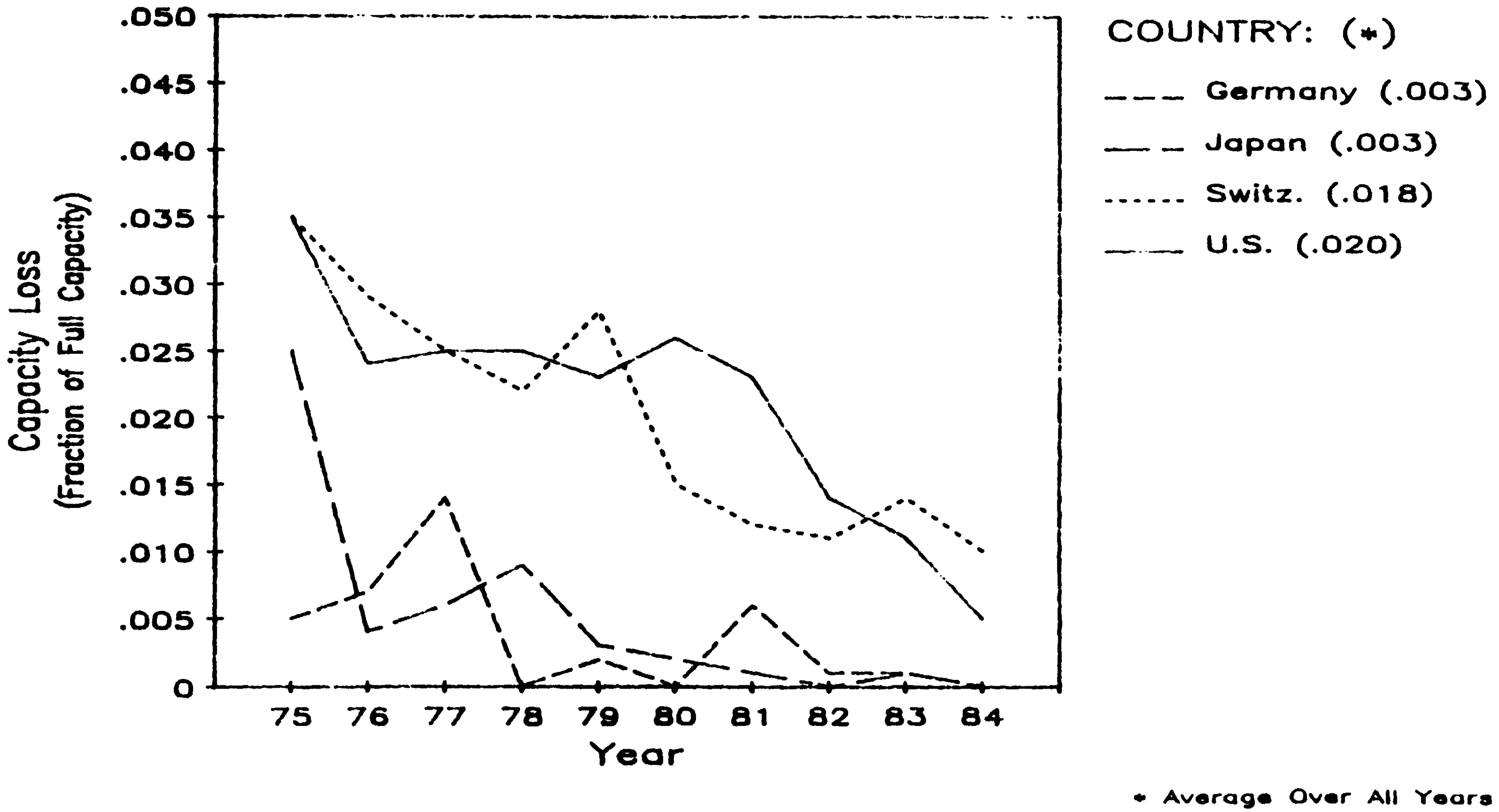
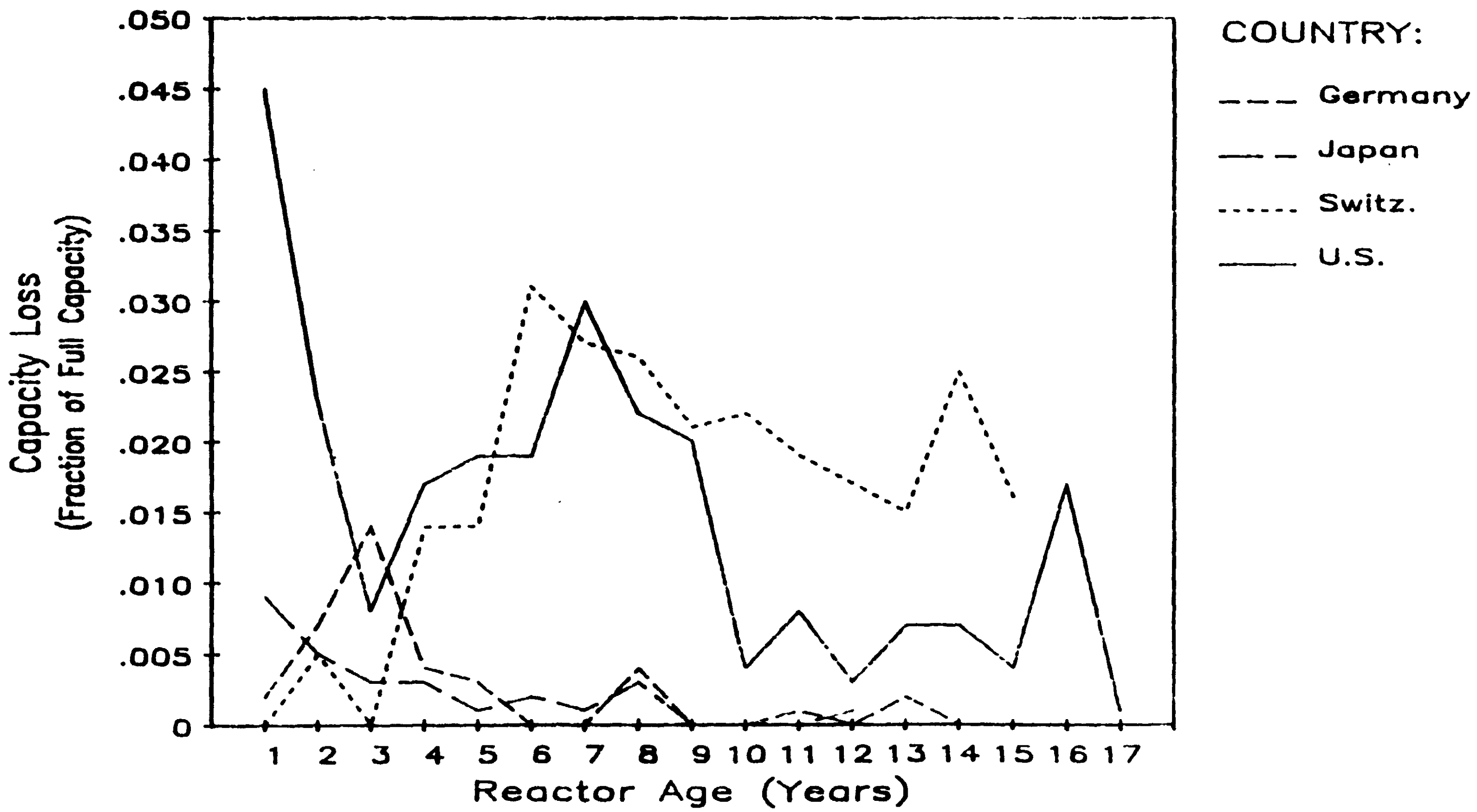


Figure 3.26

PWR Capacity Losses By Reactor Age
Turbines



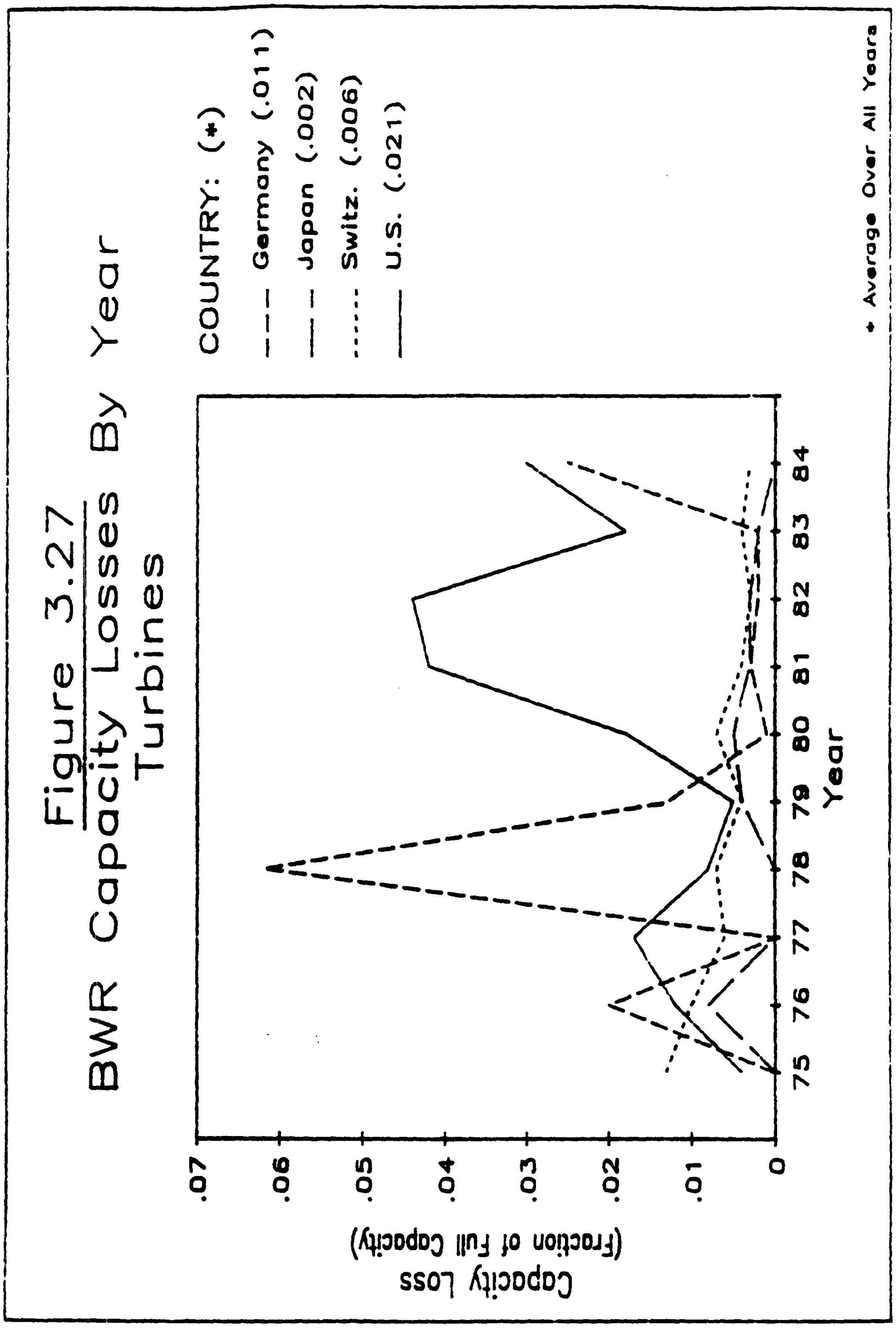
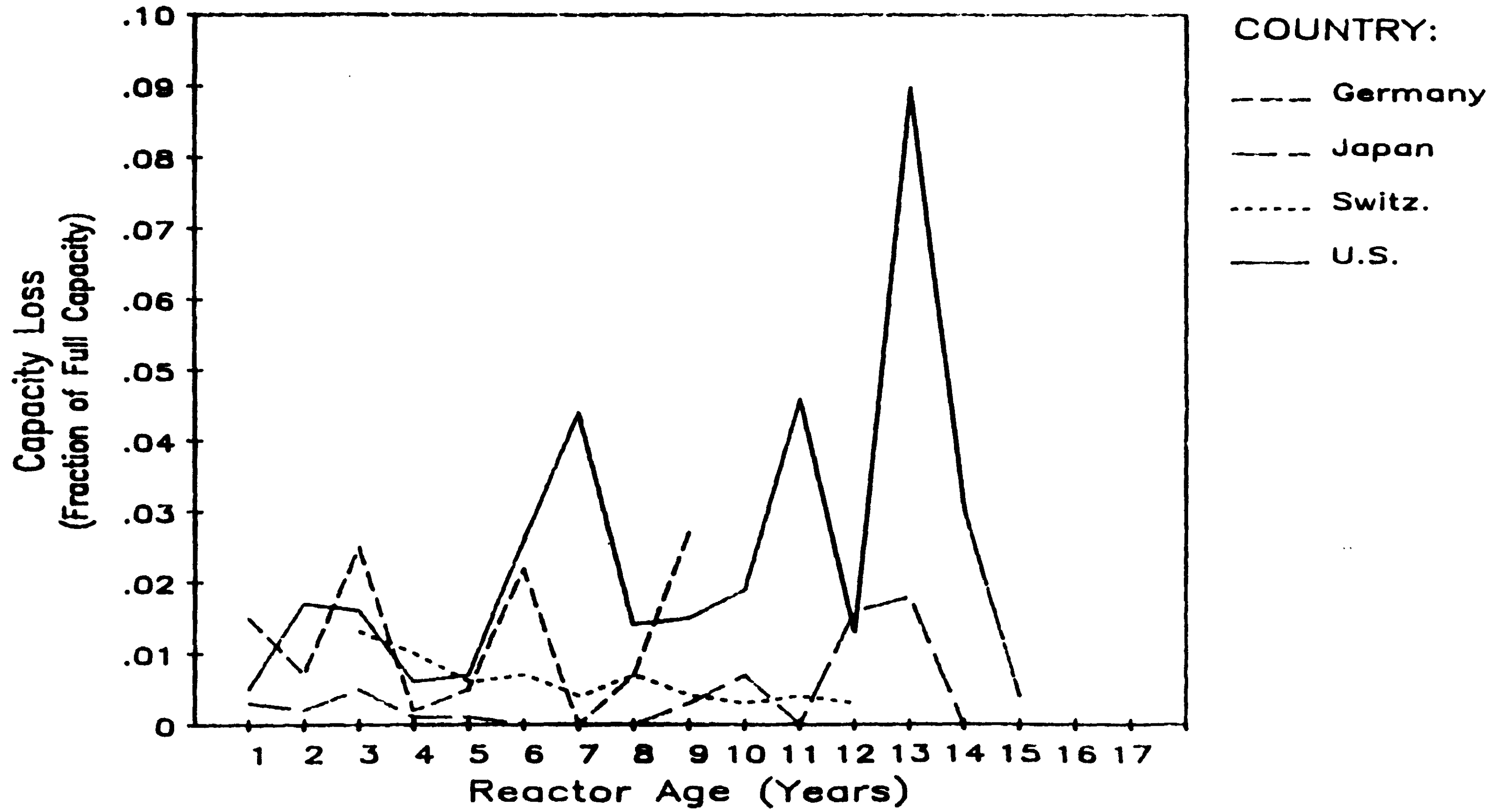


Figure 3.27
BWR Capacity Losses By Year
Turbines
Capacity Loss
(Fraction of Full Capacity)
.07
.06
.05
.04
.03
.02
.01
0
75
76
77
78
79
80
81
82
83
84
Year
COUNTRY: (*)
Germany (.011)
Japan (.002)
Switz. (.006)
U.S. (.021)
* Average Over All Years

## Figure 3.28
## BWR Capacity Losses By Reactor Age
## Turbines



### 3.3.3 Generators

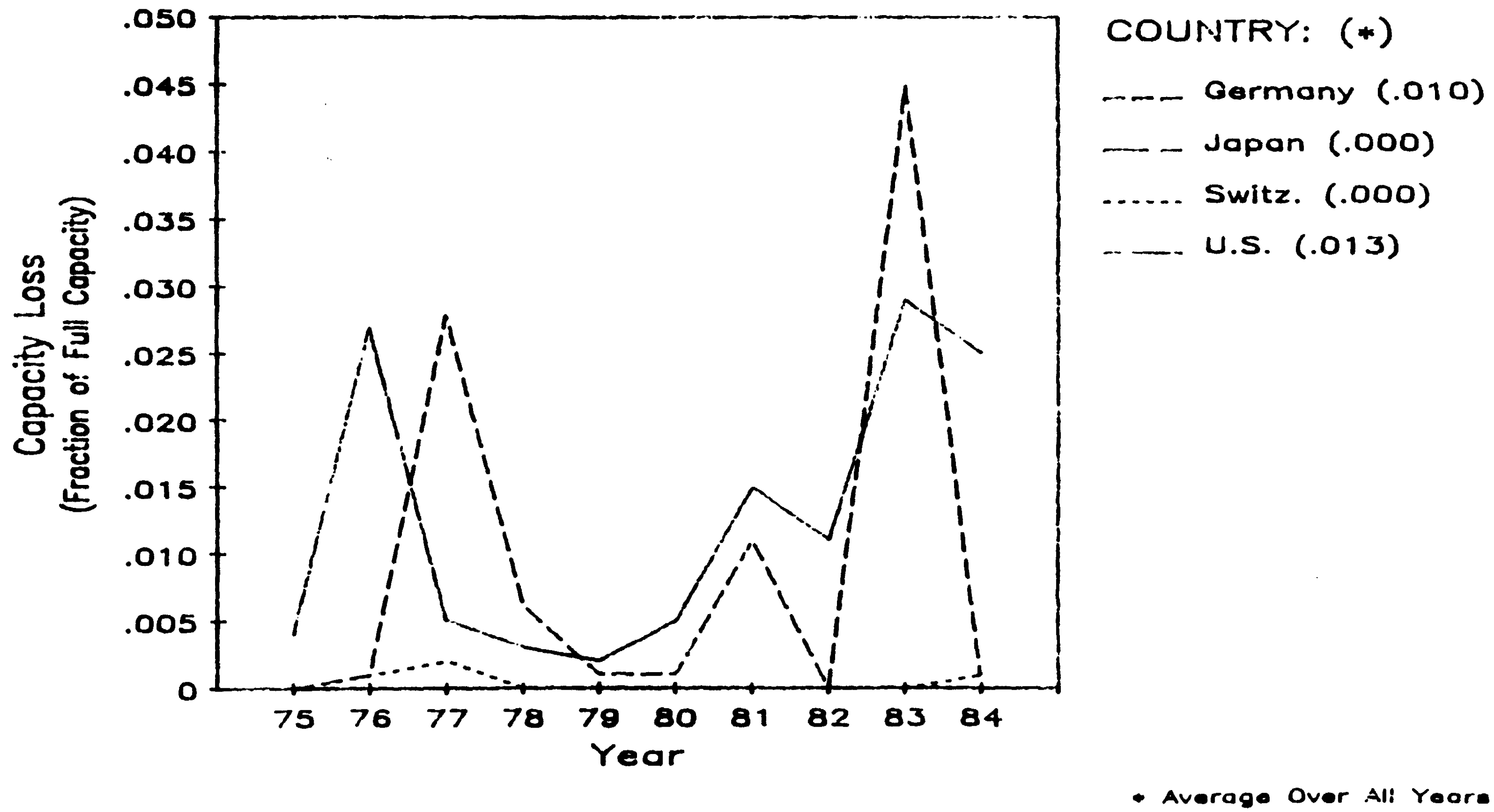
*PWR* generator losses are plotted as a function of time in Figure 3.29. The Japanese have not had any generator problems in their PWR's while the Swiss have had negligible losses. Germany and the U.S. show losses averaging approximately 1.0% with matching peaks in several years. Examination of the data indicates that the majority of the losses in the peaks were from a minority of the plants. The U.S. peak in 1976 was from one plant with a 59.9% outage and another with a 12.4% outage, averaged over 30 commercial PWR's. Together the two plants represent almost 90.0% of the total generator loss for 1976. The U.S. peak in 1981 was caused by three out of forty-six plants contributing 80.0% of the loss. Again in 1983 the U.S. peak was caused by four out of fifty-two plants contributing 90.0% of the losses. The German peak in 1977 is a significant peak with three out of five plants contributing. The large German peak in 1983 has one out of seven plants contributing 84.4% of the total generator loss. Since the majority of the large losses were from a small minority of the plants, these curves do not show losses that are representative of all the plants. However, the nuclear industries in both Germany and the U.S. have in general shown substantially more generator losses than have Japan or Switzerland.

The PWR generator losses by reactor age are given in Figure 3.30. Since the peaks in this figure correspond to the peaks in Figure 3.29, generator losses as a function of age do not indicate anything further.

*BWR* generator losses are plotted by year in Figure 3.31. Averaged from 1975 through 1984, BWR generator losses have been almost negligible, averaging 0.5% or less. Compared to the PWR generators, the BWR's have performed better. The fact that BWR generators spin slower than their PWR counterparts may account for this. The Swiss have had virtually no problems with their generators while the German and Japanese losses have also been small with only a couple of plants contributing to the losses shown. The U.S. has had more generator losses than the other countries, averaging 0.5%, which is five times the averages of the others. In comparison with the data for the U.S. PWR's, the BWR's have had less than half the generator related losses. As with the PWR's, the majority of the generator losses in U.S. BWR's has come from only a fraction of the operating plants. In 1977, 83.3% of the losses were from only one of the twenty-one BWR's, while from 1978 to 1980 at least half the losses reported were from a small number of plants. In 1983, two plants contributed 90.2% of the generator losses.

The BWR generator losses are plotted as function of age in Figure 3.32. The U.S. losses are predominant over the losses from the other countries. The age dependent trend shown by the U.S. curve is misleading. The relatively high loss in the first year is from one plant which contributed 81.7% of the total loss. If this plant is removed from the data the loss for the first year is around 0.3% which is consistent with the rest of the data. The peak at age 11 for the U.S. was also one plant out of ten causing 86.7% of the loss. The Japanese BWR's range in age up to 14 but all of their generator losses have occurred in plants younger than age 7. This age dependent trend may or may not be significant as the number of data points is low and the first several years of data is missing from the older plants.

## Figure 3.29
## PWR Capacity Losses By Year
## Generators



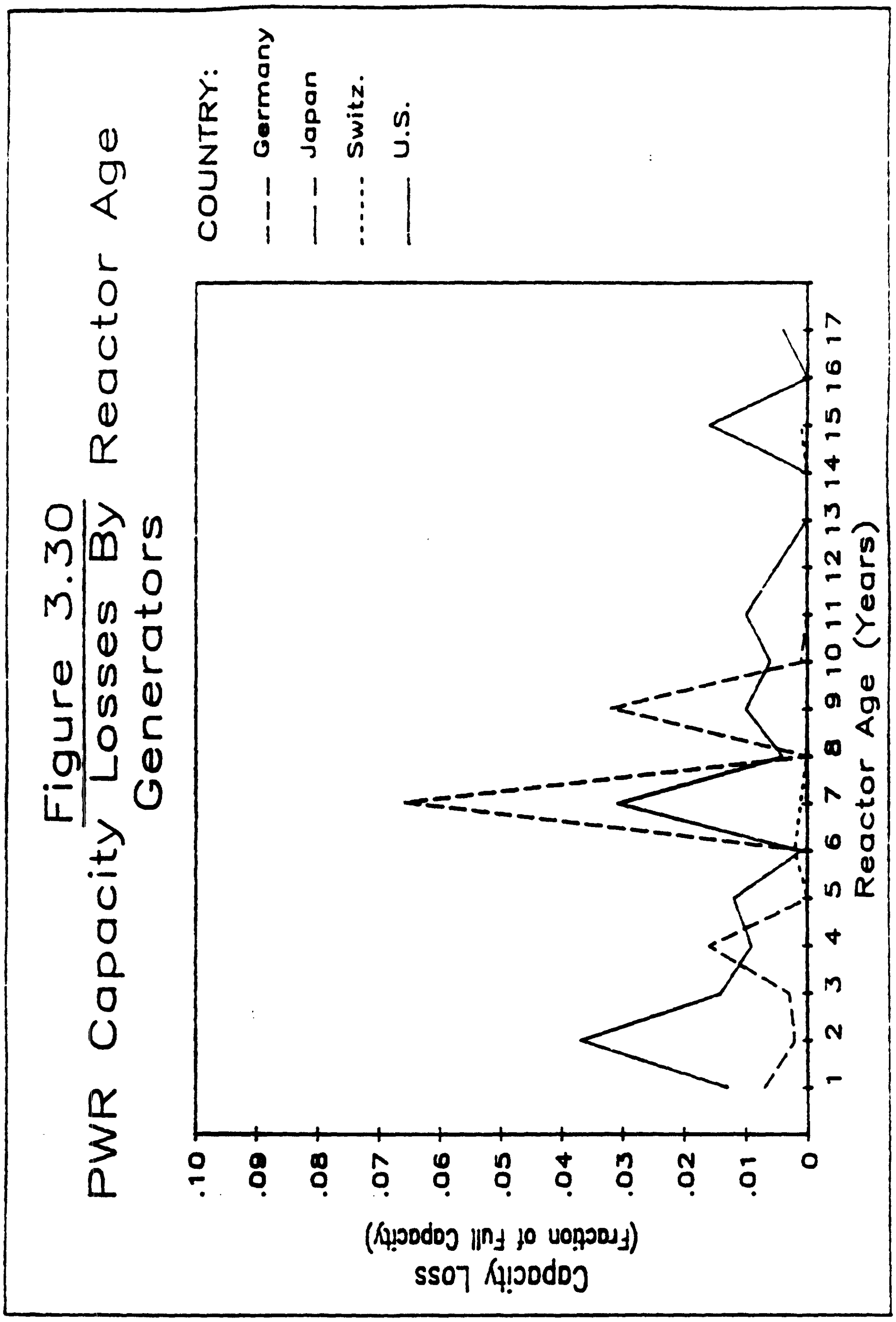



Figure 3.30
PWR Capacity Losses By Reactor Age
Generators

## Figure 3.31
## BWR Capacity Losses By Year
## Generators

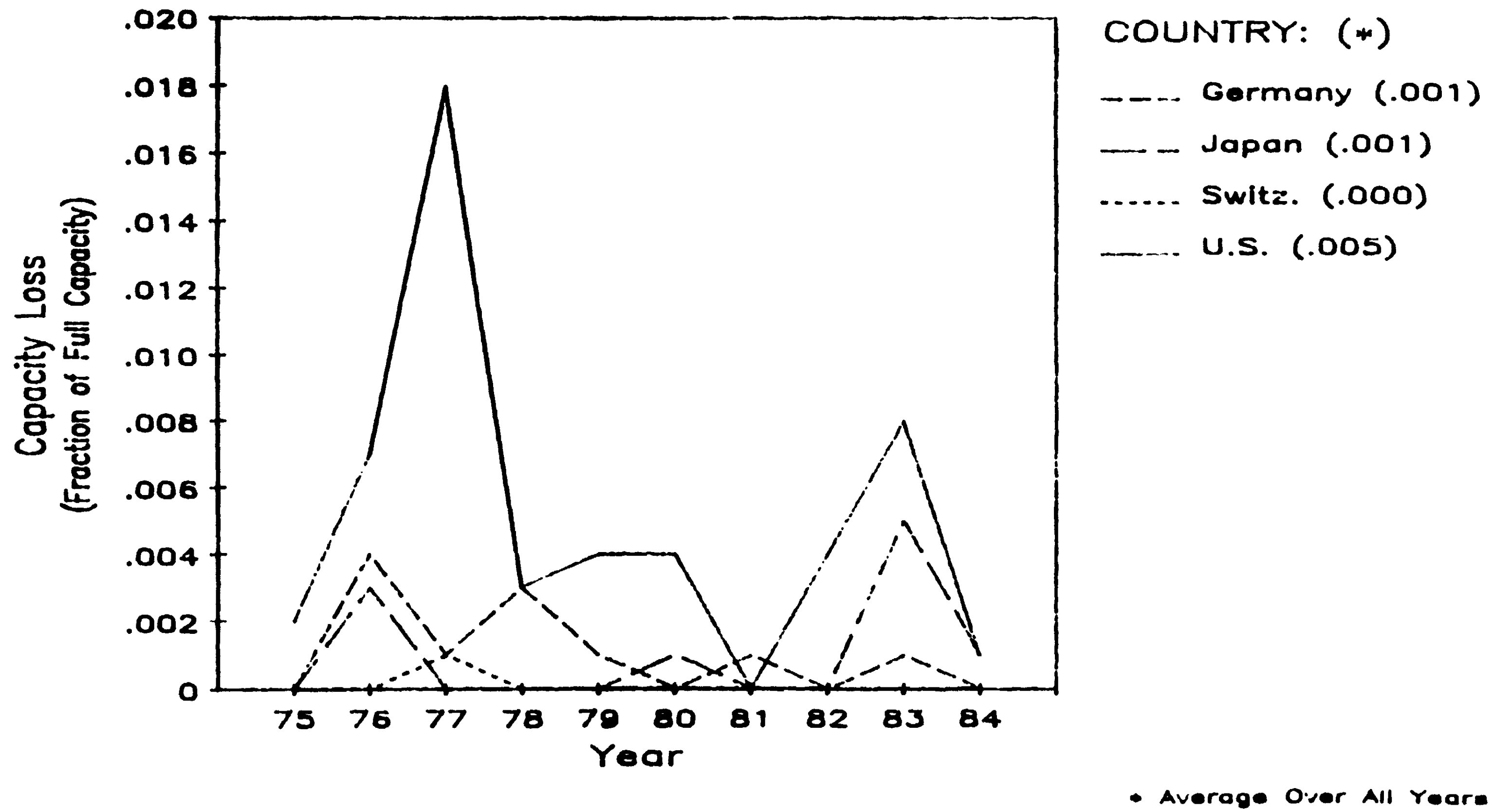
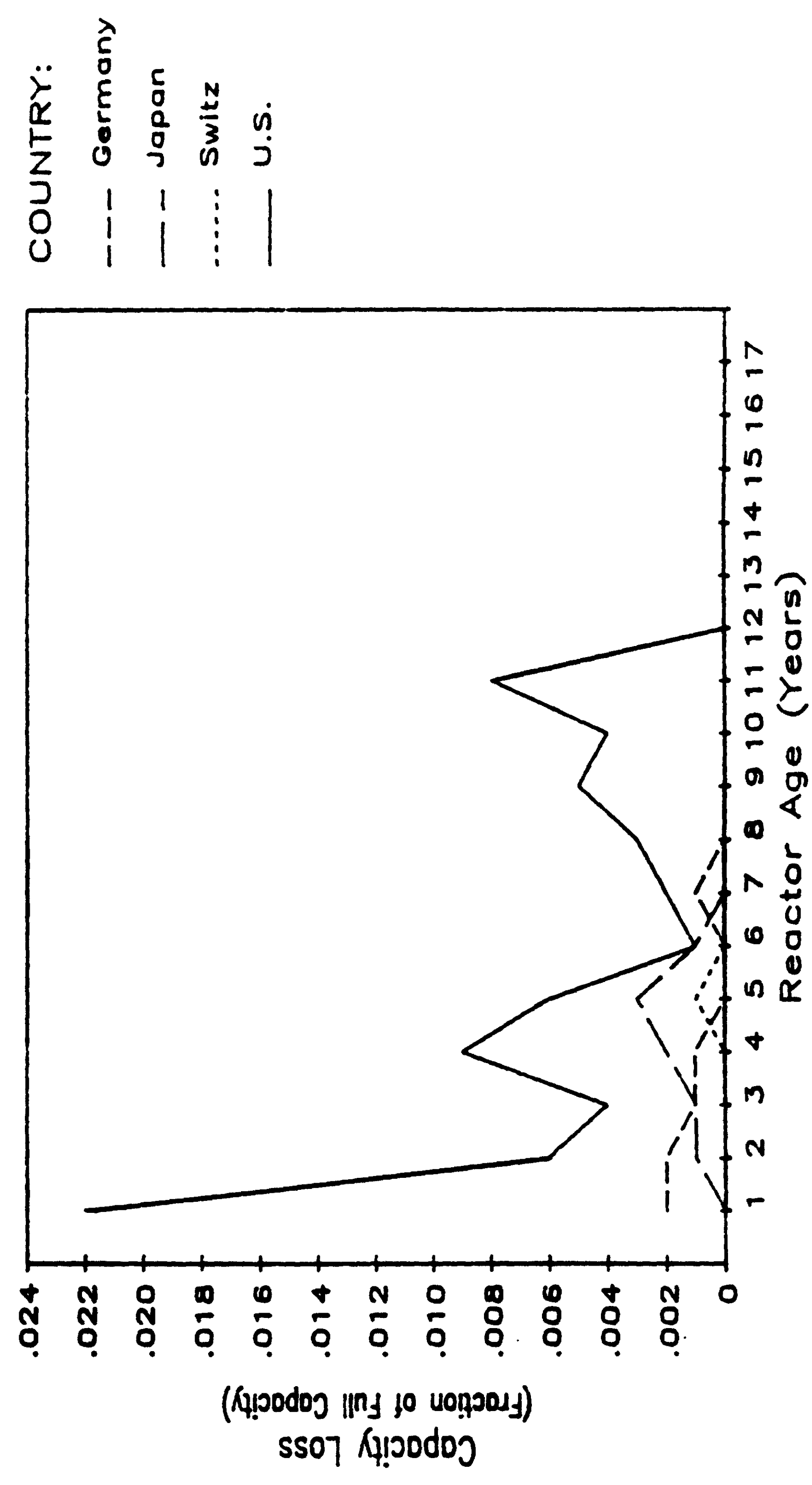


Figure 3.32
BWR Capacity Losses By Reactor Age
Generators



### 3.3.4 Condensers

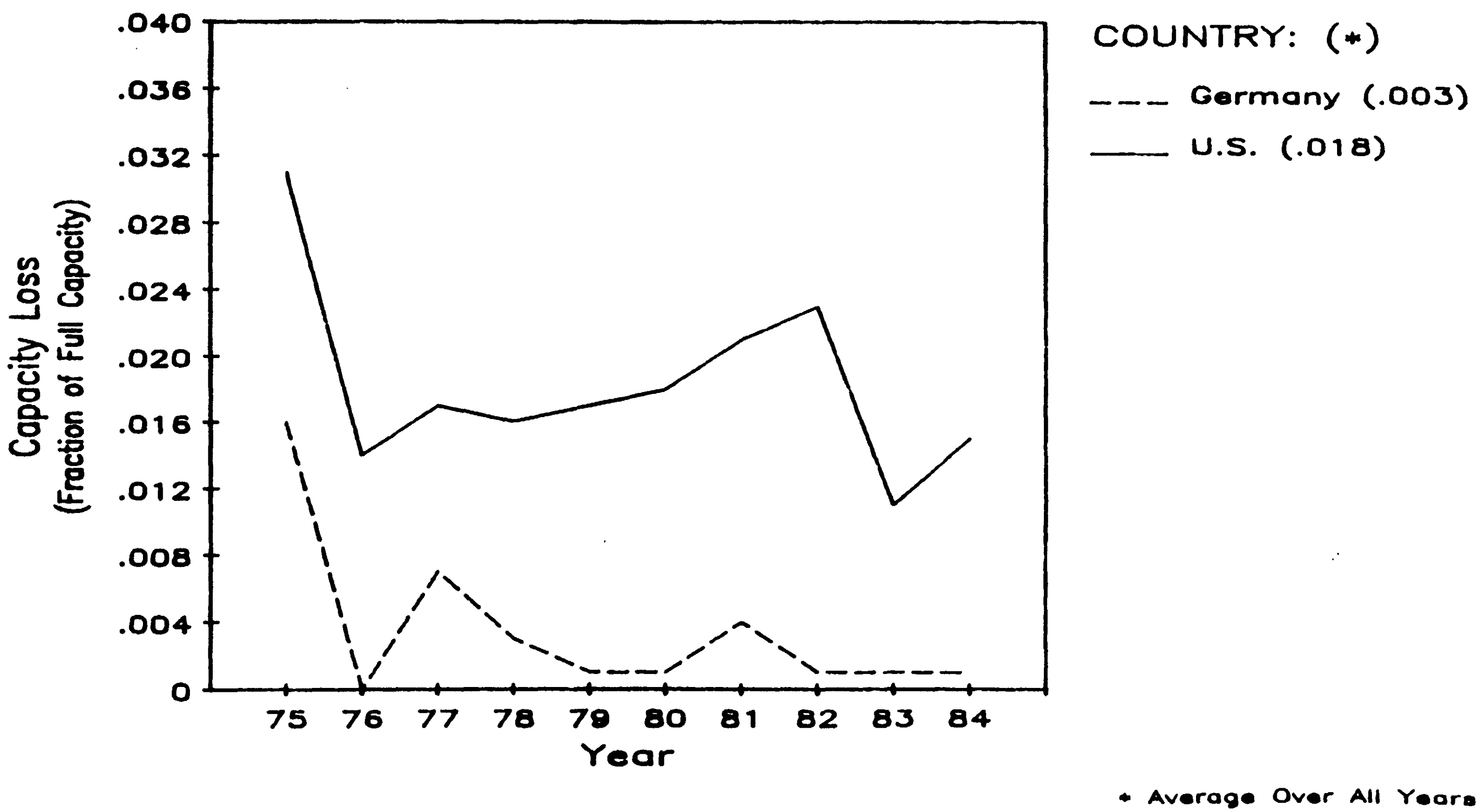
*PWR* condenser losses are shown as a function of time in Figure 3.33. As mentioned previously, data for condenser losses was only available for Germany and the U.S. The U.S. losses, averaging 1.8%, were six times higher than the average of the German losses. Many plants contributed to the averages in the U.S. so the data is not as sensitive to outages at individual plants. In Germany there are far fewer PWR's and the contributions were evenly spread over most of the plants with losses. The exception to this was in 1975 and 1977 when one plant contributed 66% and 78% respectively.

The same losses as a function of reactor age are shown in Figure 3.34. Both the U.S. and German condenser losses show an age dependence, with the older plants having smaller losses. It is not possible to determine with the data collected whether the losses are decreasing with age, or whether there is a technological reason why the older plants generally have fewer losses.

*BWR* condenser losses are given by year in Figure 3.35. Again the U.S. losses were higher than the German losses although the difference is not as great as it was for the PWR's. The U.S. losses show a slight improvement from 1975 to 1984. The improvement is significant because nearly all of the U.S. BWR's contributed condenser losses each year. The German losses show a curve that peaked in 1981 as a result of an 11.6% loss at a single plant averaged over four plants. Unlike the U.S., where nearly every BWR had condenser losses each year, only about half the German BWR's had condenser losses in any given year.

In Figure 3.36 the BWR condenser losses are plotted by reactor age. The U.S. losses were relatively uniform as a function of age. In Germany, however, the figure shows an age dependence with the older plants contributing fewer losses than the younger plants. The peak at age three was from the 11.6% outage mentioned in the preceding paragraph.

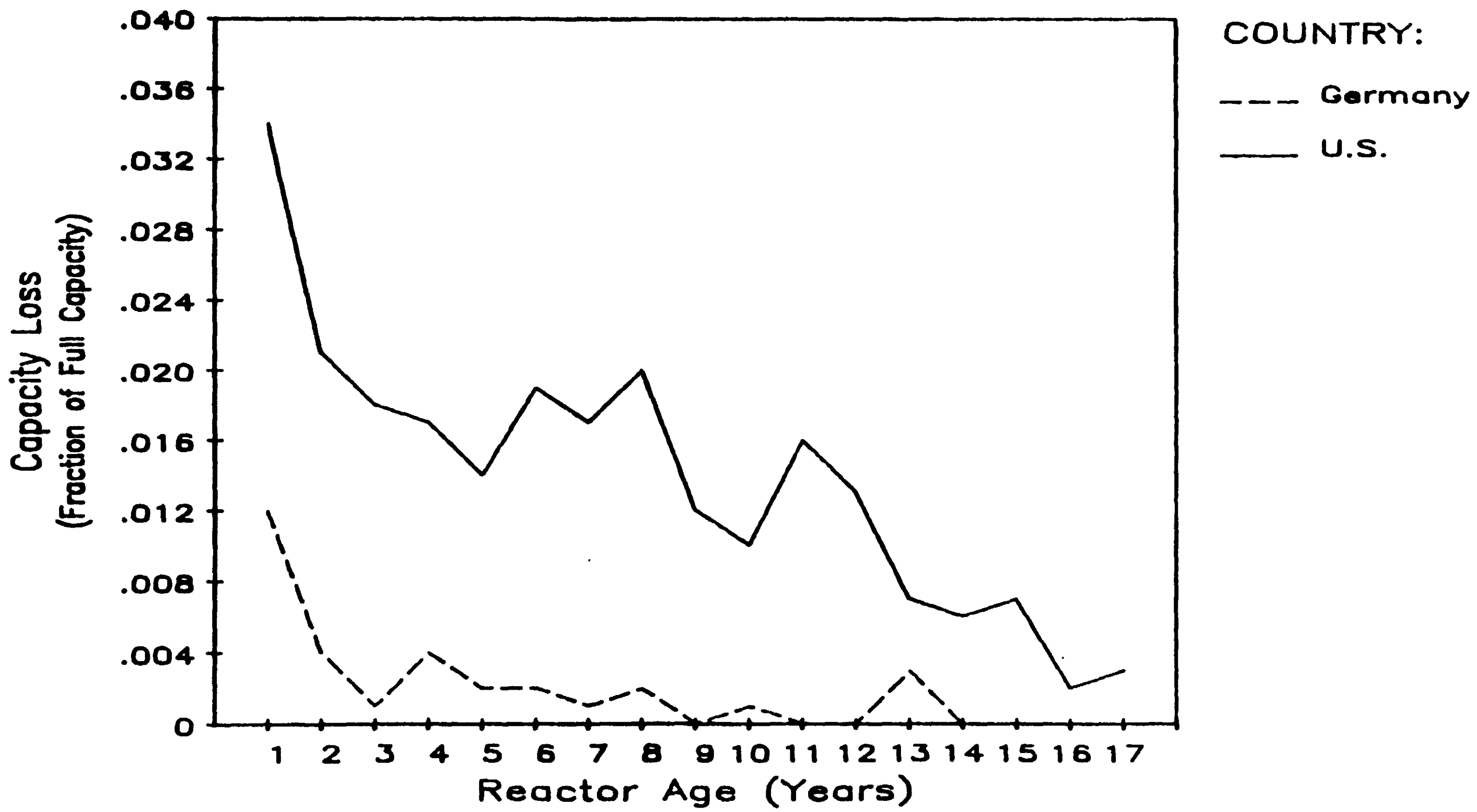
## Figure 3.33
PWR Capacity Losses By Year
Condensers



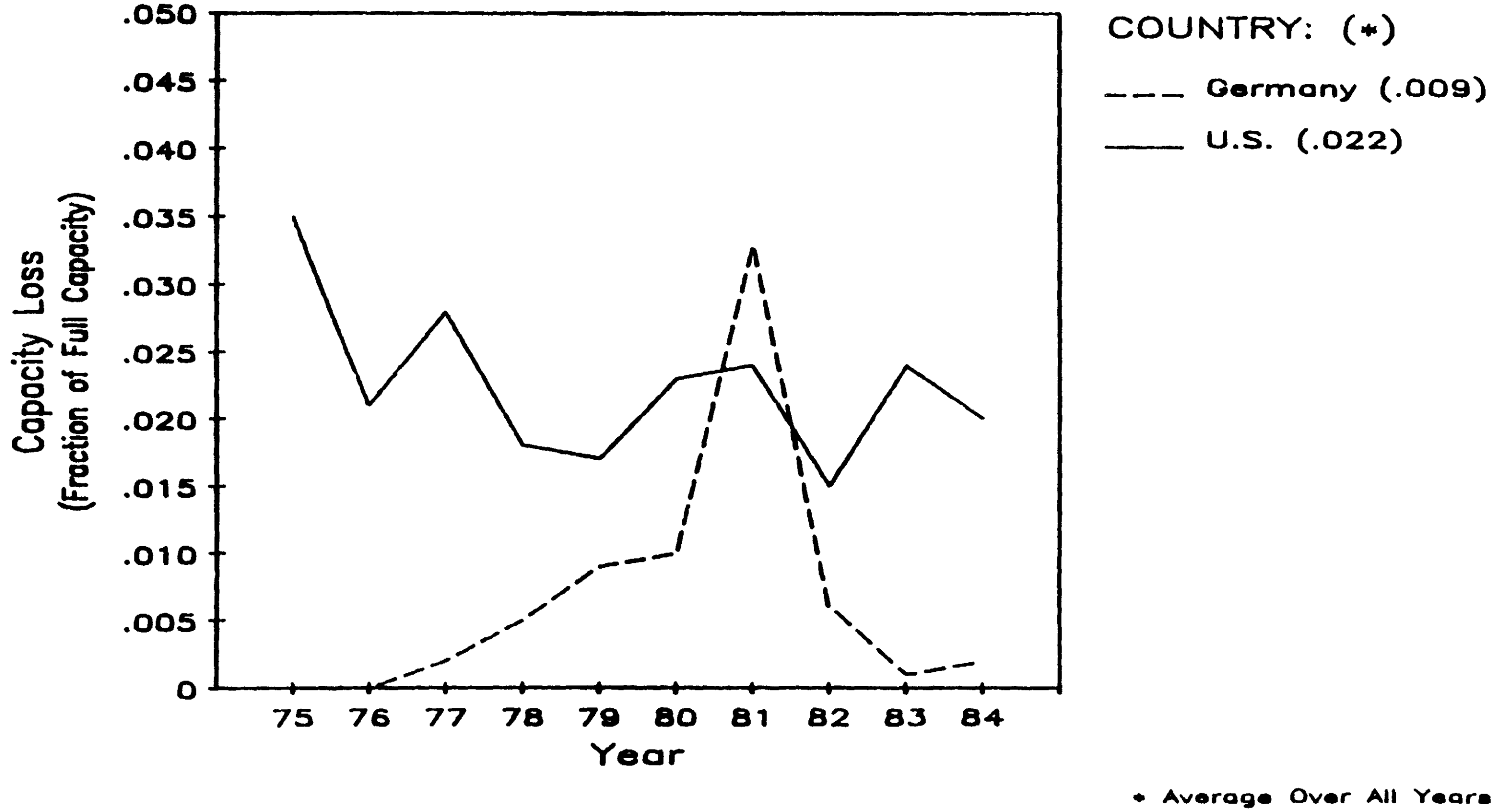
## Figure 3.34

PWR Capacity Losses By Reactor Age

Condensers



## Figure 3.35
BWR Capacity Losses By Year
Condensers



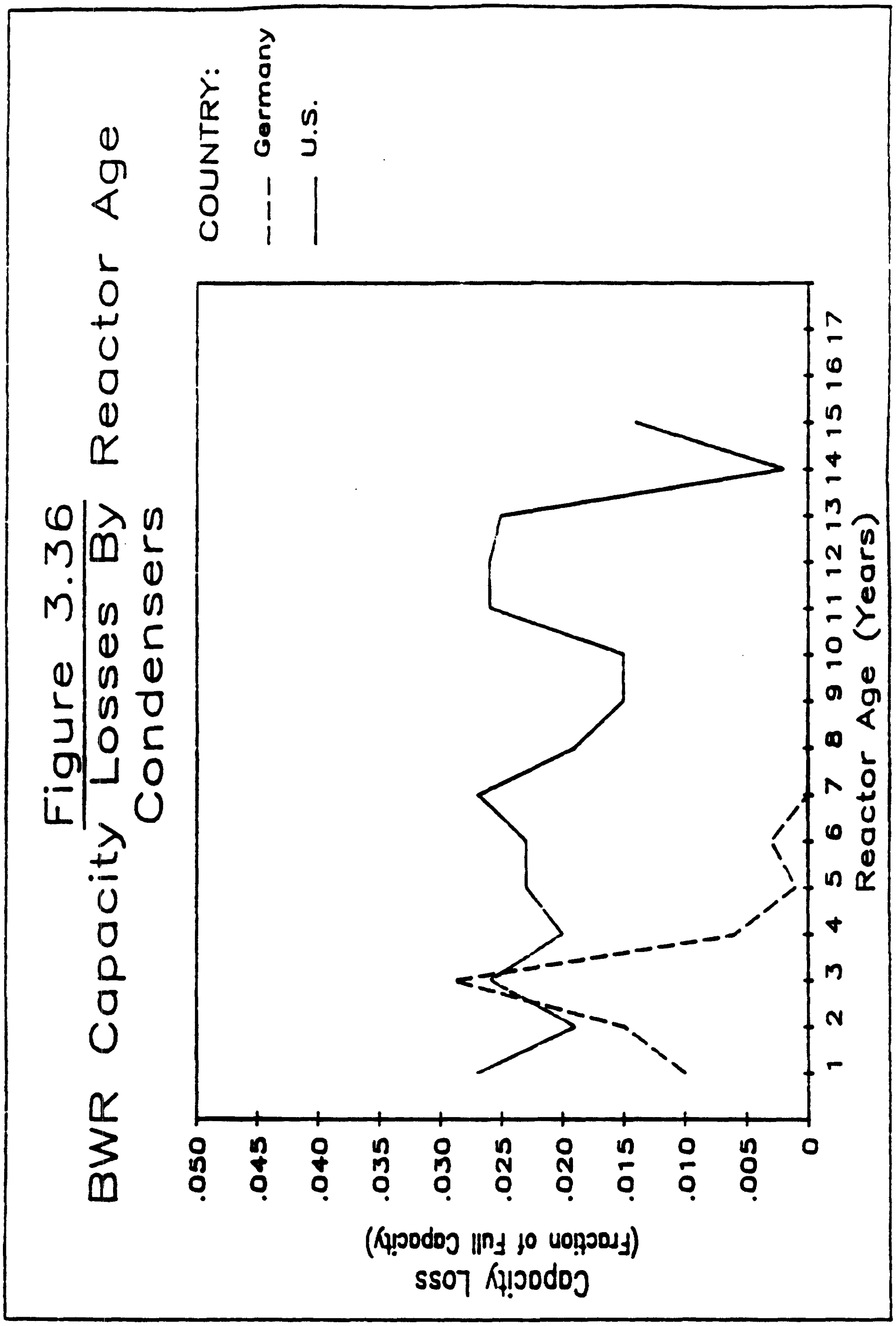



Figure 3.36
BWR Capacity Losses By Reactor Age
Condensers

### 3.3.5 CW, SW, and CCW Systems

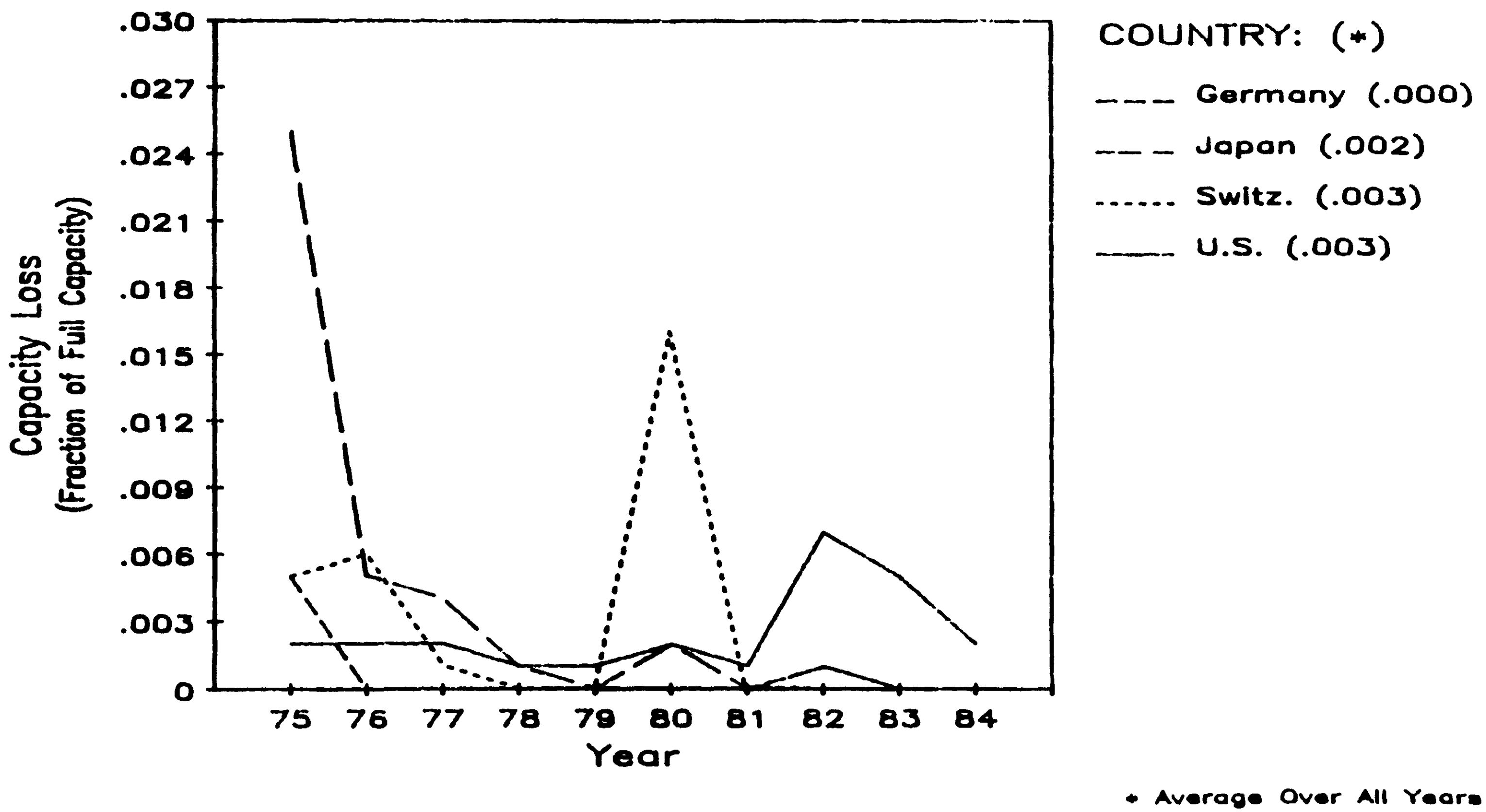
*PWR* losses as a function of time are shown in Figure 3.37 for the circulating water, service water, and component cooling water systems (CW/SW/CCW). For all of the countries shown the average losses were quite small, less than 0.3%. Germany has the lowest losses of any of the countries, showing negligible losses. Japanese losses show an improvement over time as not only the fraction of plants affected by losses drops, but also the magnitude of the losses decreases. The peak in 1975 was primarily due to a large outage at one plant. The U.S. and Switzerland both had the highest CW/SW/CCW losses averaging 0.3% each. Each had a peak that was from larger losses at one or two plants.

Figure 3.38 shows the PWR CW/SW/CCW losses as a function of reactor age. Fluctuation can be seen in the losses but this is insignificant since the magnitude of the losses is small. Japanese losses show an improvement over age with no losses being contributed by plants over seven years of age. The Swiss peak at age 1 was from a single outage at one plant and is not significant. U.S. losses are spread over all ages and do not exhibit any trend.

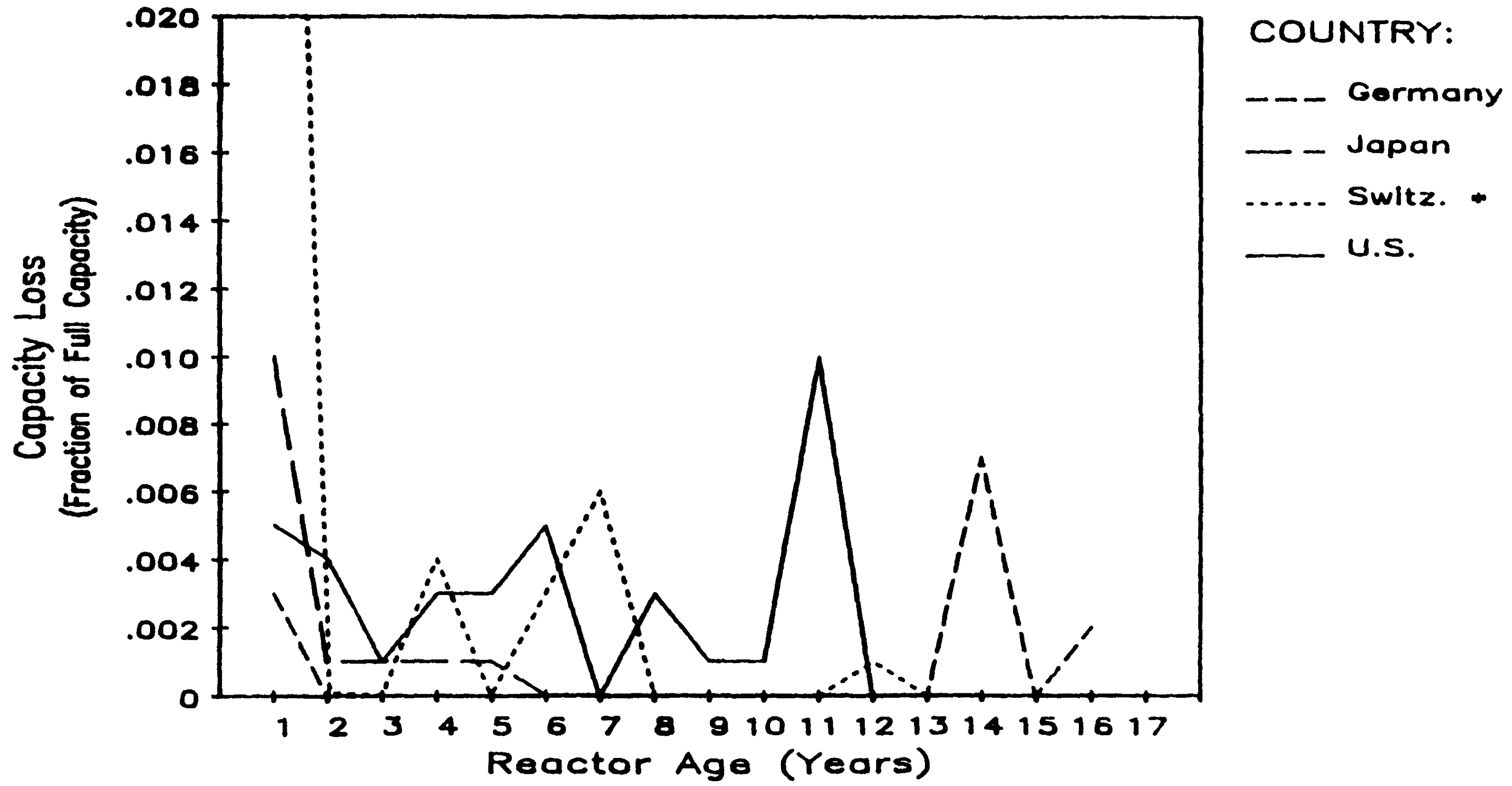
*BWR* CW/SW/CCW losses are plotted by year in Figure 3.39. As with the PWR's, the average losses are almost negligible. U.S. losses were the largest, averaging 0.4% and showing an improvement with time. German losses appeared in 1979 and have improved since then. Swiss losses were small and occurred in only three years.

BWR CW/SW/CCW losses plotted in Figure 3.40 as a function of age indicate that none of the countries exhibits an age dependence.

Figure 3.37
PWR Capacity Losses By Year
CW/SW/CCW Systems



## Figure 3.38
PWR Capacity Losses By Reactor Age
CW/SW/CCW Systems




* Loss Of .048 For AGE=1

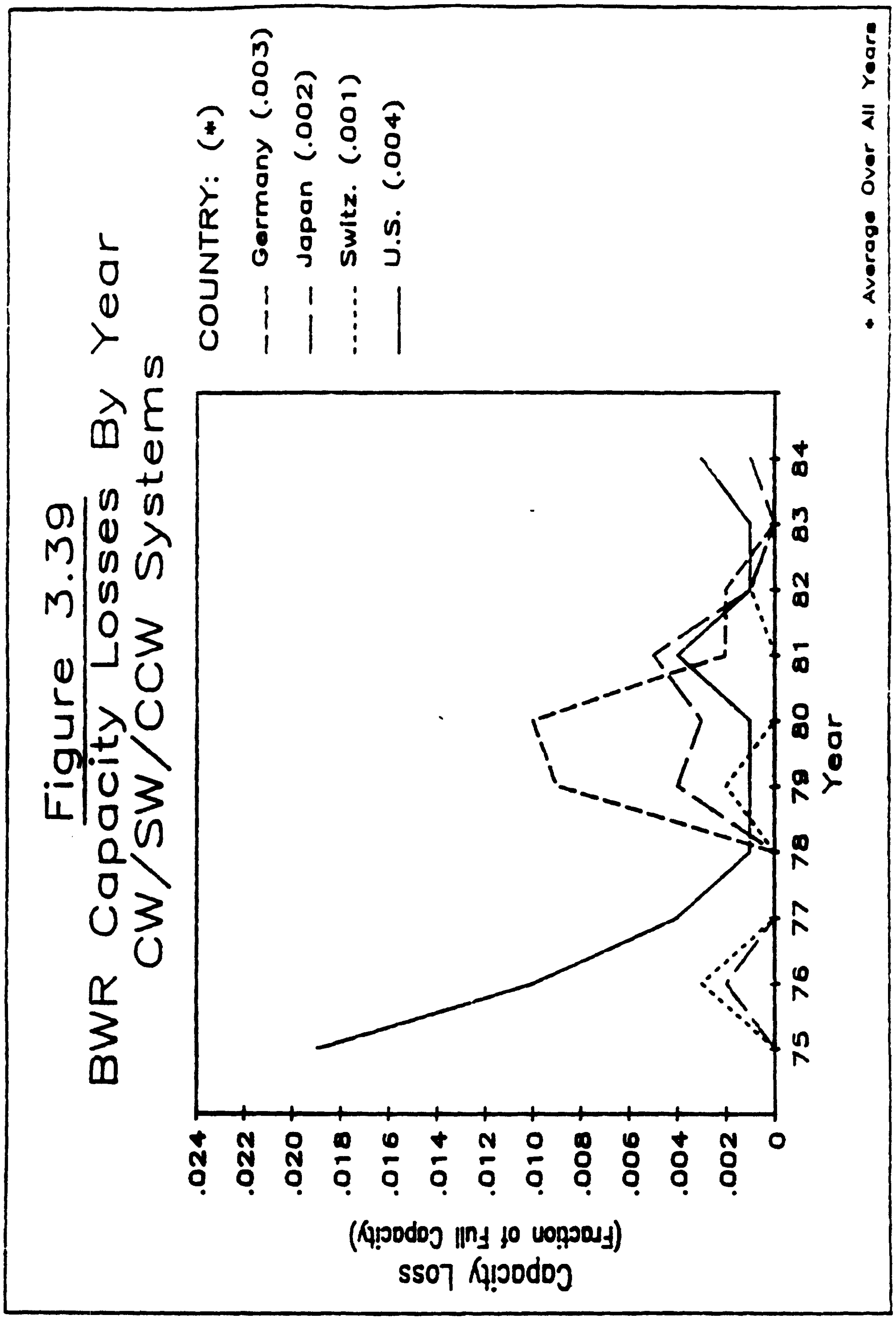
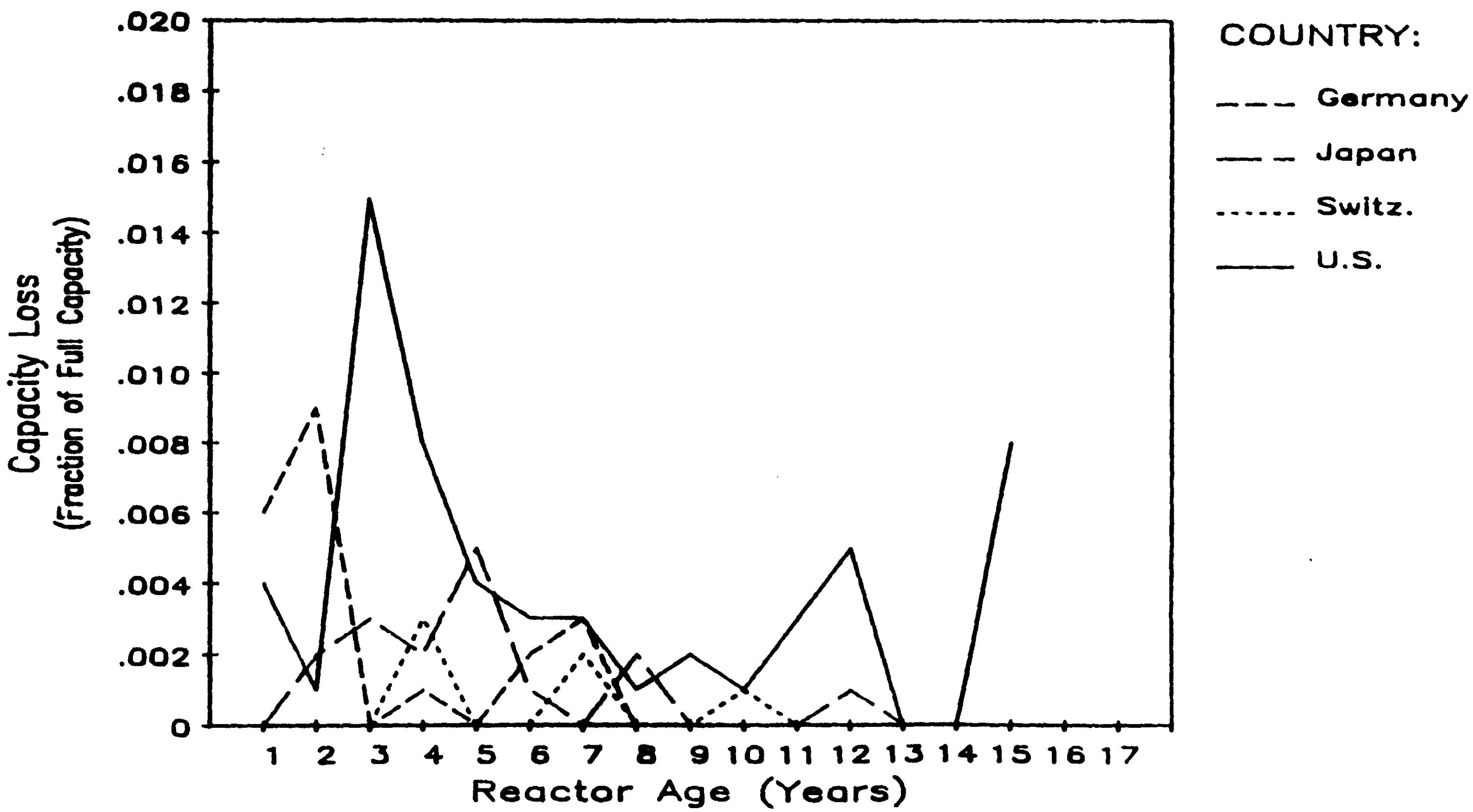


Figure 3.39
BWR Capacity Losses By Year
CW/SW/CCW Systems
COUNTRY: (*)
Germany (.003)
Japan (.002)
Switz. (.001)
U.S. (.004)
Capacity Loss
(Fraction of Full Capacity)
.024
.022
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
0
75
76
77
78
79
80
81
82
83
84
Year
* Average Over All Years

Figure 3.40

BWR Capacity Losses By Reactor Age CW/SW/CCW Systems



## 3.4 Economic

In this section the economic losses are compared. As mentioned in Section 3.0, economic losses are dependent upon the performance index used. The main difference in economic losses between capacity and energy availability is that economic grid losses are included when capacity is used. This must be considered when examining the figures below.

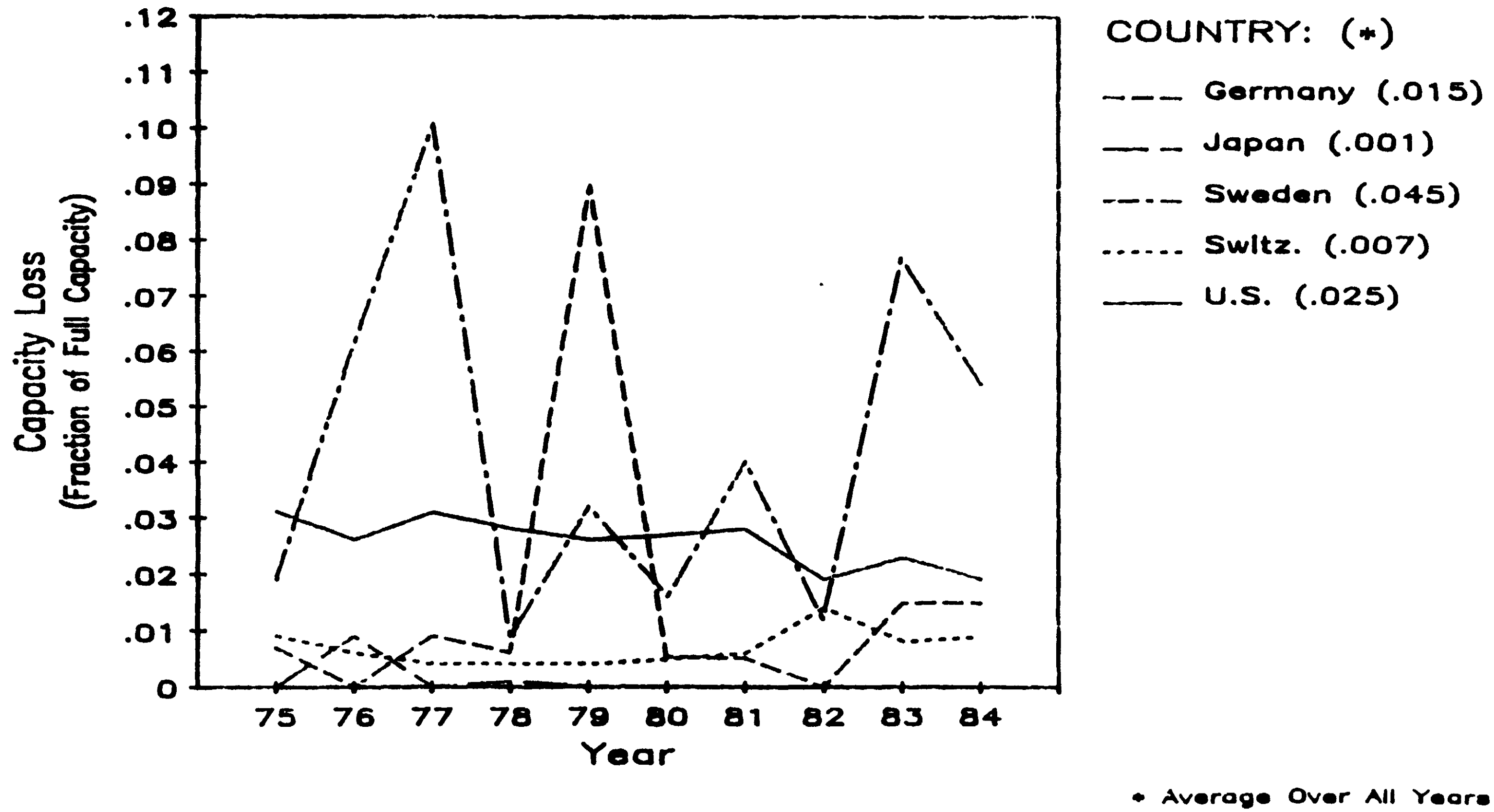
*PWR* economic losses are plotted by year in Figure 3.41. Sweden, with capacity as the performance index, had the highest average loss of 4.5%. The losses fluctuate because Sweden had no more than three commercial PWR's in any given year. U.S. economic losses, using energy availability as the performance index, were slightly more than half the size of the average Swedish losses and show little fluctuation. In addition, the U.S. losses also show a slow improvement with time. Since almost all the U.S. PWR's contribute to the average loss each year the improvement has significance. Swiss economic losses, averaging less than 1.0% using capacity as an index, also show very little fluctuation. The Swiss losses appear to be increasing slightly in recent years. The German economic losses, with energy availability as the performance index, show some fluctuation with no indication of a trend. Most of the German economic losses were from fuel cycle extensions. The large peak in 1979 was the result of fuel conservation and fuel cycle extension at two plants. The Japanese have had negligible economic losses.

The economic losses are plotted by reactor age in Figure 3.42. The German and Swedish losses fluctuate and do not show any dependence upon age. The U.S. and Swiss economic losses show very little fluctuation. In addition, the U.S. economic losses appear to decrease with age.

*BWR* economic losses are shown by year in Figure 3.43. The U.S. and Sweden have had the highest BWR economic losses with averages of 3.1%. In both countries the losses increased with time. The Swiss, with only one BWR, have averaged 1.8% losses, a little more than half that of the U.S. and Sweden. The Swiss losses have been slowly decreasing with time. German economic losses, mostly caused by fuel cycle extension, started in 1979 and have shown no increasing or decreasing tendency. The Japanese have had insignificant economic losses averaging 0.2%.

BWR economic losses are plotted by age in Figure 3.44. The German, Swedish and U.S. data fluctuate without obvious trends, although the U.S. may have a slight increasing age dependence. The peak in the U.S. data at age 10 is statistically significant while the peak at age 13 had one plant that contributed 80.6% of the total loss. The one Swiss BWR has shown decreasing economic losses as a function of age which is consistent with the time dependency observed in Figure 3.43.

## Figure 3.41
## PWR Capacity Losses By Year
## Economic



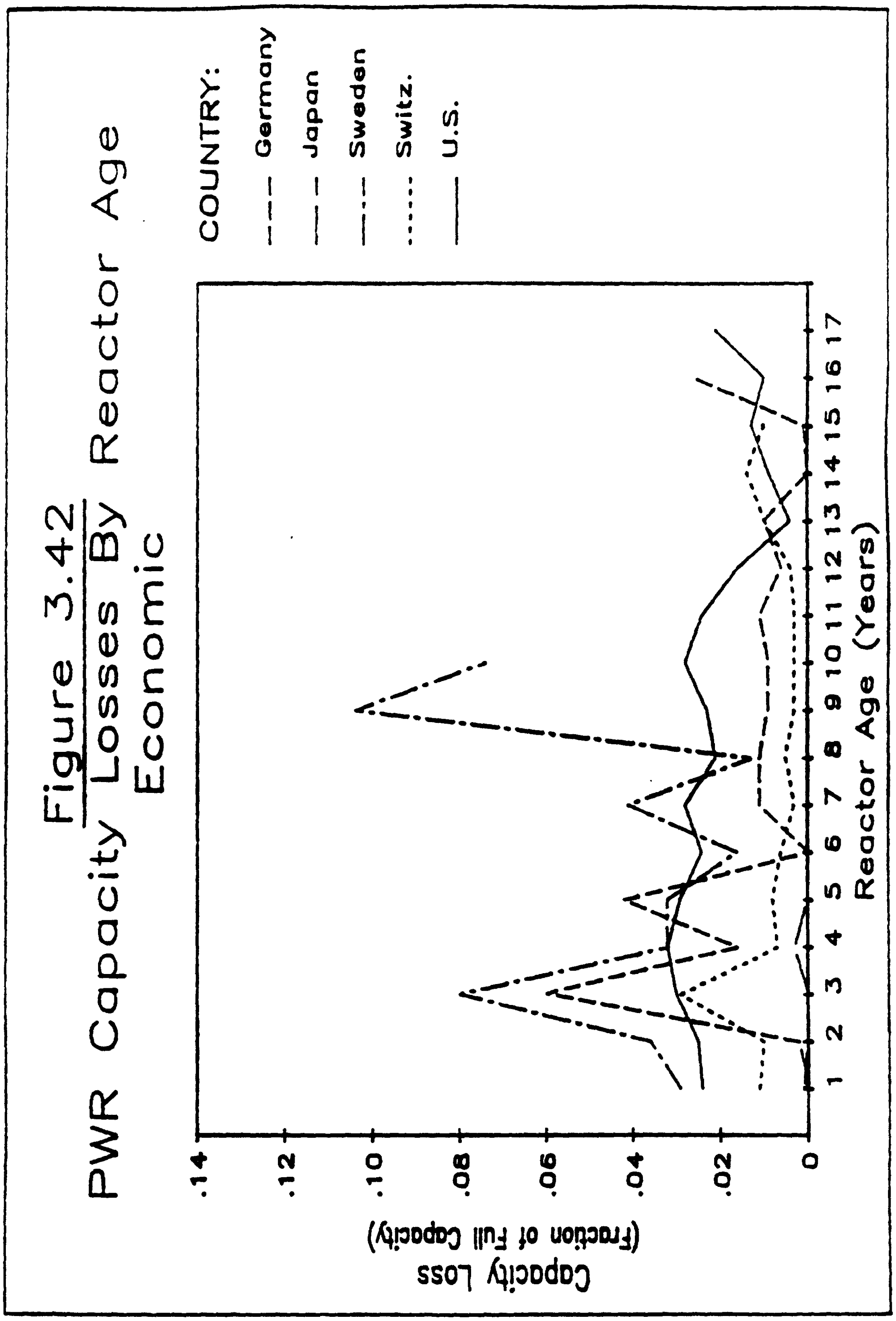



Figure 3.42
PWR Capacity Losses By Reactor Age
Economic

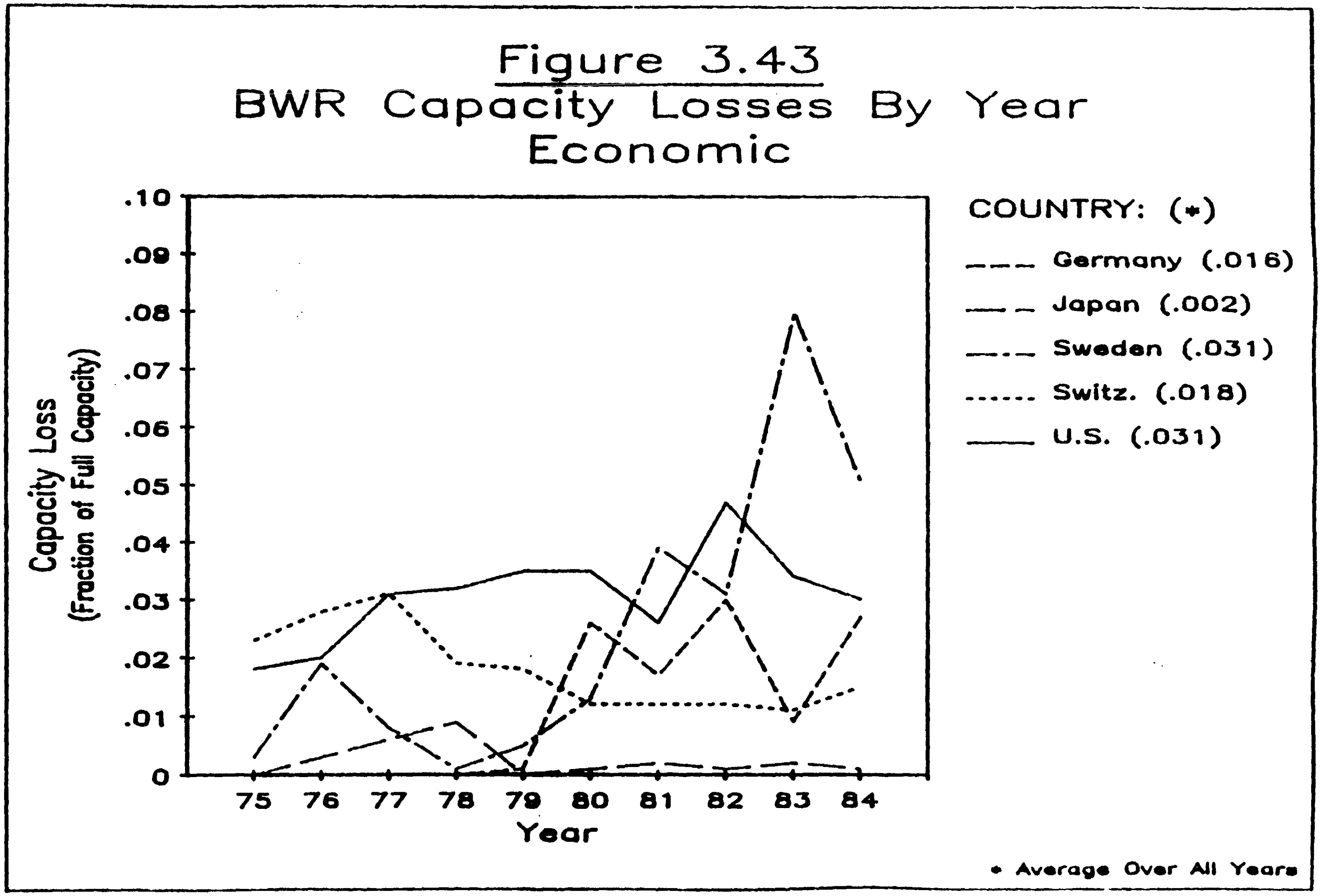


Figure 3.43
BWR Capacity Losses By Year
Economic
Capacity Loss
(Fraction of Full Capacity)
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
75
76
77
78
79
80
81
82
83
84
Year
COUNTRY: (*)
Germany (.016)
Japan (.002)
Sweden (.031)
Switz. (.018)
U.S. (.031)
* Average Over All Years

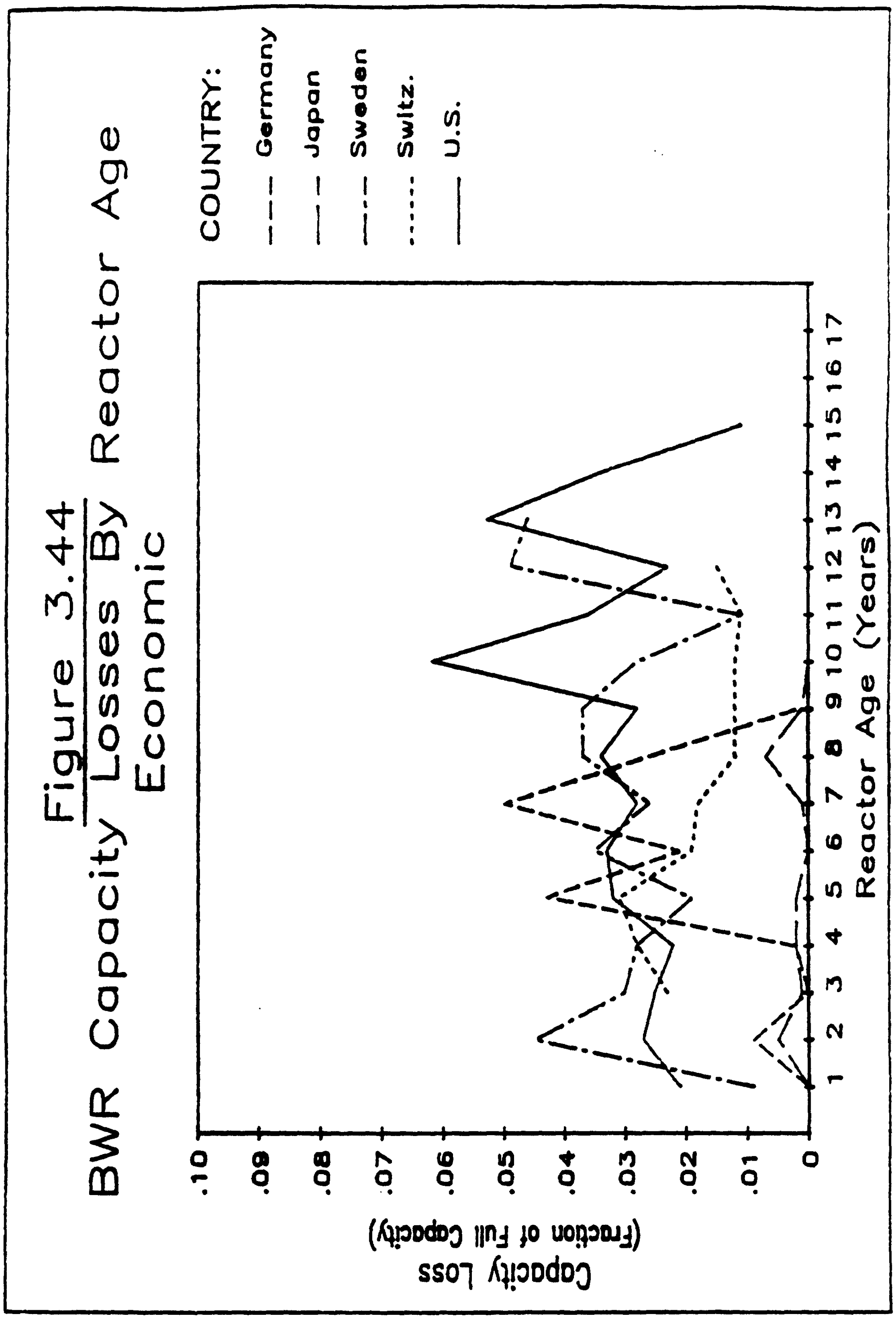


Figure 3.44
BWR Capacity Losses By Reactor Age
Economic
Capacity Loss
(Fraction of Full Capacity)
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Reactor Age (Years)
COUNTRY:
Germany
Japan
Sweden
Switz.
U.S.

## 3.5 Human

*PWR* losses caused by human error are plotted over time in Figure 3.45. Losses for all countries were generally small, averaging 0.5% or less. The U.S. has had the highest losses with an average of 0.5%. Although there is fluctuation in the U.S. losses, the peaks in 1978, 1981, and 1984 were the result of losses at a significant number of plants, and not from large outages at one or two plants as in the peak of 1976. Thus, human losses in U.S. PWR's are generally increasing. Whether this is actually a trend or whether the industry is admitting to more of their mistakes is unknown. The Swedish PWR's have shown the second largest human losses with an average of 0.2%. All of the losses prior to 1984 were from one plant in each year. The French, Japanese and Swiss PWR's have had little or no human losses.

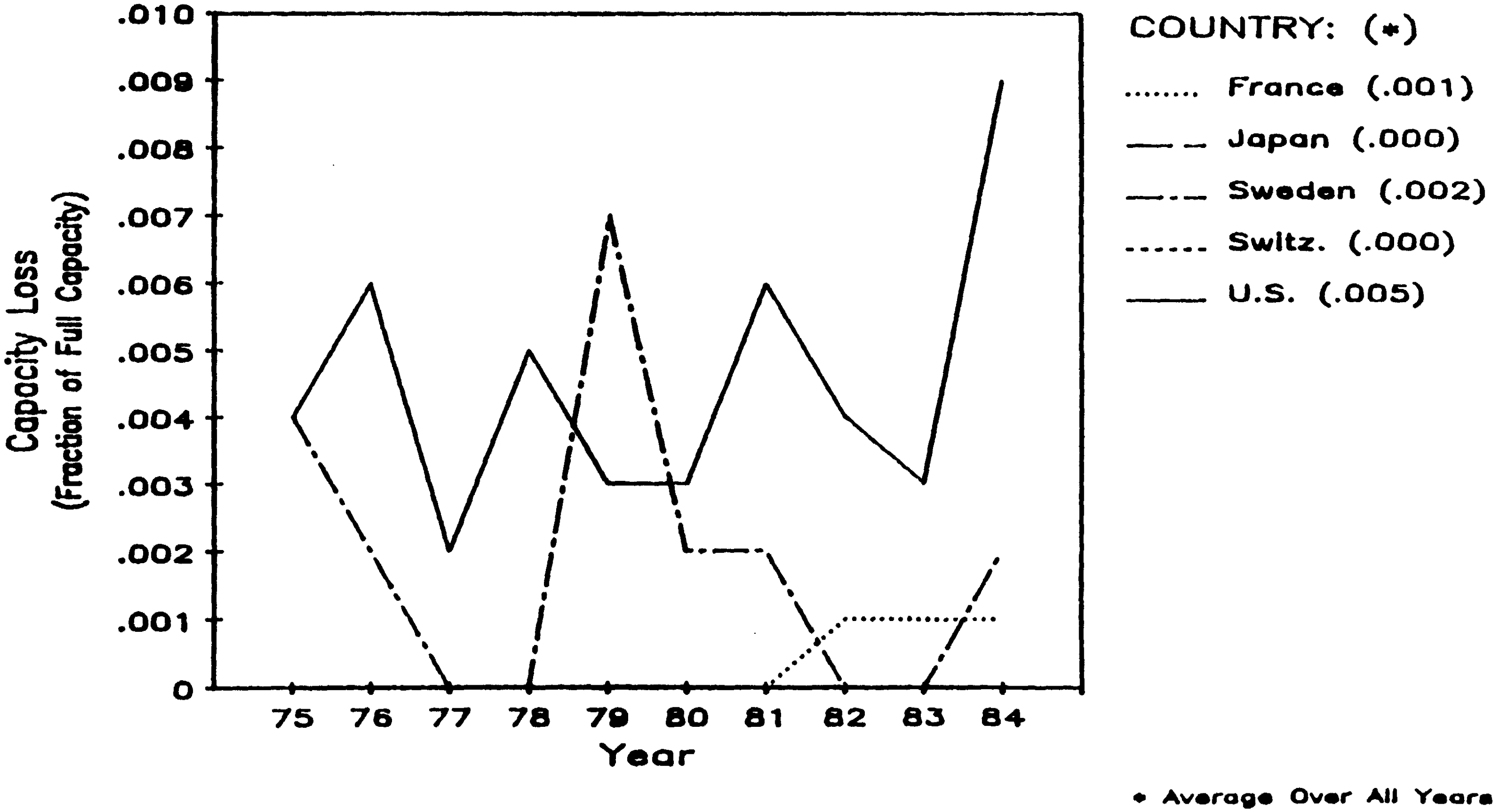
The PWR human losses as a function of age are shown graphically in Figure 3.46. No trend is apparent for the U.S. plants as the peak in the second year corresponds to the single outage mentioned above in 1976. Human losses in the Swiss PWR's have only occurred during the first six years of operation. The Swedish data shows only fluctuation with no trend.

*BWR* losses caused by human error are plotted over time in Figure 3.47. The U.S. is the only country showing significant losses with an average of 0.7%. In addition, human losses in U.S. BWR's have been increasing since 1975. As with the PWR's, this may be caused by less reluctance on the part of the industry to report outages resulting from human error.

The BWR human losses are plotted as a function of plant age in Figure 3.48. In this figure the U.S. losses appear to improve with age. The peak at ages 1 and 2 is comprised of outages from many plants and is therefore significant. The peaks at ages four, eight, and fifteen all had one plant contributing a large fraction of the losses. The trend indicated could be the result of the greater personnel experience at the older plants.

# Figure 3.45

## PWR Capacity Losses By Year
## Human



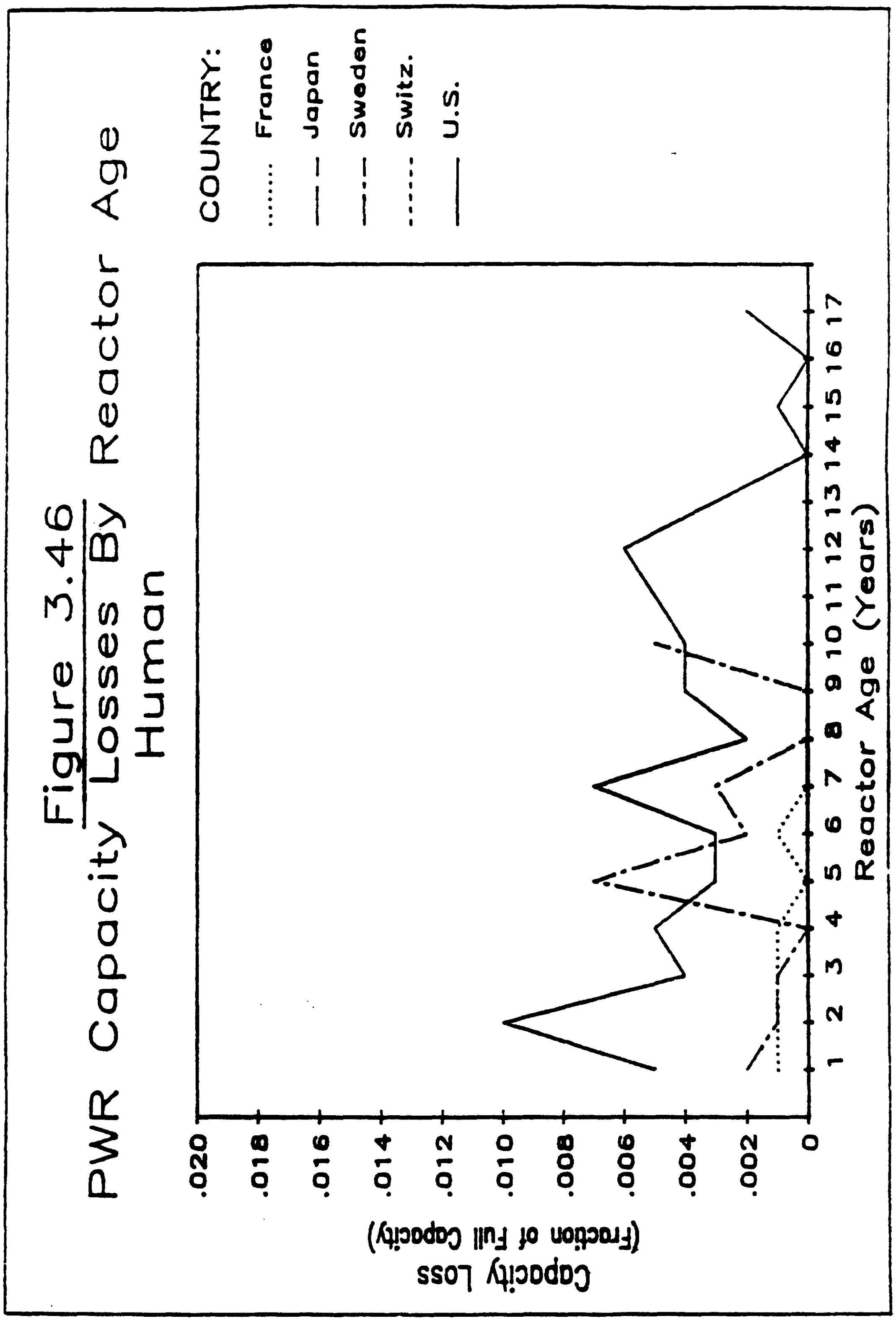
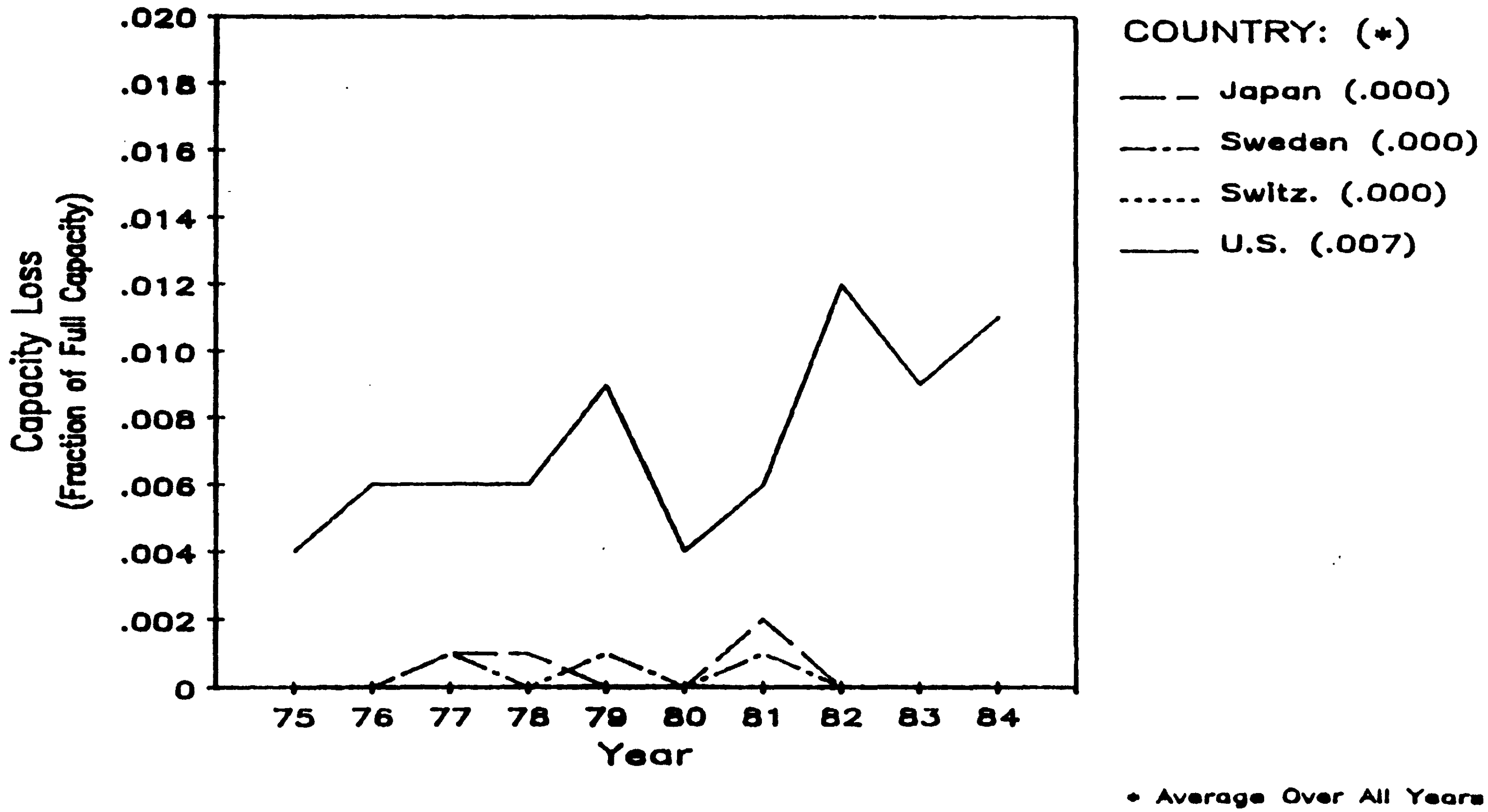


Figure 3.46
PWR Capacity Losses By Reactor Age
Human
COUNTRY:
France
Japan
Sweden
Switz.
U.S.
Capacity Loss
(Fraction of Full Capacity)
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Reactor Age (Years)

## Figure 3.47

BWR Capacity Losses By Year
Human



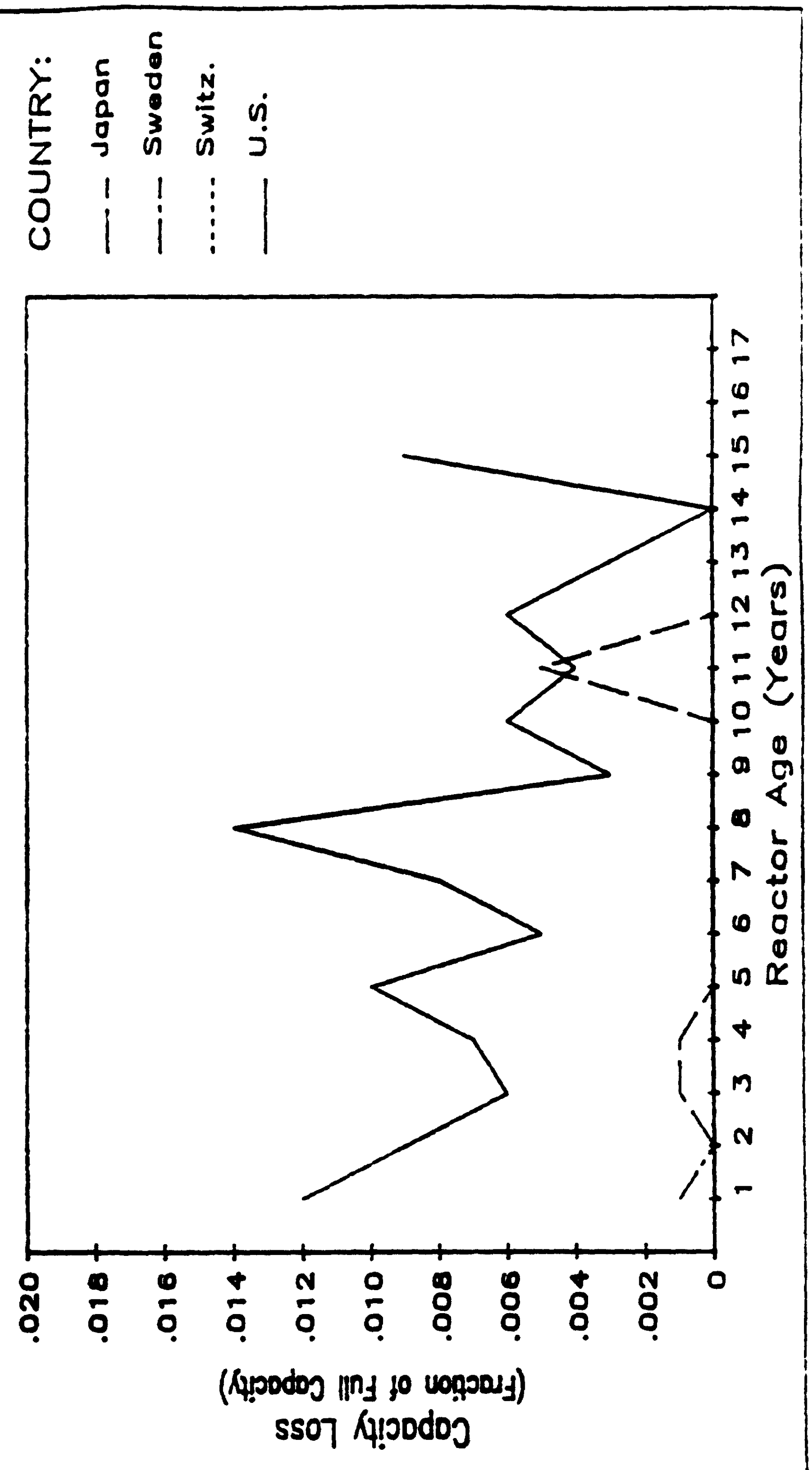



Figure 3.48
BWR Capacity Losses By Reactor Age
Human

## 3.6 Regulatory

*PWR* regulatory losses are plotted over time in Figure 3.49. The French, Japanese, and Swiss plants have reported no regulatory losses. Germany, Sweden and the United States have all had regulatory losses with averages of 0.9%, 4.4%, and 10.9% respectively. The reported German regulatory losses have generally been small, never amounting to more than 2.8% average per year. In all years except 1976 and 1984, when there were relatively large losses at single plants, average losses have been less than 0.8%. Swedish regulatory losses have been only 40% as high as the U.S. losses. From 1975 to 1982 the losses shown were from single plants. The large peak spanning 1982 and 1983 affected only two units. The specific issue requiring the shutdown of the plants is unknown. Regulatory losses have been the highest in the U.S. From 1975 to 1978 U.S. losses were less than 5.3%. In 1979, after the accident at Three Mile Island, regulatory losses jumped to over 16% and have not dropped below 10% since. Both TMI reactors have been included in the losses. The inclusion of the damaged reactor adds at most only 2.2% to the total regulatory loss.

PWR regulatory losses are plotted as a function of reactor age in Figure 3.50. Generally one would not expect regulatory losses to exhibit an age dependence since regulatory issues are time dependent. However, certain issues may affect older plants more severely than the younger ones. The German losses are spread out over all ages and show no age dependence. The Swedish losses have a peak at ages two and three which corresponds to the large losses in 1982 and 1983 that were mentioned above. The U.S. regulatory losses show an average of approximately 9% from ages 1 through 12, with several large peaks occurring at ages 13 and 16. The peak at age 13 is composed of large outages at four out six plants, while the peak from age 16 to age 17 is from lone units contributing over 96% of the loss for that age. Regulatory losses from increased regulation in the wake of the TMI accident were generally spread over reactors of all ages. The abrupt age dependency shown may be the result of this regulation having a greater impact on older plants with technologically inferior design and/or equipment.

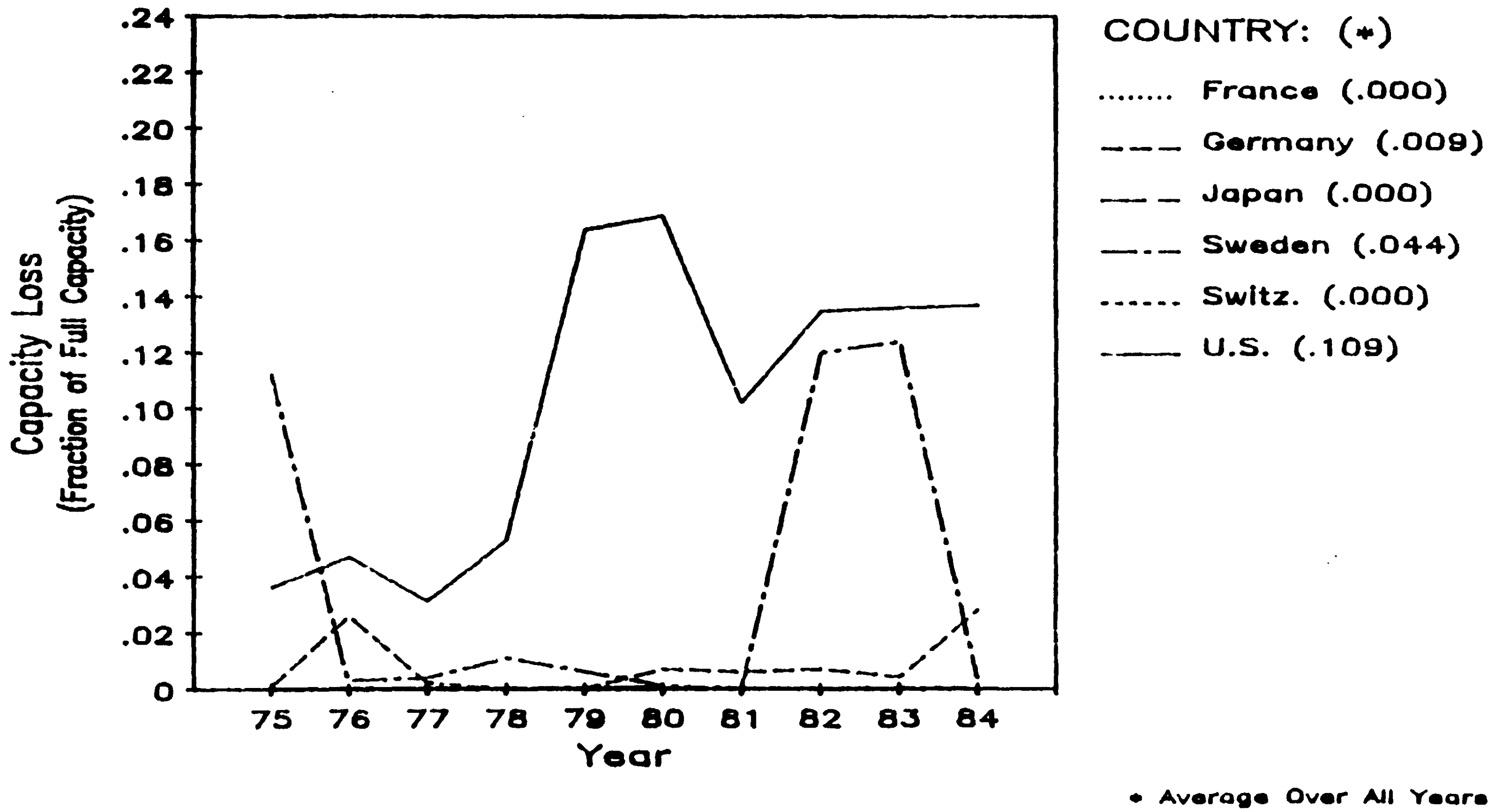
*BWR* regulatory losses are shown graphically in Figure 3.51. German regulatory losses were the largest with an average of 11.3%, just exceeding the U.S.'s average of 10.4%. The German data exhibits two large peaks, one in 1976 and the other in 1979 and 1980. The first peak was the result of a single large outage at the only BWR commercial at that time. The second peak arises from a very large outage at one plant that was spread over two years. The plot of the U.S. data shows that the BWR regulatory losses have been steadily increasing with time, from 7.4% in 1975 to 21.8% in 1984. Sweden reported almost negligible losses with an average of 0.7%. Swedish losses doubled in 1980 most likely as a result of TMI. Japan and Switzerland reported no BWR regulatory losses.

BWR regulatory losses as a function of reactor age are plotted in Figure 3.52. The German losses are all clustered about the ages 3 and 4. This peak corresponds to the peaks exhibited by the German data in Figure 3.51. The plot of the U.S. losses shows some fluctuation in the older plants with a general trend of increasing losses with age. Again, this could have been the result of a differential in the impact in regulation between younger and older plants. As in the previous figure, the Swedish losses are fairly evenly distributed over age.

# Figure 3.49

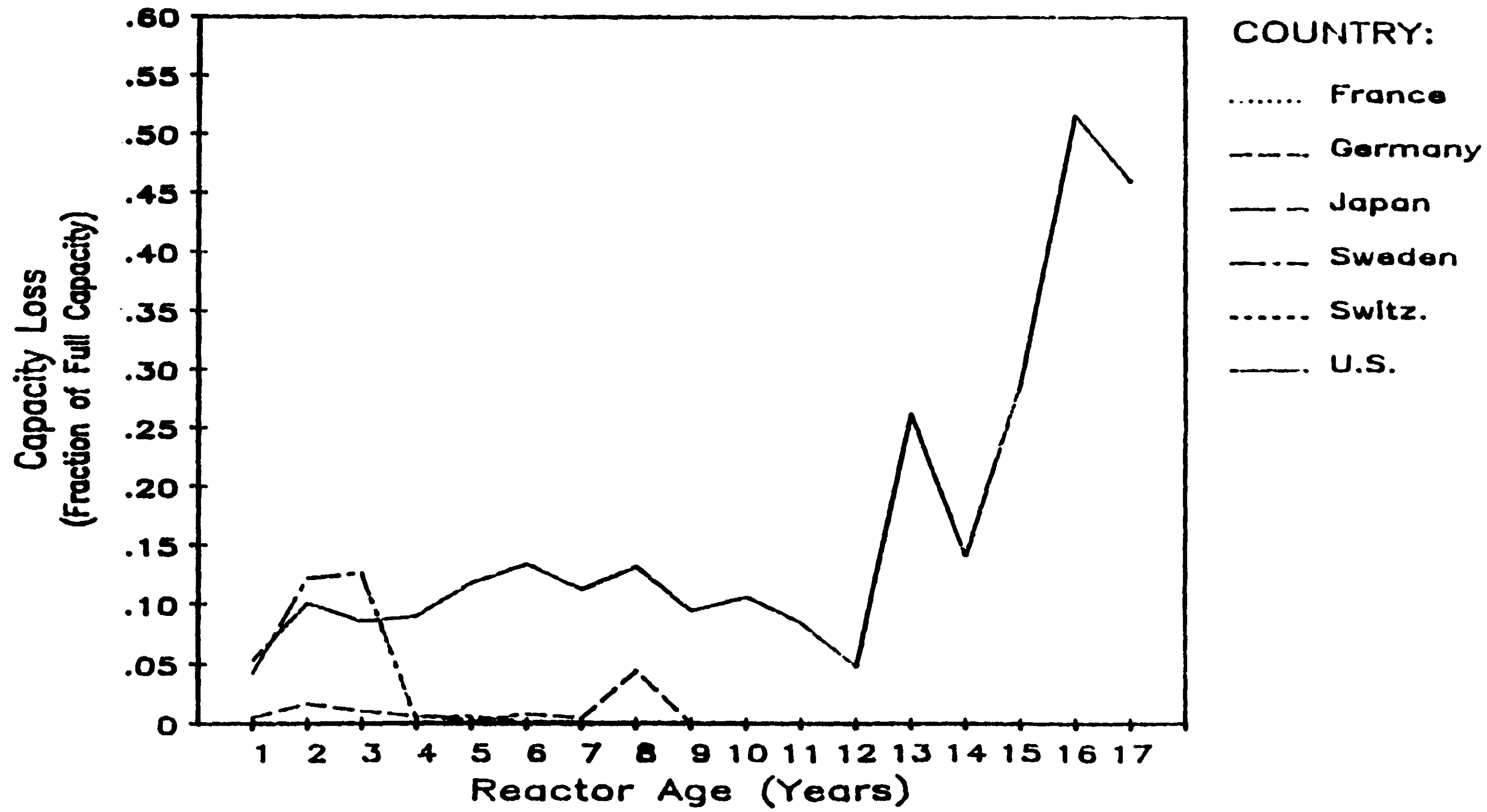
## PWR Capacity Losses By Year

## Regulatory



## Figure 3.50

PWR Capacity Losses By Reactor Age
Regulatory



# Figure 3.51
## BWR Capacity Losses By Year
## Regulatory

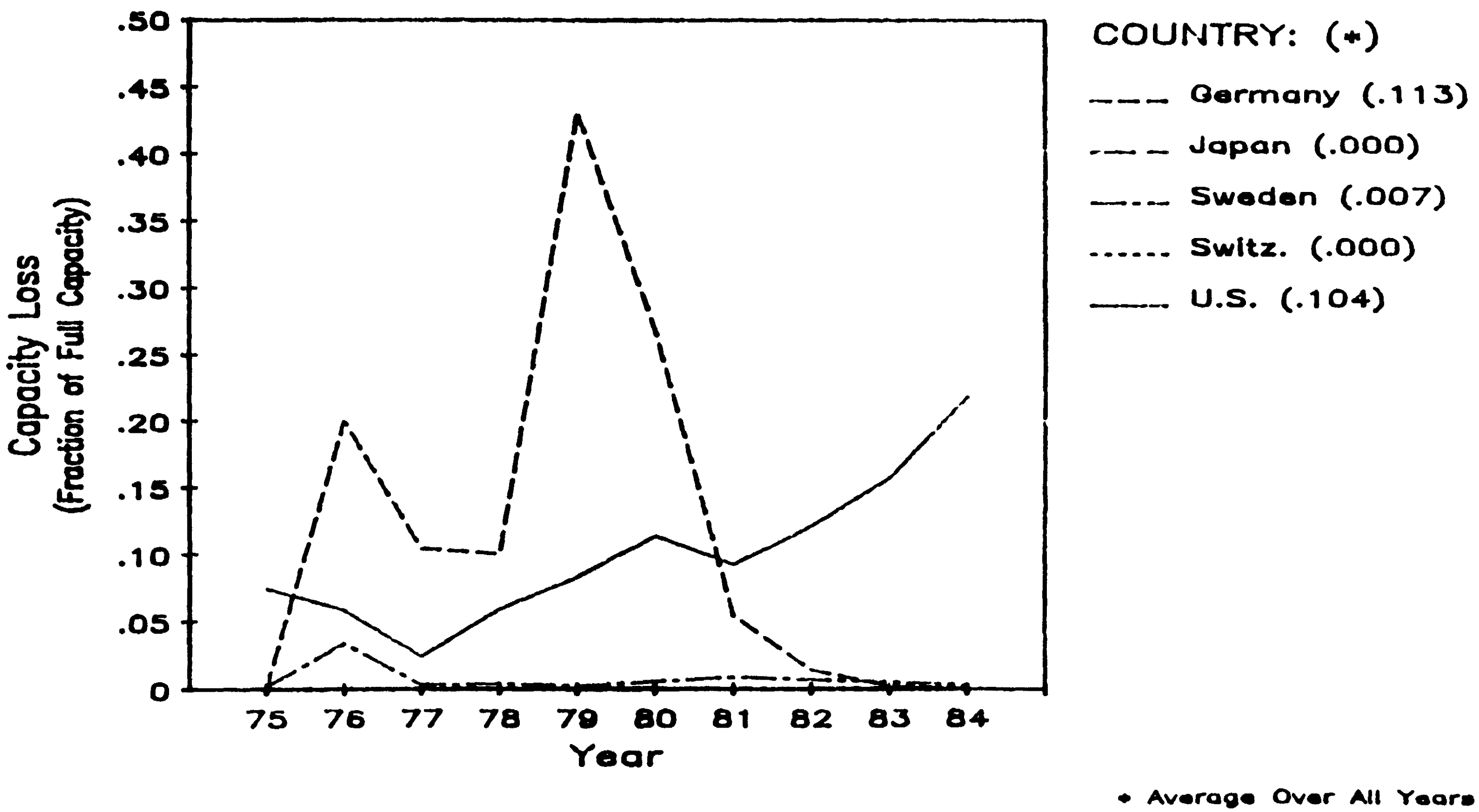
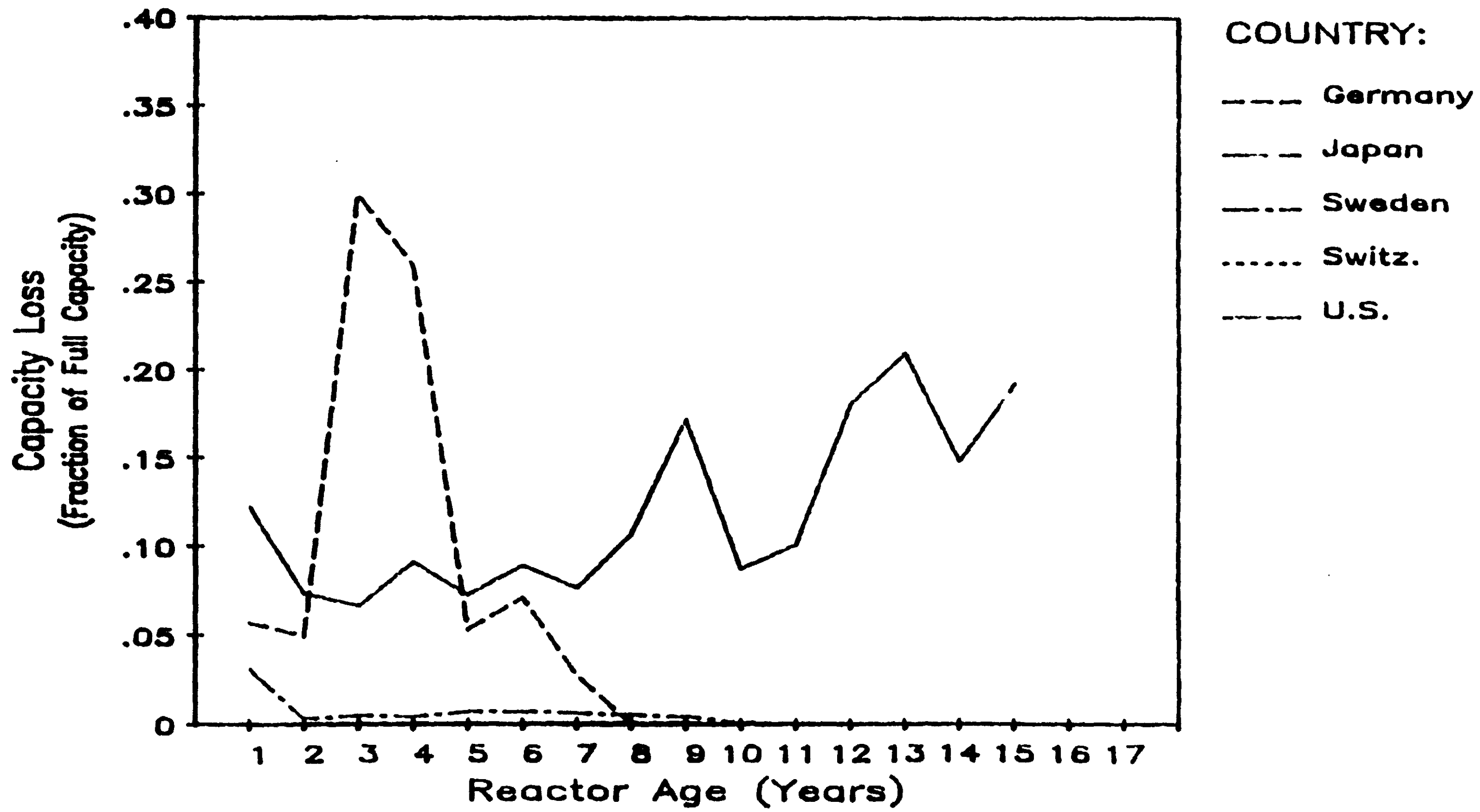


Figure 3.52
BWR Capacity Losses By Reactor Age
Regulatory



## 4.0 Discrepancies in Performance

In this chapter the discrepancies in nuclear power plant performance will be discussed. Using the results of the data analysis in Chapters 2 and 3, the performance of countries that performed well will be compared with that from countries that performed poorly. The result of this chapter will be the identification of the systems and operations that have been causing low performance. PWR and BWR performance will be discussed separately and unless otherwise stated, all averages given are over the entire study period from 1975 to 1984.

## 4.1 Pressurized Water Reactors

Table 4.1 contains a summary of the average PWR performance over 1975 to 1984 for each category. The countries are ordered from left to right by decreasing overall performance. The losses shown are for combined forced and scheduled losses. The exceptions to this are France and Sweden where the data shown is only for forced outages. The Swiss data shown is for all three PWR's. However, the Swiss reporting of maintenance performed during refueling was inconsistent with that done in the other countries. Therefore, the data for the one Swiss PWR that reported maintenance performed during

Table 4.1 - Summary of Average PWR Performance
(Percent of Full Capacity)

| Category | Switz. | Ger. | Fra.* | Jap. | U.S. | Swe.* |
|---|---|---|---|---|---|---|
| Fuel | 0.1 (0.7) | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| RCS | 3.4 (0.3) | 0.8 | 0.5 | 0.2 | 3.3 | 0.0 |
| SG | 2.7 (0.1) | 0.5 | 0.5 | 1.6 | 2.5 | 8.4 |
| Refuel | 4.7 (12.5) | 15.2 | 0.0 | 32.5 | 10.7 | 0.0 |
| NSSS Other | 0.0 (0.0) | 0.6 | 2.6 | 0.3 | 1.5 | 3.1 |
| Turbines | 1.8 (0.1) | 0.3 | 0.6 | 0.3 | 2.0 | 0.5 |
| Generator | 0.0 (0.0) | 1.0 | 0.7 | 0.0 | 1.3 | 1.1 |
| Condenser | | 0.3 | 0.3 | | 1.8 | |
| CW/SW/CCW | 0.3 (1.0) | 0.0 | 0.1 | 0.2 | 0.3 | 2.9 |
| BOP Other | 0.1 (0.1) | 0.2 | 1.2 | 0.0 | 0.6 | 4.0 |
| Economic | 0.7 (1.2) | 1.5 | 0.0 | 0.1 | 2.5 | 4.5 |
| Human | 0.0 (0.0) | 0.2 | 0.1 | 0.0 | 0.5 | 0.2 |
| Regul. | 0.0 (0.0) | 0.9 | 0.0 | 0.0 | 10.9 | 4.4 |
| Capacity Factor | 85.8 | 78.2 | 73.1 | 63.3 | 60.2 | 54.4 |

* Forced outages only.

refueling consistent with the other countries is given in the parenthesis. The data in parenthesis will be used in the comparisons made below.

As is indicated by Table 4.1, the overall PWR performance separates the countries into two distinct groups with approximately a 10% gap in performance between them. The Swiss, German, and French PWR's are in the high performance group, while the Japanese, U.S. and Swedish PWR's are in the low performance group.

Reactor coolant system losses have been reported by all the countries except Sweden. The losses have been generally small, less than 1%, and have not differed substantially with the exception of the U.S. In the U.S. PWR RCS losses have averaged 3.3%. Thus, while RCS losses have not contributed to the performance discrepancies of the other low performance countries, they have contributed to the U.S. discrepancy.

Table 4.1 shows that steam generator losses have differed between the high and the low performing countries. Losses in the high performance countries have averaged 0.5% or less. All of the low performance countries have reported much higher losses. The Japanese have reported losses of 1.6%, while the U.S. and Sweden have reported losses of 2.5% and 8.4% (forced only) respectively. As a result, steam generator losses are a significant contributor to the differences observed in PWR performance between countries.

Differences in refueling losses have not contributed to the low performance observed in the U.S. or Sweden. The Japanese PWR's, however, have had large refueling losses for mandatory inspections and maintenance which have significantly affected performance. From the view point of overall performance, these large losses have not helped to significantly reduce other losses. The German PWR's have had losses very similar in magnitude with those of the Japanese PWR's. However, the German plants have had 17.3% less refueling losses than the Japanese. This accounts for all of the difference in the overall performance between the two countries. This does not say, however, that the Japanese have not benefitted in plant reliability and safety as a result of the large amounts of maintenance performed.

Turbine losses do not appear to be a major factor in PWR performance as the losses in both groups have been low. U.S. losses have been somewhat higher and have contributed to the lower U.S. PWR performance.

Condenser losses were available only for the U.S. and Germany as condenser losses in the other countries were assigned to BOP OTHER. Examination of the BOP OTHER category in Switzerland and Japan indicate that any condenser losses that do exist are small. In France or Sweden the losses could have been as high as 1.2% and 4.0% respectively, or higher. It is not possible to absolutely conclude whether condenser problems have contributed to low performance. However, condenser losses do represent 1.5% of the discrepancy in performance between the U.S. and German PWR's.

Losses in the circulating water, service, and component cooling water systems (CW/SW/CCW) have been small in almost all the countries, averaging 0.3% or less. The exception is Sweden where the losses in the CW/SW/CCW have accounted for at least 2.9 percentage points of the difference in performance between Swedish PWR's and those in other countries.

Economic losses in general have been larger in the low performance countries with the U.S. and Sweden averaging 2.5% and 4.5% respectively. The high performance countries have averaged 1.5% or less, resulting in a minimum difference of 1%. As a result, economic losses account for at least 1% of the performance difference observed between the high and low performing countries.

Regulatory losses have clearly been the most significant cause of low performance. Of the high performance countries, the Swiss and the French have had no regulatory losses while the Germans have reported less than 1%. Regulatory losses in the low performance countries have been considerably higher with 4.4% being reported in Sweden and 10.9% in the U.S. The U.S. regulatory losses from the undamaged TMI unit account for only 1.3 percentage points of the U.S. regulatory losses.

Fuel, generator, and human losses have been distributed relatively evenly across the PWR's in both the low and the high performance countries. Therefore, they are not major contributors to low performance.

From the above discussion of the PWR data, it can be concluded that regulatory, steam generator and economic losses are the common causes of low performance in PWR's. For the U.S. the difference in losses in these three categories and the French losses amounts to over 15%. This is greater than the total difference in the U.S. and French PWR performance.

## 4.1 Boiling Water Reactors

Table 4.2 contains a summary of the average BWR performance over 1975 to 1984 for each category. The countries are ordered from left to right by decreasing overall performance. The losses shown are for combined forced and scheduled losses. The exception to this is Sweden, where the data shown is only for forced outages.

The division of the countries into the BWR high and low performance groups is also based on a 10% performance gap. The high BWR performance countries are Switzerland and Sweden, while the low performance countries are Japan, Germany and the U.S.

Fuel losses is one area where the high and the low performance countries differ. The high performance countries have had almost no fuel losses, while the U.S. and

Table 4.2 - Summary of Average BWR Performance
(Percent of Full Capacity)

| Category | Switz. | Swe.* | Jap. | U.S. | Ger. |
|---|---|---|---|---|---|
| Fuel | 0.0 | 0.1 | 1.3 | 2.3 | 0.0 |
| RCS | 0.5 | 0.2 | 0.3 | 4.5 | 17.5 |
| Refuel | 8.8 | 0.0 | 33.1 | 9.1 | 11.8 |
| NSSS Other | 0.0 | 1.9 | 0.2 | 2.6 | 2.9 |
| Turbines | 0.6 | 1.1 | 0.2 | 2.1 | 1.1 |
| Generator | 0.0 | 1.5 | 0.1 | 0.5 | 0.1 |
| Condenser | | | | 2.2 | 0.9 |
| CW/SW/CCW | 0.1 | 2.2 | 0.2 | 0.4 | 0.3 |
| BOP Other | 0.1 | 3.9 | 0.1 | 2.1 | 0.3 |
| Economic | 1.8 | 3.1 | 0.2 | 3.1 | 1.6 |
| Human | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 |
| Regul. | 0.0 | 0.7 | 0.0 | 10.4 | 11.3 |
| Capacity Factor | 88.0 | 71.9 | 61.0 | 58.0 | 51.1 |

* Forced outages only.

Japan have averaged 2.3% and 1.3% respectively. Part of the reason for this is the General Electric PCIOMR fuel recommendations that both countries follow. Thus, differences in fuel losses have contributed to the discrepancy in overall BWR performance.

Reactor coolant system losses has also been another area where losses in the two groups have differed. The high performance countries have had RCS losses averaging less than 0.6%. In contrast, two of the low performance countries have had large RCS losses. The U.S. has reported 4.5% lost to RCS problems while Germany has reported 17.5%. Part of the reason for Germany's high losses has been massive pipe replacements. The pipe replacements have affected other systems as well but it was not possible to separate out the losses for each system. Therefore the losses were assigned to the RCS, making it larger.

Refueling losses have generally not differed too greatly between the groups with the exception of Japan. As with the PWR's, the BWR's undergo large, mandatory inspections and maintenance at each refueling that result in an average of 33.1% lost to refueling.

Regulatory losses are the largest contributor to the difference between high and low performance. In the high performance countries regulatory losses were only reported at the Swedish BWR's and averaged 0.7%. In the low performance plants the U.S. and Germany had large regulatory losses averaging 10.4% and 11.3% respectively.

Turbine, generator, condenser, CW/SW/CCW, economic and human losses have been distributed relatively evenly across both the low and the high performance countries. Therefore, they are not major contributors to low performance.

From the above discussion of the BWR data, it can be concluded that regulatory losses, reactor coolant system losses and fuel losses are the largest causes of performance discrepancies in PWR's. For the U.S. and Germany, differences in losses in these three categories accounts for approximately 16 and 27.6 percentage points of the total losses respectively.

## 5.0 Summary and Conclusions

In this section of the report the major findings of this study will be summarized. Three subsections will cover the overall performance of the nuclear power plants, discrepancies in performance, and trends in performance. A final section gives recommendations for future work.

The definitions of forced and scheduled outages used to compile the data varied from country to country. As a result, meaningful comparisons of forced and scheduled losses between countries could not be made.

### 5.1 Overall Performance

In this section of the conclusions, the overall performance from 1975 to 1984 will be given for each country. In addition, the average performance and visible trends over the last three years from 1982 to 1984 will be given. This information is given in list format by reactor type. The numbers in parenthesis represent the ranking of the performance with respect to that of other countries. Unless otherwise stated, all averages are over the ten year period from 1975 to 1984.

The overall performance for the PWR's is listed by country below:

- Swiss PWR capacity factors have averaged 85.8% (1). Over the last three years performance has slowly been increasing, averaging 86.9% (1).
- German PWR energy availability factors have averaged 78.2% (2). Over the last three years performance has fluctuated, averaging 82.4% (2).
- French PWR energy availability factors have averaged 71.3% (3) from 1982 to 1984. Over the last three years performance has averaged 71.3% (4).
- Japanese PWR capacity factors have averaged 63.3% (4). Over the last three years performance has been approximately constant, averaging 73.1% (3).
- U.S. PWR energy availability factors have averaged 60.2% (5). Over the last three years performance has slowly been rising, averaging 57.9% (5).
- Swedish PWR capacity factors have averaged 54.4% (6). Over the last three years performance has been increasing, averaging 53.4% (6).

The overall performance for the BWR's is listed below:

- Swiss BWR capacity factors have averaged 88.0% (1). Over the last three years performance has been approximately constant, averaging 89.3% (1).
- Swedish BWR capacity factors have averaged 71.9% (2). Over the last three years performance has fluctuated, averaging 77.2% (2).
- Japanese BWR capacity factors have averaged 61.0% (3). Over the last three years performance has generally been improving, averaging 70.3% (3).
- U.S. BWR energy availability factors have averaged 58.0% (4). Over the last three years performance has been decreasing, averaging 53.6% (5).
- German BWR energy availability factors have averaged 51.1% (5). Over the last three years performance has been increasing sharply, averaging 59.0% (4).

## 5.2 Discrepancies in Performance

In this section the discrepancies in nuclear power plant performance will be discussed. Using the results of the data analysis, several categories were identified for each reactor type that represent the areas that have been causing the major differences in reactor performance.

For PWR's, it was revealed that low performance has resulted primarily from three categories. The most significant of these was regulatory losses which was very high in both the U.S. (10.9%) and Sweden (4.4%), the two countries with the lowest PWR performance. Steam generators was another category in which there was a considerable difference in losses between high and low performance countries. In the three lowest performing countries, Japan (63.3%), the U.S. (60.2%), and Sweden (54.4%), the average steam generator losses were 1.6%, 2.5%, and 8.4% respectively. In the highest performing countries the average steam generator losses were less than or equal to 0.5%. Economic losses was the final category identified as a cause of differences in PWR performance. Losses for the low PWR performance countries were from 1 to 3 percentage points higher than those reported for the high PWR performance countries.

For the U.S., the differences in losses for these categories represents 13.5% of capacity. Additionally, reactor coolant system and turbine problems account for another 3.9% of the performance difference.

For BWR's, it was determined that low performance occurred largely as a result of losses in three areas. As with the PWR's, the most significant of these was regulatory losses which were again high in the U.S. and Germany, averaging 10.4% and 11.3% respectively. Differences in losses in the reactor coolant system also contributed to low performance, particularly in the U.S. and Germany, averaging 4.5% and 17.5% respectively. Finally, fuel losses were also identified as another common cause of low performance, with the U.S. reporting 2.3% and Japanese 1.3%. In both of these countries the General Electric PCIOMR fuel limits are used.

For the U.S. and Germany, differences in losses in these three categories accounted for 16 and 27.6 percentage points of the total losses respectively.

## 5.3 Trends in Performance

In performing this study many time and age dependent trends were identified. As the causes for these trends are presently unknown, the trends are presented below in list format by reactor type.

The trends in PWR performance are listed by country below:

- French PWR performance has been improving over time from 63.1% in 1982 to 81.6% in 1984.
- Japanese PWR balance of plant losses have been decreasing over time from 5.0% in 1975 to 0.0% in 1984.
- Japanese PWR balance of plant losses have been decreasing with increasing age as a result of improvements in turbine performance. Losses have decreased from 1.9% at age 1 to 0.0% at age 9.
- Japanese, Swiss, and U.S. PWR turbine losses have all decreased with time. For Switzerland and the U.S., the losses have decreased from approximately 3.4% in 1975 to approximately 0.8% in 1984.
- Swiss PWR reactor coolant system losses have increased with increasing age: from 0.0% at age 1 to approximately 5.0% at age 14.
- U.S. PWR reactor coolant system losses have decreased with increasing age: from 5.7% at age 1 to 0.2% at age 14.
- U.S. PWR steam generator losses exhibit an age dependence, increasing with increased age: from 1.2% at age 1 to 18.9% at age 14.
- U.S. PWR balance of plant losses have been decreasing with increasing age as a result of reductions in condenser and turbine losses with increasing age. Losses have decreased from 10.7% at age 1 to 0.8% at age 17.
- U.S. PWR condenser losses have decreased as a function of reactor age. Losses have decreased from 3.3% at age 1 to 0.3% at age 17.
- U.S. PWR economic losses have decreased over time from 3.1% in 1975 to 1.9% in 1984.

The trends in BWR performance are listed by country below:

- Japanese BWR NSSS losses have decreased from 45.4% in 1978 to 27.2% in 1984. This was caused by a similar reduction in refueling losses.

- Japanese and U.S. BWR fuel losses have been steadily decreasing over time from approximately 3% in 1978 to approximately 1% in 1984. In the U.S. this resulted from similar reductions in losses from the General Electric PCIOMR.

- Swedish BWR performance has been improving over time from 64.6% in 1975 to 80.9% in 1984.

- Swedish BWR performance has been improving with age from 62.8% at age 1 to approximately 77% at age 13.

- U.S. BWR human error losses have been increasing with time, from 0.4% in 1975 to 1.1% in 1984.

- U.S. BWR regulatory losses have been increasing with time, from 2.4% in 1977 to 21.8% in 1984.

## 5.4 Recommendations for Future Work

In this section three recommendations are made for future work.

The first recommendation is to enlarge the scope of the database used in this study. The data provided and used was insufficient. Missing data for the years prior to 1975 prevented meaningful comparisons of performance as a function of reactor age from being made. Therefore, any work done in the future should use a complete database that includes data from the beginning of commercial operation for each nuclear plant.

As mentioned in Section 1.4.3, the statistical analysis of the observations made in this report was left for further study. Now that the trends and discrepancies have been identified, a statistical analysis would be helpful in determining the significance of these observations.

The last recommendation concerns the collection of international performance data. Presently, the performance data reported by each country is dependent upon the definitions used for the outage types, plant systems and the performance indices. As a result, international performance comparisons are subject to inconsistencies in the data. To eliminate this problem it is recommended that a standardized set of outage type and plant system definitions be devised to facilitate consistent reporting of performance data. As each country has its own definitions, the standardized set of definitions should be sufficiently detailed so that all other definitions are a subset of the standard. This would permit countries to continue using the definitions currently in use, while still allowing consistent international comparisons to be performed. To implement such a standard, the data for each country would have to be reported with the additional detail required by the standard definitions. Each country could then examine the data with the definitions it finds useful by aggregating the standardized definitions.

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## Appendix A - Definitions and Abbreviations

| | | |
|---|---|---|
| APC | = | Alabama Power Company |
| APL | = | Arkansas Power & Light |
| B-E | = | Badenwerk & Energie-Versorgung Schwaben AG |
| BAY | = | Bayernwerk AG |
| BEC | = | Boston Edison Company |
| BGE | = | Baltimore Gas & Electric Company |
| BKW | = | Bernische Kraftwerke AG |
| BOL | = | Beginning of Life |
| BOP | = | Balance of Plant |
| BWR | = | Boiling Water Reactor |
| Capacity Factor | = | The ratio of the net electrical energy generated in a period to the product of net electrical rating and the period length = (NEG)/[(NER).(PL)] |
| CCW | = | Component Cooling Water System |
| CEC | = | Consolidated Edison Company |
| CF | = | Capacity Factor |
| CHB | = | Chubu Electric Power Company |
| CHG | = | Chugoku Electric Power Company |
| CPC | = | Consumers Power Company |
| CPL | = | Carolina Power & Light Company |
| CW | = | Circulating Water System |
| CWE | = | Commonwealth Edison Company |
| DLP | = | Duquesne Light Company |
| DPC | = | Duke Power Company |
| EAF | = | Energy Availability Factor |

## Appendix A - (Continued)

| | | |
|---|---|---|
| ECGL | = | Externally Caused Generation Losses (MWHe) |
| EdF | = | Electricite de France |
| Energy Availability Factor | = | The capacity factor minus the ratio of the Externally Caused Generation Losses in a period of time and the product of Net Electrical Rating of the plant and the Period Length = CF - (ECGL)/[(NER)·(PL)] |
| EOL | = | End Of Life |
| FPC | = | Florida Power Corporation |
| FPL | = | Florida Power & Light Company |
| GH | = | Generator Hours Online |
| GKN | = | Gemeinschaftskernkraftwerk Neckar |
| GPC | = | Georgia Power Company |
| GPU | = | GPU Nuclear Corporation |
| HEW | = | Hamburgische Elektricitats-Werke AG |
| IEL | = | Iowa Electric Light & Power Company |
| IME | = | Indiana & Michigan Electric Company |
| INPO | = | Institute of Nuclear Power Operations |
| JAP | = | Japan Atomic Power Company LTD. |
| JCP | = | Jersey Central Power (GPU) |
| KEP | = | Kansai Electric Power Company, Inc. |
| KGD | = | Kernkraftwerk Gosgen-Daniken AG |
| KWO | = | Kernkraftwerk Obrigheim GmbH |
| KYU | = | Kyushu Electric Power Company, Inc. |
| MEC | = | Metropolitan Edison Company (GPU) |
| MW | = | Megawatt |
| MWH | = | Megawatt-Hours |

| | | |
|---|---|---|
| MYA | = | Maine Yankee Atomic Power Company |
| NEG | = | Net Electricity Generated ($MWH_e$) |
| NER | = | Net Electrical Rating ($MW_e$) |
| NMP | = | Niagara Mohawk Power Company |
| NNE | = | Northeast Utilities |
| NOK | = | Nordostschweizerische Kraftwerke AG |
| NPP | = | Nebraska Public Power District |
| NSP | = | Northern States Power Company |
| NWK | = | Nordwestdeutsche Kraftwerke AG |
| OKG | = | OKG Aktiebolag |
| OPEC-2 | = | Operating Plant Evaluation Code - A database containing the U.S. performance data |
| OPP | = | Omaha Public Power District |
| PE | = | Preussische Elektrizitats AG |
| PEC | = | Philadelphia Electric Company |
| PEG | = | Public Service Electric & Gas Company |
| PL | = | Period Length (Hours) |
| PNY | = | Power Authority of New York |
| PPL | = | Pennsylvania Power & Light Company |
| PSC | = | Portland General Electric Company |
| PWR | = | Pressurized Water Reactor |
| RCS | = | Reactor Coolant System |
| RGE | = | Rochester Gas & Electric Company |
| RH | = | Reserve Hours or the number of hours the plant was available but not operating |
| RWE | = | Rheinisch-Westfalisches Elektrizitatswerk AG |

Appendix A - (Continued)

| | | |
|---|---|---|
| Rx | = | Reactor |
| SAB | = | Sydkraft A.B. |
| SCE | = | Southern California Edison |
| SCG | = | South Carolina Electric & Gas Company |
| SG | = | Steam Generators |
| SHI | = | Shikoku Electric Power Company |
| SMU | = | Sacremento Municipal Utility District |
| SSP | = | Statens Vattenfallsverk |
| SW | = | Service Water system |
| TEC | = | Toledo Edison Company |
| TEP | = | Tokyo Electric Power Company |
| TAF | = | Time Availability Factor |
| Time Availability Factor | = | The faction of time the facility was or could have been operating = (GH + RH)/(PL) |
| TOH | = | Tohoku Electric Power Company, Inc. |
| TVA | = | Tennessee Valley Authority |
| VEP | = | Virgina Electric Power Company |
| VYA | = | Vermont Yankee Nuclear Power Corporation |
| WMP | = | Wisconsin Electric Power Company |
| WPS | = | Wisconsin Public Service Corporation |

## Appendix B - Sample Calculations

### Calculation of Capacity and Energy Availability Factors

$$EAF = CF + \frac{[ECGL]}{[NER] \cdot [PL]}$$

$$CF = \frac{[NEG]}{[NER] \cdot [PL]}$$

where:

| | | |
|---|---|---|
| CF | = | Capacity Factor |
| EAF | = | Energy Availability Factor |
| ECGL | = | Externally Caused Generation Losses (Megawatt-Hours) |
| NEG | = | Net Electrical Generation (Megawatt-Hours) |
| NER | = | Net Electrical Rating (Megawatts) |
| PL | = | Period Length (Hours). |

## Calculation of Weighted Averages and Standard Deviation

$$x(ave) = \frac{\Sigma\, w(i) \cdot x(i)}{\Sigma\, w(i)}$$

$$\sigma = \left[ \frac{\Sigma\, w(i) \cdot [x(ave) - x(i)]}{\Sigma\, w(i)} \right]^{1/2}$$

where:

- w(i) = weighting factor for the $i^{th}$ data point. The ratio of the number of hours as a commercial plant in a given year, to the number of hours in that year
- x(i) = value of $i^{th}$ data point
- x(ave) = the average of all x(i)
- $\sigma$ = standard deviation of all x(i)

## Appendix C - Data Information

This appendix contains information pertaining to the collection of the data used in this study. This includes the source, scope, and assumptions and limitations of the data. Each country will be discussed individually.

Several tables are provided for reference. Table C.1 is a listing of the system category assignments that were used for the collection of the U.S. data. Deviations from these assignments in the data for the remaining five countries, if known, are indicated in the appropriate section. Table C.2 and Table C.3 list the number of reactors or data points that make up the data each year and age respectively. These numbers are the same as those found in parenthesis in some of the data tables in Chapter 2. This table should be consulted when examining the figures in this report to insure the significance of any observations. Table C.4 is a listing of the data breakdown provided by the sources given below and is needed to determine which comparisons can and cannot be made.

## Table C.1 - Listing of System Category Assignments

### Condenser

Auxiliary Feedwater System
Condensate System
Condenser
Feedwater System
Makeup Water System

### CW/SW/CCW

Circulating Water System
Component Cooling Water System
Service Water System

### Economic

- Fuel Economic
  - Coastdown to Refueling and Fuel Depletion
  - Fuel Conservation
- Grid Economic*
  - Load Following
  - Low System Demand and Spinning Reserve
- Thermal Efficiency Losses

### Fuel

BWR PreConditioning Interim Operating Management - Recommendations (PCIOMR)
Fuel Densification
Fuel Failure
Fuel Failure - Off Gas Limits
RCS Activity

### Generator

### Human

Maintenance Error
Operator Error
Personnel Involvement Suspected to Have Precipitated Event
Testing Error

* (no penalty for energy availability)

Table C.1 - (Continued)

Other BOP

- Auxiliary Systems
  - Auxiliary Boiler
  - Off-Gas Systems
  - Fire Protection Systems
  - Instrument/Service Air or Nitrogen Systems
  - Meteorological Systems
  - Process Computer
  - Radioactive Waste Systems
  - Seismic Instruments
- Electrical
  - Cable Routing
  - Cable Splices and Electrical Connectors
  - Cable and Cable Insulation Fires
- Electrical Systems
  - Safety Related Equipment
  - Switchgear/Buses
- Structures
  - Auxiliary Building
  - Control Building
  - Main Steam Tunnel

Other NSSS

- Chemical & Volume Control System
- Containment System
- Core Cooling System
- Main Steam System
- Reactor Core
  - BWR Control Rod Changes
  - Burnable Poison Problems
  - Core D/P
  - Control Rod Guide Tube & Nut
  - Control Rod Repatch
  - Foreign Object in Core
  - Poison Curtain Changes
  - Poison Curtain Vibrations
  - LPRM Vibrations
- Reactor Trip System
- Reactor Water Cleanup System
- Safety Injection System

Table C.1 - (Continued)

Other (non BOP OTHER or NSSS OTHER)

Initial Plant Startup/Operator Training
Paired Unit Impact
Refueling Maintenance
Utility Grid (Non Economic)*
    Grid Maintenance
    Loss of Offsite Power or Other Electrical Disturbance
    Loss/Rejection of Load

Reactor Coolant System

Refueling

Core Physics Tests
Refueling
Refueling Equipment Problems

Regulatory

BWR Fuel Limits
    Maximum Critical Power Ratio
    Maximum Average Planer Heat Generation Rate
    General Thermal Limits
EPA Discharge Limit
Excessive Fish Kill
Licensing Proceedings and Hearings
Regulatory/Operational Limit
Regulatory Requirement to Inspect for Deficiency
Regulatory Requirement to Modify Equipment
Safety Restrictions
    ECCS Peaking Factor (PWR)
    EOL Scram Reactivity/Rod Worth Restrictions
    Core Tilt/Xenon Restriction
    BWR Thermal Limits
    Thermal Power Restriction
    Reactivity Coefficient
Unavailability of Safety Related Equipment

Steam Generators

Turbines

Undefined Failure

* (no penalty for energy availability)

## Table C.2 - Number of Nuclear Plant Data Points by Year

| Country | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 |
|---|---|---|---|---|---|---|---|---|---|---|
| France | | | | | | | | | | |
| PWR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 19 | 24 |
| Germany | | | | | | | | | | |
| PWR | 3 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 7 |
| BWR | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 4 | 4 | 4 |
| Japan | | | | | | | | | | |
| PWR | 4 | 5 | 6 | 6 | 8 | 8 | 9 | 10 | 10 | 11 |
| BWR | 3 | 5 | 5 | 9 | 10 | 10 | 10 | 11 | 11 | 13 |
| Sweden | | | | | | | | | | |
| PWR | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 |
| BWR | 2 | 4 | 4 | 5 | 5 | 5 | 7 | 7 | 7 | 7 |
| Switzerland | | | | | | | | | | |
| PWR | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| BWR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| United States | | | | | | | | | | |
| PWR | 27 | 30 | 36 | 39 | 40 | 41 | 46 | 47 | 49 | 52 |
| BWR | 18 | 19 | 21 | 21 | 22 | 22 | 22 | 22 | 23 | 25 |

## Table C.3 - Number of Nuclear Plant Data Points by Rx Age

| Country | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| France | | | | | | | | | | | | | | | | | |
| PWR | 8 | 14 | 14 | 13 | 6 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Germany | | | | | | | | | | | | | | | | | |
| PWR | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 0 |
| BWR | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Japan | | | | | | | | | | | | | | | | | |
| PWR | 9 | 9 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| BWR | 11 | 10 | 10 | 9 | 10 | 9 | 5 | 5 | 5 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| Sweden | | | | | | | | | | | | | | | | | |
| PWR | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BWR | 5 | 6 | 6 | 6 | 5 | 5 | 5 | 4 | 4 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Switzerland | | | | | | | | | | | | | | | | | |
| PWR | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| BWR | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| United States | | | | | | | | | | | | | | | | | |
| PWR | 37 | 36 | 41 | 37 | 38 | 38 | 35 | 34 | 29 | 26 | 15 | 11 | 6 | 5 | 3 | 2 | 2 |
| BWR | 14 | 12 | 17 | 19 | 20 | 21 | 21 | 21 | 19 | 16 | 10 | 10 | 5 | 3 | 2 | 0 | 0 |

Table C.4 - Summary of Data Breakdown Available by Country

| Category | | | Fra | FRG | Jap | Swe | Swi | USA |
|---|---|---|---|---|---|---|---|---|
| Forced | NSSS | Fuel | X | X | X | X | X | X |
| | | RCS | X | X | X | X | X | X |
| | | SG | X | X | X | X | X | X |
| | | Refuel | X | X | | | | X |
| | | Other | X | X | X | X | X | X |
| | | Total | X | X | X | X | X | X |
| | BOP | Turbine | X | X | X | X | X | X |
| | | Generator | X | X | X | X | X | X |
| | | Condenser | X | X | | | | X |
| | | CW/SW/CCW | X | X | X | X | X | X |
| | | Other | X | X | X | X | X | X |
| | | Total | X | X | X | X | X | X |
| | Economic | | X | X | | X | X | X |
| | Human | | X | | X | X | X | X |
| | Other | | X | X | X | X | X | X |
| | Total | | X | X | X | X | X | X |
| Scheduled | NSSS | Fuel | | X | X | | X | X |
| | | RCS | | X | X | | X | X |
| | | SG | | X | X | | X | X |
| | | Refuel | | X | X | | X | X |
| | | Other | | X | X | | X | X |
| | | Total | | X | X | | X | X |
| | BOP | Turbine | | X | X | | X | X |
| | | Generator | | X | X | | X | X |
| | | Condenser | | X | | | | X |
| | | CW/SW/CCW | | X | X | | X | X |
| | | Other | | X | X | | X | X |
| | | Total | | X | X | | X | X |
| | Economic | | | X | X | X | X | X |
| | Human | | | | | | | X |
| | Other | | | X | X | | | X |
| | Total | | X | X | X | X | X | X |
| Regulatory | | | X | X | X | X | X | X |
| Unknown | | | X | X | X | X | X | X |

France

*Source:* The French reactor performance data was compiled and provided by Electricite de France (EdF).

*Scope.* The data provided by EdF covered the 28 PWR reactors for the years 1982 through 1985 representing 62.0 plant-years of experience. Data for years prior to 1982 was not available in sufficient detail for use in this study. Since the scope of this study was 1975 to 1984, the 1985 data provided was not included in the analysis. Table C.5 provides a summary and a list of the French reactors included in the study.

*Assumptions and Limitations.* There are several limitations in the French data which should be noted. The most important of these is the extent of the disaggregation of the data. Table C.4 lists the outage categories which were provided by EdF. Forced outages were provided in disaggregate form whereas only the total scheduled outage loss was provided. As a result, no systems comparisons were made with the French data.

The definitions of forced and scheduled outages that are used by the French nuclear industry are important when comparing these losses to those in other countries. In France, a scheduled outage may be of two types, either planned or special. A planned outage is one that is planned at the beginning of the year with a scheduled start date and a specified duration. Planned outages are for refueling and maintenance. The duration of planned outages does not vary from year to year. A special outage is for non-refueling maintenance and is scheduled a minimum of three months in advance. According to EdF, there are very few performance losses associated with special outages. From the above definition of a scheduled outage, a forced outage is then defined to be any outage not planned at least three months in advance. This is an important point as these definitions are not the same as those used by other countries.

The economic losses for the French reactors consisted of fuel cycle extension, load following, and load reduction for optimum outage scheduling. Because the French load follow with their reactors, and the breakdown of economic losses was unavailable, the economic losses were not included in the performance loss calculations. This resulted in the energy availability data that was used for this study.

## Table C.5 - List of French Reactors Included in Study

Summary:

| | |
|---|---|
| Total Number of Reactors: | 28 |
| Plant-years experience: | 62.0 |
| Total Number of PWR's: | 28 |
| PWR plant-years experience: | 62.0 |
| Total Number of BWR's: | 0 |
| BWR plant-years experience: | 0 |

Pressurized Water Reactors (PWR):

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| BLAYAIS 1 | 910 | EdF | 12/81 |
| BLAYAIS 2 | 910 | EdF | 2/83 |
| BLAYAIS 3 | 910 | EdF | 11/83 |
| BLAYAIS 4 | 910 | EdF | 10/83 |
| BUGEY 2 | 920 | EdF | 2/79 |
| BUGEY 3 | 920 | EdF | 2/79 |
| BUGEY 4 | 900 | EdF | 6/79 |
| BUGEY 5 | 900 | EdF | 1/80 |
| DAMPIERRE 1 | 890 | EdF | 9/80 |
| DAMPIERRE 2 | 890 | EdF | 2/81 |
| DAMPIERRE 3 | 890 | EdF | 5/81 |
| DAMPIERRE 4 | 890 | EdF | 11/81 |
| FESSENHEIM 1 | 880 | EdF | 12/77 |
| FESSENHEIM 2 | 880 | EdF | 3/78 |
| GRAVELINES 1 | 910 | EdF | 11/80 |
| GRAVELINES 2 | 910 | EdF | 12/80 |
| GRAVELINES 3 | 910 | EdF | 6/81 |
| GRAVELINES 4 | 910 | EdF | 10/81 |
| ST LAURENT B1 | 880 | EdF | 8/83 |
| ST LAURENT B2 | 880 | EdF | 8/83 |
| TRICASTIN 1 | 915 | EdF | 12/80 |
| TRICASTIN 2 | 915 | EdF | 12/80 |
| TRICASTIN 3 | 915 | EdF | 5/81 |
| TRICASTIN 4 | 915 | EdF | 11/81 |

Germany

*Source.* The German data was compiled by Dipl.-Ing. Ulrich Lorenz of the Technische Universität of Berlin. The data was obtained manually from plots of net reactor power vs. time found in certain issues of the journal Atomwirtschaft[3-19] over the specified years of interest.

*Scope.* The German data consists of performance data for seven PWR's and four BWR's from 1975 to 1984. This represents 54.6 and 27.7 plant-years of experience for each plant type respectively. Table C.6 contains a summary and listing of the German reactors included in the study.

*Assumptions and Limitations.* The performance losses in Germany were calculated by direct measurement of the power vs. time plots found in Atomwirtschaft. All losses for each year were summed and the total loss was compared to published values. Any discrepancy found was proportionately spread over all losses. Table C.4 lists the outage categories that were distinguishable in the above journal.

Capacity losses resulting from human error were not distinguished from other outages in the reference mentioned above. This does not mean that they do not exist in Germany.

In the Federal Republic of Germany a policy known as Basisicherheit, or "Basis Safety Concept" was developed in 1977 and became a legal requirement in 1979.[20] The policy was formulated after pipe cracking was detected in some BWR's. It called for substantial amounts of safety and non-safety related piping to be replaced. The areas affected were the main feedwater and steam lines, parts of the pressure suppression system, and the reactor cooling system.[21] All of the losses were placed in the RCS category. The actual system breakdown of outage time was not available so that the amount of time spent on systems other than RCS is unknown. The plants affected by this were the following BWR's: Brunsbuettel, Isar I, Philippsburg 1, and Wurgassen. No PWR's have yet been affected by this policy.

For the Brunsbuettel reactor, RCS piping and other nuclear grade piping inside the containment were replaced during a refueling outage in 1983 as a result of the Basisicherheit policy. The outage amounted to a 64.7% capacity loss. Because some of the outage was RCS pipe cracking related, the outage was divided between REFUEL and RCS. This was accomplished by assigning the average refueling loss (16.5%) for 1981 and 1984 to REFUEL, with the remainder of the loss (48.2%) placed in RCS.

Several utilities in Germany have made contracts with the German coal companies which require them to burn a specified amount of coal each year. In some years it was necessary to reduce power at several nuclear plants in order to meet this requirement. These losses were quite substantial in some instances. Because these losses are external to the plant itself, and result from an oversupply of electricity, these losses were considered load following losses. Since energy availability was used as the performance index, these losses were not included in the calculations of performance losses.

Table C.6 - List of West German Reactors Included in Study

Summary:

| | |
|---|---|
| Total Number of Reactors: | 11 |
| Plant-years experience: | 82.3 |
| Total Number of PWR's: | 7 |
| PWR plant-years experience: | 54.6 |
| Total Number of BWR's: | 4 |
| BWR plant-years experience: | 27.7 |

**Pressurized Water Reactors (PWR):**

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| BIBLIS A | 1146 | RWE | 2/75 |
| BIBLIS B | 1240 | RWE | 1/77 |
| GRAFENRHEINFELD | 1235 | BAY | 6/82 |
| NECKARWESTHEIM 1 | 795 | GKN | 12/76 |
| OBRIGHEIM | 340 | KWO | 3/69 |
| STADE | 630 | NWK | 5/72 |
| UNTERWESER | 1230 | NWK | 9/79 |

**Boiling Water Reactors (BWR):**

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| BRUNSBUETTEL | 771 | HEW | 2/77 |
| ISAR 1 | 907 | BAY | 3/79 |
| PHILIPPSBURG 1 | 864 | B-E | 2/80 |
| WUERGASSEN | 640 | PE | 11/75 |

## Japan

*Source.* The Japanese data was provided by the Director of the Nuclear Information Center at the Central Research Institute of the Electric Power Industry (CRIEPI) in Japan. The net electrical rating for the Japanese reactors was obtained from the Nuclear Engineering International "Power Reactors 1985."[22]

*Scope.* The Japanese performance data spans 11 PWR's and 13 BWR's from 1975 to 1984 representing 71.5 and 82.1 plant-years of experience for each reactor type respectively. Table C.7 presents a summary and list of the Japanese reactors included in the study.

*Assumptions and Limitations.* Table C.4 shows the disaggregation of the Japanese data as provided by CRIEPI. All refueling outages and economic losses are considered to be scheduled outages. All human losses are considered to be forced outages. Condenser losses were not distinguished from the rest of the data and so their losses are included in the "BOP OTHER" category.

The performance index used for the Japanese data was capacity. Since the Japanese do not use any of their reactors for load following, the difference between capacity and energy availability is very small and can be considered negligible. Therefore, when comparisons are made between Japan and countries that use energy availability as a performance index, no special consideration needs to be given.

No information was available as to the exact definitions of the data categories used in compiling the Japanese data. It was thus assumed that the definitions were the same as in the U.S.

## Table C.7 - List of Japanese Reactors Included in Study

Summary:

| | |
|---|---|
| Total Number of Reactors: | 24 |
| Plant-years experience: | 153.3 |
| Total Number of PWR's: | 11 |
| PWR plant-years experience: | 71.5 |
| Total Number of BWR's: | 13 |
| BWR plant-years experience: | 82.1 |

Pressurized Water Reactors (PWR):

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| GENKAI 1 | 529 | KYU | 10/75 |
| GENKAI 2 | 529 | KYU | 3/81 |
| IKATA 1 | 538 | SHI | 9/77 |
| IKATA 2 | 538 | SHI | 3/82 |
| MIHAMA 2 | 470 | KEP | 7/72 |
| MIHAMA 3 | 780 | KEP | 12/76 |
| OHI 1 | 1120 | KEP | 3/79 |
| OHI 2 | 1120 | KEP | 12/79 |
| SENDAI 1 | 846 | KYU | 7/84 |
| TAKAHAMA 1 | 780 | KEP | 11/74 |
| TAKAHAMA 2 | 780 | KEP | 11/75 |

Boiling Water Reactors (BWR):

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| FUKUSHIMA I-1 | 439 | TEP | 3/71 |
| FUKUSHIMA I-2 | 760 | TEP | 7/74 |
| FUKUSHIMA I-3 | 760 | TEP | 3/76 |
| FUKUSHIMA I-4 | 760 | TEP | 10/78 |
| FUKUSHIMA I-5 | 760 | TEP | 4/79 |
| FUKUSHIMA I-6 | 1067 | TEP | 10/79 |
| FUKUSHIMA II-1 | 1067 | TEP | 4/82 |
| FUKUSHIMA II-2 | 1067 | TEP | 2/84 |
| HAMAOKA 1 | 516 | CHB | 3/76 |
| HAMAOKA 2 | 814 | CHB | 11/78 |
| ONAGAWA 1 | 497 | TOH | 6/84 |
| SHIMANE 1 | 439 | CHG | 3/74 |
| TOKAI II | 1056 | JAP | 11/78 |

## Sweden

*Source.* The reactor performance data for Sweden was provided by the Managing Director at the Nuclear Safety Board of the Swedish Utilities (R.K.S.). The net electrical rating of each reactor was obtained from the Nuclear News "World List of Nuclear Power Plants."[23]

*Scope.* The Swedish reactor performance data covers three PWR's and seven BWR's from 1975 to 1984 representing 14.2 and 52.2 plant-years of experience respectively. Table C.8 presents a summary and a list of the Swedish reactors included in this study.

*Assumptions and Limitations.* The disaggregation of the Swedish data as it was provided is shown in Table C.4. Refueling was always assumed to be a scheduled outage while human related performance losses were always forced outages. Condenser losses were not distinguished from the rest of the data and are assumed to be in "BOP OTHER". The scheduled NSSS and BOP losses for Sweden were only available as a total scheduled loss.

Capacity was used as the performance index for the Swedish data. It is not known whether the difference between capacity and energy availability is substantial, but it is assumed to be negligible.

## Table C.8 - List of Swedish Reactors Included in Study

Summary:

| | |
|---|---|
| Total Number of Reactors: | 10 |
| Plant-years experience: | 66.3 |
| Total Number of PWR's: | 3 |
| PWR plant-years experience: | 14.2 |
| Total Number of BWR's: | 7 |
| BWR plant-years experience: | 52.2 |

Pressurized Water Reactors (PWR):

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| RINGHALS 2 | 800 | SSPB | 5/75 |
| RINGHALS 3 | 900 | SSPB | 4/81 |
| RINGHALS 4 | 900 | SSPB | 11/83 |

Boiling Water Reactors (BWR):

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| BARSEBECK 1 | 570 | SAB | 1/75 |
| BARSEBECK 2 | 570 | SAB | 7/77 |
| FORESMARK 1 | 900 | SSPB | 12/80 |
| FORESMARK 2 | 900 | SSPB | 7/81 |
| OSKARSHAMN 1 | 440 | OKGA | 2/72 |
| OSKARSHAMN 2 | 595 | OKGA | 12/74 |
| RINGHALS 1 | 750 | SSPB | 2/76 |

Switzerland

*Source.* The Swiss data was provided by the Station Superintendent at the Beznau Nuclear Power Station in Doettingen, Switzerland.

*Scope.* The Swiss performance data covers three PWR's and one BWR from 1975 to 1984 representing 25.0 and 10.0 plant-years of experience respectively. Table C.9 presents a summary and list of the Swiss reactors included in the study.

*Assumptions and Limitations.* Table C.4 lists the data breakdown for the Swiss data. Refueling losses were always considered scheduled outages while human related losses were always classified as forced outages. As with the Japanese and Swedish data, condenser losses were not categorized and are assumed to be in the BOP OTHER category.

One important discrepancy in the Swiss data is that for two of the three PWR's, maintenance losses performed during a refueling were assigned to the appropriate system category and not to refueling. The refueling losses for these two plants are just the losses arising from the actual refueling of the core. The data for the other five countries includes this maintenance work as part of the refueling losses. It was not possible to obtain this data in aggregate form with the refueling and refueling maintenance losses combined.

Capacity was also used as the performance index for Switzerland. It is not known whether the difference between capacity and energy availability is substantial, but it is assumed to be negligible.

## Table C.9 - List of Swiss Reactors Included in Study

Summary:

| | |
|---|---|
| Total Number of Reactors: | 4 |
| Plant-years experience: | 35.0 |
| Total Number of PWR's: | 3 |
| PWR plant-years experience: | 25.0 |
| Total Number of BWR's: | 1 |
| BWR plant-years experience: | 10.0 |

Pressurized Water Reactors (PWR):

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| BEZNAU 1 | 350 | NOK | 12/69 |
| BEZNAU 2 | 350 | NOK | 3/72 |
| GOSGEN | 920 | KGD | 11/79 |

Boiling Water Reactors (BWR):

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| MUHLEBERG | 320 | BKW | 10/72 |

United States

*Source.* The U.S. performance data was obtained from the Operating Plant Evaluation Code (OPEC-2)[24] database compiled by the S.M. Stoller Corporation of Boulder, Colorado. Access to the OPEC-2 database was provided by the Institute for Nuclear Power Operations (INPO).

*Scope.* The OPEC-2 database contained performance loss data on 52 PWR's and 25 BWR's from 1975 to 1984 representing 396.0 and 210.8 plant-years of experience respectively. Table C.10 gives a summary and listing of the U.S. reactors included in the study.

*Assumptions and Limitations.* Table C.4 lists the study categories that were available from the U.S. data in the OPEC-2 database.

Energy availability was used as the performance index for the United States data. The difference between capacity and energy availability in the U.S. amounts to approximately 2% or less.

Table C.10 - List of United States Reactors Included in Study

Summary:

| | |
|---|---|
| Total Number of Reactors: | 77 |
| Plant-years experience: | 606.8 |
| Total Number of PWR's: | 52 |
| PWR plant-years experience: | 396.0 |
| Total Number of BWR's: | 25 |
| BWR plant-years experience: | 210.8 |

Pressurized Water Reactors (PWR):

| Name | $MWE_N$ | Utility | Commercial |
|---|---|---|---|
| **Babcock and Wilcox:** | | | |
| ARKANSAS 1 | 820 | APL | 1/75 |
| CRYSTAL RIVER 3 | 856 | FPC | 4/77 |
| DAVIS-BESSE 1 | 906 | TEC | 4/78 |
| OCONEE 1 | 887 | DPC | 8/73 |
| OCONEE 2 | 887 | DPC | 10/74 |
| OCONEE 3 | 887 | DPC | 1/75 |
| RANCHO SECO | 917 | SMU | 5/75 |
| THREE MILE ISLAND 1 | 819 | MEC | 10/74 |
| THREE MILE ISLAND 2 | 906 | MEC | 1/79 |
| **Combustion Engineering:** | | | |
| ARKANSAS 2 | 912 | APL | 4/80 |
| CALVERT CLIFFS 1 | 880 | BGE | 6/75 |
| CALVERT CLIFFS 2 | 880 | BGE | 4/77 |
| FORT CALHOUN | 478 | OPP | 7/74 |
| MAINE YANKEE | 825 | MYA | 1/73 |
| MILLSTONE POINT 2 | 870 | NNE | 1/76 |
| PALISADES | 740 | CPC | 1/72 |
| SAN ONOFRE 2 | 1087 | SCE | 9/83 |
| SAN ONOFRE 3 | 1087 | SCE | 4/84 |
| ST. LUCIE 1 | 846 | FPL | 1/77 |
| ST. LUCIE 2 | 804 | FPL | 9/83 |
| **Westinghouse:** | | | |
| BEAVER VALLEY 1 | 852 | DLP | 3/77 |
| CONN YANKEE--HADDAM | 582 | NNE | 1/68 |
| COOK 1 | 1054 | IME | 9/75 |
| COOK 2 | 1100 | IME | 7/78 |
| FARLEY 1 | 829 | APC | 12/77 |
| FARLEY 2 | 829 | APC | 8/81 |
| GINNA | 490 | RGE | 4/70 |

Table C.10 - (Continued)

Pressurized Water Reactors (PWR): (Cont.)

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| Westinghouse: (Cont.) | | | |
| INDIAN POINT 2 | 873 | CEC | 7/74 |
| INDIAN POINT 3 | 965 | PNY | 9/76 |
| KEWAUNEE 1 | 535 | WPS | 7/74 |
| MCGUIRE 1 | 1180 | DPC | 12/81 |
| MCGUIRE 2 | 1180 | DPC | 3/84 |
| NORTH ANNA 1 | 907 | VEP | 7/78 |
| NORTH ANNA 2 | 907 | VEP | 1/81 |
| POINT BEACH 1 | 497 | WMP | 1/71 |
| POINT BEACH 2 | 497 | WMP | 5/73 |
| PRAIRIE ISLAND 1 | 530 | NSP | 1/74 |
| PRAIRIE ISLAND 2 | 530 | NSP | 1/75 |
| ROBINSON 2 | 730 | CPL | 4/71 |
| SALEM 1 | 1090 | PEG | 7/77 |
| SALEM 2 | 1115 | PEG | 11/81 |
| SAN ONOFRE 1 | 430 | SCE | 1/68 |
| SEQUOYAH 1 | 1148 | TVA | 7/81 |
| SEQUOYAH 2 | 1148 | TVA | 6/82 |
| SUMMER 1 | 900 | SCG | 1/84 |
| SURRY 1 | 788 | VEP | 1/73 |
| SURRY 2 | 788 | VEP | 5/73 |
| TROJAN | 1130 | PSC | 6/76 |
| TURKEY POINT 3 | 693 | FPL | 1/73 |
| TURKEY POINT 4 | 693 | FPL | 10/73 |
| ZION 1 | 1040 | CWE | 1/74 |
| ZION 2 | 1040 | CWE | 10/74 |

Boiling Water Reactors (BWR):

| Name | MWEN | Utility | Commercial |
|---|---|---|---|
| BWR 2: | | | |
| NINE MILE POINT | 610 | NMP | 1/70 |
| OYSTER CREEK | 650 | JCP | 1/70 |
| BWR 3: | | | |
| DRESDEN 2 | 794 | CWE | 7/72 |
| DRESDEN 3 | 794 | CWE | 1/72 |
| MILLSTONE POINT 1 | 660 | NNE | 4/71 |
| MONTICELLO | 545 | NSP | 8/71 |
| PILGRIM 1 | 668 | BEC | 1/73 |
| QUAD CITIES 1 | 789 | CWE | 3/73 |
| QUAD CITIES 2 | 789 | CWE | 4/73 |

Table C.10 - (Continued)

Boiling Water Reactors (BWR): (Cont.)

| Name | $MWE_N$ | Utility | Commercial |
|---|---|---|---|
| BWR 2: (Cont.) | | | |
| SUSQUEHANNA 1 | 1065 | PPL | 7/83 |
| BWR 4: | | | |
| BROWNS FERRY 1 | 1065 | TVA | 8/74 |
| BROWNS FERRY 2 | 1065 | TVA | 3/75 |
| BROWNS FERRY 3 | 1065 | TVA | 3/77 |
| BRUNSWICK 1 | 821 | CPL | 4/77 |
| BRUNSWICK 2 | 821 | CPL | 12/75 |
| COOPER STATION | 778 | NPP | 7/74 |
| DUANE ARNOLD | 515 | IEL | 2/75 |
| FITZPATRICK | 821 | PNY | 8/75 |
| HATCH 1 | 786 | GPC | 1/76 |
| HATCH 2 | 784 | GPC | 10/79 |
| PEACH BOTTOM 2 | 1065 | PEC | 8/74 |
| PEACH BOTTOM 3 | 1065 | PEC | 1/75 |
| VERMONT YANKEE | 514 | VYA | 12/72 |
| BWR 5: | | | |
| LASALLE 1 | 1078 | CWE | 1/84 |
| LASALLE 2 | 1078 | CWE | 11/84 |